TIPS for sewering informal settlements: Technology, Institutions, People and Services

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Executive summary

In 2001 the South African national government introduced a Free Basic Services (FBS) policy which focused on infrastructure delivery to meet the basic infrastructure needs of the country's urban and rural poor (Still *et al.*, 2009). Municipalities consequently were mandated to provide limited amounts of clean water, electricity, sanitation, drainage and solid waste removal services for free to all South Africans (Essop & Moses, 2009; Still *et al*., 2009). 'Full-flush' toilets were deemed by national government to be the most appropriate sanitation technology for dense urban settlements (DWAF, 2003), and generally preferred by users. Installing conventional (gravity) sewerage in informal settlements as part of the FBS policy, however, is not easy given various social and technological constraints. Informal settlement residents often demand that local authorities upgrade services in the areas where they currently live because the settlements are close to existing formalised neighbourhoods, transport links, *etc*. Yet dwellings tend to be laid out in a manner that is not conducive for retrofitting drainage according to conventional engineering standards. Coupled with unfavourable ground conditions (ranging from settlements in flood-prone areas to discontinued landfills), retrofitting and/or installing conventional sewerage in such conditions is inherently problematic, particularly in situations where residents refuse to relocate (even temporarily) for fear of further marginalisation.

Alternative approaches to providing sewerage to informal settlements need to be investigated in order to determine whether there are other means of providing these areas with low-cost wastewater collection systems (Otis & Mara, 1985; Mara, 2006). Such alternative systems have been developed and applied worldwide either through changing the design criteria and the implementation approach for conventional gravity sewerage (*e.g.* simplified and settled sewerage), or taking a somewhat different approach altogether (*e.g.* vacuum sewerage) (Bakalian *et al.*, 1994). The research team distinguishes between simplified sewerage and settled systems in that simplified sewers are designed to convey sewage without settling solids in interceptor tanks like settled sewers (Mara, 1998: 249, 252). Simplified sewerage is also commonly referred to as 'condominial' sewerage (Watson, 1995); however, in this report a 'condominial system' refers to the approach or model used to engage users in the project process when implementing simplified sewerage. Vacuum systems, in contrast, use differential air pressure to propel sewage through their own dedicated pipes to the main sewer network in an area. Unlike conventional, simplified or settled sewerage, vacuum systems only partly rely on gravity flows for wastewater conveyance and are thus less limited by topographical constraints.

This report builds on South African research into alternative sewerage systems (Du Pisani, 1998a, b; Eslick & Harrison, 2004; Van Vuuren & Van Dijk, 2011a, b) by presenting the outcome of their utilisation and management in three Western Province applications: simplified sewers and vacuum sewers in two Cape Town informal settlements and settled sewers in the formal areas of Hermanus. The progress in planning a pilot settled sewer project for the Cape Town informal settlement of Barcelona is also presented. The four case studies reported upon in the document endeavour to illustrate a variety of socio-political and risk factors that cause sanitation facilities and projects to succeed or fail, especially in informal settlements. A significant amount of 'best practice' literature and discourse were also reviewed on how best to develop alternative sewerage schemes and participatory approaches as a means to possibly improve urban sanitation conditions in South Africa's high-density informal settlements. What follows are the major technological, institutional, social and servicing lessons learnt from the research study on the implementation of alternative sewerage systems by South African municipalities.

Technology: Implementing alternative sewerage

The most common technical challenge with applying alternative sewerage technology in South Africa has been the lack of experience and familiarity of designing, constructing or operating such infrastructure in densely settled informal areas. Skilled professionals are required to plan, construct and manage alternative sewerage systems for the purpose of minimising the risk of poor design, construction or operation and maintenance (O&M). No matter what alternative system is installed, a teething period should be expected with unfamiliar systems where there will be initial design, construction and management problems. Problems, when encountered, should be immediately addressed and prevented as far as is possible by training responsible maintenance personnel. Furthermore, two potential issues that should be negotiated in advance are the prevention of unauthorised private connections to communal drainage services and building over shallowly-laid sewers as both of these risks can affect the integrity of the sewers.

Eslick & Harrison (2004) noted that national legislation and the National Building Regulations (NBR) often conflict with innovative methods for developing low-income areas. For example, in eThekwini's simplified sewer pilot project, the premise of 'shared' property conflicted with South African legal property acts because servitudes cannot be given to non-legal entities, and they can only be attached to individual land titles. Furthermore, the NBR does not allow for non-licensed professionals to install or manage drainage systems, thus defeating the sweat equity principle in the condominial approach. Eslick & Harrison (2004) consequently suggested the need to change inflexible policies and building regulations based on historical ideas of property and conventional technology to allow for the introduction of alternative technologies and methods. This is particularly critical when using participatory approaches and instituting non-conventional infrastructure for informal settlements.

Lastly, involved parties should distinguish between technical problems caused by design or construction issues and systems malfunctioning due to poor management. Any sewerage technology – regardless of whether it is installed in a formal or informal area – will fail if no one manages the components of the system (*i.e.* toilets, pipes, pumps, *etc*.), and ensures that the technology is used according to design.

Institutions: Establishing responsibility for municipal toilets

South African municipal officials have reported the failure of shared sanitation facilities despite residential leaders' 'promises' to manage them (Mjoli *et al.*, 2009; Taing *et al.*, 2011). Generally in practice, shared toilets are mismanaged because neither the local authorities nor users accept responsibility for them. From the users' perspectives, as noted by Beauclair (2010) and Taing *et al.* (2011), 'community-managed' toilets often fall into disrepair because the users do not want to 'take ownership' of shared toilets. Instead, residents generally expect that government-funded full-flush sanitation toilets should be accompanied with a government-funded janitorial and operation and maintenance (O&M) service. This thus means that toilets in informal settlements functioned like toilets that are provided at publicly financed facilities such as parks. When modifying the policies that dictate practice, service providers should bear in mind that informal settlement residents expect to be provided with the same sanitation technology and service as neighbouring formal areas, thus sanitation service delivery should aim for this outcome. Service providers thus should not expect informal settlement residents to readily accept different levels of servicing based on their circumstances.

Given that the 'community-managed' toilet management system is failing and informal settlement residents are reluctant to manage shared toilets, municipalities should provide public toilets with janitorial services in informal settlements as part of their FBS and Water Services Authority (WSA) obligations. According to the Water Services Act, the WSAs are ultimately responsible and accountable "*for ensuring that end-users have **access** to water and sanitation services*" (DWAF, undated: 8; text bolded for emphasis). Managers of municipalities, as policy and operation leaders in WSAs, should therefore delegate tasks to service providers (*i.e.* a municipal department or "*any person who provides water services to [users]*"), regulate their progress and arbitrate when conflicts arise.

People: Coordinating contributions

Many WSAs are fragmented by severe decentralisation that has resulted in uncoordinated delivery of services from municipal departments, as well as the occasional ad-hoc duplication of roles and tasks. This subsequently makes it difficult for officials to establish clear lines of accountability in projects and coordinate services across rigid departmental management and budget silos. Municipal sanitation delivery is further complicated by the WSAs' capacity and experience constraints, leading to significant project roles such as engaging public participation, designing sewer systems and building toilets being outsourced informally to civil society organisations or contracted to private firms. Municipal outsourcing of public engagement to civil society organisations – who are meant to represent the interests of municipal FBS services beneficiaries – has also been popular as of late in South Africa due to the widely supported belief that all South Africans are collectively responsible for ensuring that those who lack access to basic services get them (Eales, 2008; Schaub-Jones, 2010).

Participatory approaches have had merits in demonstrably building consensus between service providers, users and civil society organisation representatives, as well as obtaining users' input into and consent of technical designs. The popular theory that residents' sentiments of long-term ownership and responsibility will develop, however, is flawed in that such sentiments are not guaranteed as a result when managing municipally funded services, despite engaging beneficiaries in a participatory process. For example, the municipalities of eThekwini (in the Emmaus and Briardale simplified sewer pilots) and City of Cape Town (in the Hangberg, Kosovo and Barcelona examples) found they were held accountable for delivering services by residents, social movement advocates and university researchers regardless of whether projects were planned in collaboration with users or not.

If organisations choose a 'partnership' approach as their main operating model then, as experience from the case studies discussed in this report has shown, they should define each party's expectations and roles at the very beginning of their projects. Moreover, each partner must be flexible because, as outlined in the report, partners need to constantly renegotiate and to redefine the terms of their partnerships when partners' limitations and constraints turn out to pose significant obstacles. In instances where municipal services are provided as part of their FBS obligations, local authorities should be 'managing partners' in which they coordinate collaborations between stakeholders.

Services: Transitioning from 'community-managed' facilities to municipal services

DWAF (2003), in the Strategic Framework for Water Services, distinguishes between sanitation 'facilities' and 'services' as follows: a sanitation facility is infrastructure that "*enables safe and appropriate treatment and/or removal*" of waste, whilst a sanitation service includes the "*provision of a basic sanitation facility … [that] includ[es] the safe removal of human waste and wastewater*". What that means is that a sanitation service is different from a sanitation facility in that a service requires those who have provided it to ensure that all waste that enters it will be removed safely, whereas a facility simply ensures the possibility for that removal to occur. It is important to recognise that municipal officials tend to provide shared sanitation facilities instead of services in that the officials expect that the users will manage the shared toilets collectively as a 'community'. Yet – just as the 'city' or municipality has different departments and groups of professionals that have distinctive procedures and interests – an informal settlement comprises of a diverse range of people who may not collectively organise as a coherent group. The deteriorating state of 'community-managed' shared toilets, for example, represents the consequences of imagining informal settlement residents as a 'community' with shared purpose. Given the failure of communal toilets in informal settlements, there is an undoubted need for WSAs to transition from providing shared facilities that are maintained collectively by users, to providing public toilets that are serviced by the municipality. In other words, WSAs – when fulfilling their FBS obligations –

should only offer sanitation services in which they will be responsible for ensuring that toilets function as designed from the facilities' set-up phase to its eventual decommissioning.

Interviews conducted in 2010 to early 2011 indicated that eThekwini, Overstrand and City of Cape Town (CoCT) officials generally considered janitorial services for toilets in informal settlements as necessary when fulfilling the municipalities' FBS obligation. During that period, eThekwini and Overstrand officials supported a city-wide caretaker service for shared toilets in Durban's and Hermanus' informal settlements. eThekwini and Overstrand officials noted that their janitorial services were cost-effective because their departments have less rehabilitation costs for municipally provided toilets located in informal settlements. In addition, they said that most users reported they were satisfied with the local authority's cleaning and maintenance of the facilities. At the time the research was conducted, CoCT officials supported a janitorial service that was limited to toilet blocks in settlements in Khayelitsha and Pooke se Bos. CoCT launched services throughout the city – in late 2011/early 2012 (Cape Times 2012a, b). Despite criticism from media and activist groups about operational problems with CoCT's janitorial service for informal settlements, the interviewed CoCT officials generally supported employing local residents as janitors to clean toilets that were provided as part of the municipality's FBS obligations.

While not the focus of this report, it bears mentioning that many of the problems linked with sewerage can also be tied to the shortcomings of stormwater infrastructure and solid waste management. Even when formal stormwater drainage is provided, high volumes of litter often fall into catchpits and block drains. The location and design of solid waste skips and collection systems can also have an impact on the functionality of sewerage. The research team did not conduct an in-depth study on solid waste practices, but it was noted that collection points tended to be located on the edge of the studied settlements. Given that solid waste community workers often only collect rubbish once a week, it is not a surprise that toilets are also used as rubbish bins. Service providers responsible for sanitation provision should thus consider how lack of *any* basic service in informal settlements also impacts the operation of associated systems when designing and managing sewerage systems. This broader understanding of waste management infers the need to holistically manage 'urban sanitation' systems – similar to Brazil's 2011 national sanitation law (PLANSAB, 2011) – rather than solid waste, drainage and sanitation separately. Due to the unclear lines of responsibility and the fragmented state of service delivery, WSAs must start: (a) coordinating and regulating all their personnel involved in service delivery, (b) establishing procedures and processes to upgrade informal settlements and (c) managing public infrastructure provided as part of their FBS policy obligations.

Conclusions

More cost-effective and flexible sewerage than conventional systems are needed to sewer South African informal settlements, and this need can potentially be met through alternative technologies such as simplified, settled or vacuum sewerage. These technologies are technically proven to work elsewhere in the world; however, the South African research to date has reached the conclusion that the ability of sewers to function as designed is closely related to how sanitation technologies are planned, managed and used. In other words, the social processes that underlie the planning, provision and management of sewerage systems are just as significant as technology choice. The present report attempts to show that failure of communal toilet facilities in informal settlements is frequently linked to the users' expectations that sanitation *services* – rather than the toilets themselves – should be provided in the face of officials' explicit aims to provide only facilities that are managed by their users. This suggests that residents and users in South African informal settlements are driven by their expectations that toilets provided by the municipality should be fully subsidised and serviced by the municipality.

Given users' expectations and the difficulty of installing conventional sewerage in existing densely settled informal areas where urban planning conventions have not been followed, there is a need to consider alternative management arrangements and technologies when sewering informal settlements. This report's main goal is to demonstrate that the implementation of any kind of sanitation facility in an informal settlement requires that it be accompanied by a fully and carefully developed project management and operation and maintenance (O&M) servicing plan that accounts in full for the social context in which the facility has been introduced. In many instances, the local authority may have to introduce janitorial services as part of their FBS obligations. Such a sanitation strategy will ideally be accompanied with provision of solid waste, greywater and stormwater disposal services.

The supplementary poster guide on "*TIPS for sewering informal settlements*" focuses on the project concerns of higher-level management coordinating services, but the guide would also be helpful to municipal officials (service providers) and informal settlement residents (users) who can forward plan by determining which other departments and groups should be involved in sanitation design and management. Whether or not such a process is adopted for sewering informal settlements with janitorial services, it is significant that stakeholders understand that their actions and interaction with each other often determines whether a technology functions or fails.

The authors aim to build upon the present report's findings in a two-year Water Research Commission study on the social and institutional constraints to providing and managing janitorial services that were encountered in this research (WRC Project K5/2120). The ultimate intention of the K5/1827 and K5/2120 studies are to create simple tools that officials can use to guide the management of effective sanitation services in South African informal settlements.

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Abbreviations

BNG	Breaking New Ground programme
BSC	Barcelona Street Committee
BSSPP	Barcelona Settled Sewerage Pilot Project
CABs	Community Ablution Blocks
CAERN	The Brazilian state utility: Companhia de Aquas e Esgotos do Rio Grande do Norte (Water and Sewerage Company of Rio Grande do Norte)
CAESB	Brasilia's public utility: Companhia de Saneamento Ambiental do Distrito Federal (Federal District Company for Environmental Sanitation)
CBO	Community-Based Organisation
CLO	Community Liaison Officer
CLTS	Community-Led Total Sanitation
CoCT	City of Cape Town
CORC	Community Organisation Resource Centre
DAG	Development Action Group
DoH	Department of Housing
DSD	CoCT's Development Support Department
du	Dwelling unit
DWAF	Department of Water Affairs and Forestry
EIA	Environmental Impact Analysis
EPA	United States' Environmental Protection Agency
EPWP	Expanded Public Works Programme
EWS	eThekwini (Municipality) Water Services
FBS	Free Basic Services
H_2S	Hydrogen Sulfide
HDPE	High Density Polyethylene (used in pipe manufacture)
HiDA	Hangberg in-situ Development Association
HPMF	Hangberg Peace and Mediation Forum
ISN	Informal Settlements Network
kℓ	Kilolitres
ℓ/c.d	Litres per capita per day
m	Metres
mm	Millimetres
m/s	Metres per second
M&E	Monitoring and Evaluation
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
NBR	National Building Regulations
NGO	Non-Governmental Organisation
O&M	Operation and Maintenance

PDLGH	Provincial Department of Local Government and Housing
PM	Project Manager
SA	South Africa
SCM	Supply Chain Management
SF	Social Facilitator
TEP	The Environmental Partnership
TIPS	Technology, Institutions, People and Services
uPVC	Unplasticised Poly Vinyl Chloride (used in pipe manufacture)
RPS	CoCT's Raapenberg Pump Station
W&SD	CoCT's Water and Sanitation Department
WRC	Water Research Commission
WSSA	Water and Sanitation Services South Africa
WSISU	CoCT's Water and Sanitation Informal Settlements Unit
WWTW	Wastewater Treatment Works
UCT	University of Cape Town
UKZN	University of KwaZulu-Natal
UISP	Upgrading Informal Settlements Programme

1. Introduction

1.1 A cautionary tale

South Africa's first vacuum sewerage system was completed in Kosovo, a densely populated informal settlement in Cape Town in February 2009. Project consultants and municipal officials had initially hailed the vacuum system as the ideal technological "*solution*" for the Cape Flats' flat topography, high groundwater table and sandy soils (CoCT, 2006a). It has proved problematic, however, being continuously blocked since inception by gross solids in its collection chambers. Residents currently use the system's collection chambers as 40-litre conservancy tanks that contractors empty three times a week. Many residents, unhappy with the malfunctioning sewerage, have demanded that the municipality remove it and "*bring back [their] buckets*" (Daily Sun, 2011; 16 September).

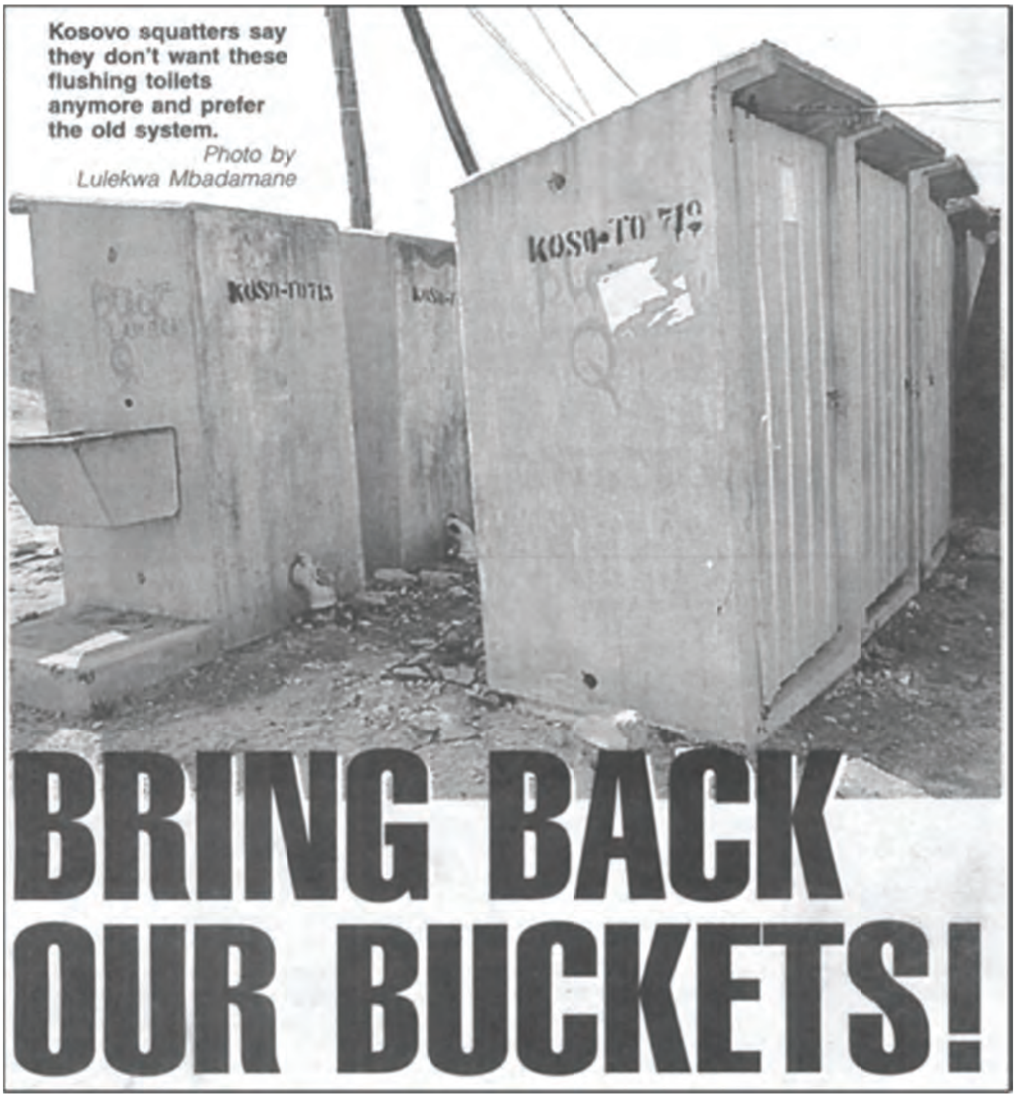

Figure 1-1: *Daily Sun*'s (2011) coverage of Cape Town's vacuum sewerage system.

CoCT Water and Sanitation officials have invested much time, money and energy to address the physical blockages of the system, which has resulted in periods when segments of the sewer network were operational. The vacuum system nevertheless has repeatedly collapsed shortly after each intervention. Kosovo's sanitation problem has become another example of how a technologically sound concept has failed disastrously in its implementation because of the strong emphasis on how technologies can 'solve' sanitation problems, a perspective that overlooks that the people who provide, use or manage such systems will likely determine if a project succeeds or fails.

1.2 Purpose of the research report

This report endeavours to explain some of the reasons why systems such as Cape Town's vacuum sewer fail, while others succeed. It suggests that local authorities and users directly address the technical, social and institutional issues that are jointly responsible for a system's failure or success. Understanding how any sanitation facility is in danger of failing if it is disconnected from the social reality in which it is planned and managed, can lead to further discussion on how municipalities can realistically and holistically address the current sanitation backlog for the purpose of preventing such situations as Cape Town's dysfunctional vacuum system from happening again.

About 58% (30.4 million people) of the country's total population (52 million people) live in urban centres (UN-DESA, 2010). According to Statistics South Africa (StatsSA, 2012), approximately 13% (1.86 million) of households lived in 'informal dwellings' or 'shacks' in 2010 with minimal access to basic services. In the past 18 years the South African government has had a major drive to meet the sanitation needs of residents by installing toilets in South Africa's urban informal settlements. In South Africa, 'informal settlements' – like slums – are generally represented in international and South African discourse (CSIR, 2000; DoH, 2009; UN-HABITAT, 2003) as physical manifestations of housing "*outside the framework of conventional town planning*" on land that may be occupied "*without the permission of the landowner*" (Harrison, 1992: 14). Moreover, Harrison (1992: 14) explained that the term informal settlement in South Africa broadly references any area with shelter that is constructed "*outside of the formal housing delivery mechanisms*." In addition, the Department of Human Settlements (DoH, 2009: 26) has stated that informal settlements generally lack access to basic municipal engineering services such as water, sanitation, electricity and roads, all primarily due to their precarious legality. As a result, informal settlements that lack basic services tend to be polluted environments where a toxic cocktail of stormwater mixed with wastewater – contaminated water from toilets, bathrooms and kitchens (Van Vuuren & Van Dijk, 2011a) – combines with refuse, and surrounds (or inundates) people's homes. Conditions in these settlements provide ideal grounds for the spread of disease, which can prove fatal to humans.

In 2001, national government introduced a Free Basic Services (FBS) policy which focused on infrastructure delivery to meet the servicing needs of the country's urban and rural poor (Still *et al.*, 2009). While 'full-flush' toilets are deemed by national government as the most appropriate sanitation technology for dense urban settlements (DWAF, 2003), and are generally preferred by residents, installing conventional (gravity) sewerage in informal settlements is not easy given various social and technological constraints. Residents of informal settlements often demand that local authorities upgrade services in the areas where they currently live. These settlements are often close to existing formalised neighbourhoods and transport links, yet they also tend to be on marginal land and settled in an extremely dense layout of dwellings that are not structured in terms of conventional planning principles. Coupled with unfavourable ground conditions (ranging from settlements in flood-prone areas or on discontinued landfills), retrofitting services in such conditions is inherently problematic, particularly in situations where residents refuse to relocate (even temporarily) for fear of further marginalisation.

Some South African authorities have attempted to redress the lack of sanitation by providing forms of communal, non-sewered sanitation services (commonly described as 'container toilets' with 'off-site' disposal). Such sanitation options however have high operation and maintenance (O&M) costs (Mels *et al.*, 2009) and generally do not address residents' needs to dispose of and treat greywater. Greywater constitutes by far the largest fraction of sewage emanating from such settlements (Holden, 2010). Carden *et al.* (2008) found that a daily average of 100 litres of wastewater per informal settlement household is discarded into stormwater drains, polluting urban waterways. Sewered systems are thus needed in informal settlements because all contaminated water – not just human waste – needs to be disposed and treated safely.

Alternatives to conventional sewerage provision need to be investigated in order to determine whether there are other methods of providing informal settlements with lower cost wastewater collection systems (Otis & Mara, 1985; Mara, 2006). Such alternative systems have been developed either through changing the design criteria and the implementation approach for conventional gravity sewerage (*e.g.* simplified and settled sewerage), or taking a somewhat different approach altogether (*e.g.* vacuum sewerage) (Bakalian *et al.*, 1994), and have had widespread worldwide application. Simplified and settled sewerage in particular have come to be widely regarded as economically viable alternatives for providing water-borne sewerage (Mara, 1998), and there is experience of these technologies in a South African context.

This report builds on current South African research into alternative sewerage systems by presenting the outcome of their utilisation and management in three Western Province applications: simplified sewers and vacuum sewers in two Cape Town informal settlements, and settled sewers in formal areas of Hermanus. The progress of planning a pilot settled sewer project for the Cape Town informal settlement Barcelona is also presented. The case studies reported on in the document endeavour to illustrate a variety of socio-political and behavioural risk factors that cause sanitation facilities and projects to succeed or fail, especially in informal settlements.

The report also shows that the ability of sewers to function as designed is closely related to how sanitation technologies are planned, managed and used. It attempts to show that failure of communal toilet facilities is very likely linked to users' expectations that sanitation 'services' should be provided for shared facilities, which is contrary to officials' explicit aims to provide only facilities that are managed by their users. The Strategic Framework for Water Services distinguishes between a basic sanitation facility and service (DWAF, 2003) as follows: a sanitation facility is infrastructure that "*enables safe and appropriate treatment and / or removal*" of waste, and a sanitation service includes the "*provision of a basic sanitation facility … [that] includ[es] the safe removal of human waste and wastewater*". What that means is that a sanitation service is different from a sanitation facility in that a service requires those who have provided it to ensure that all waste that enters it will be removed safely, whereas a facility simply ensures the possibility for that removal to occur.

Given users' expectations and the difficulty of installing conventional (gravity) sewerage in existing densely settled informal areas where urban planning conventions have not been followed (*i.e*. retrofitting in such areas), there is a need to consider alternative management approaches and technologies to sewering South African informal settlements. This report's main goal is to demonstrate that the implementation of any kind of sanitation facility in an informal settlement requires that it be accompanied by a fully and carefully developed project management and operation and maintenance (O&M) servicing plan that accounts in full for the social context in which the facility has been introduced. In many instances, the local authority may have to introduce janitorial services as part of their FBS obligations. Such a sanitation strategy will ideally be accompanied by the adequate provision of solid waste and wastewater removal services.

Water Service Authorities (WSAs) need to adopt a broad plan and to coordinate the various stakeholders (*e.g.* local authorities, consultants, contractors, users or community representatives) involved in what has become fragmented delivery of sanitation services (Eales, 2008) in South Africa. In practice, a sanitation service should remove waste safely from settlements by planning how and where to dispose of the waste, defining what tasks (such as operation and maintenance (O&M) plans or janitorial services) are necessary to deliver such a service, and addressing what roles are necessary to complete such tasks. Supplementing this report is a poster entitled, "*TIPS for sewering informal settlements*". The poster is meant to guide WSAs on how to holistically plan and coordinate the various roles and responsibilities necessary for managing a sanitation service – from the initial planning stage to managing a facility until its eventual decommissioning.

This report's introductory chapter serves to present the background and motivation for the study.

Chapter 2 presents a description of the research aims and major changes to the proposed scope and research method employed during the study.

Chapter 3 provides a brief review of literature pertaining to simplified, settled and vacuum sewerage technologies and the key technical and management lessons learnt from the technologies' international and South African applications. It also includes a short discussion on participatory approaches to development, such as implementing condominial approaches and establishing sanitation partnerships.

Chapter 4 presents the contexts and key lessons learnt from three case studies in South Africa where alternative sewerage has previously been implemented: simplified (Hangberg, Cape Town), settled (Hermanus) and vacuum (Kosovo, Cape Town) systems.

Chapter 5 provides a description of the tasks completed, at the time of writing, in the planning of a pilot settled sewerage system for Barcelona informal settlement. It discusses the research team's approach to addressing technical, institutional and residential project issues in order to highlight some of the constraints that can affect implementation of new technologies in unsewered areas.

Chapters 6 summarises the concluding remarks, recommendations for providing informal settlements with public sanitation services and introduces the research team's follow-up WRC study.

Appendix A summarises the design specifications for simplified, settled and vacuum sewerage, the principles underlying the design of each system and the requirements for its operation and maintenance.

Appendix B presents an overview of the Kosovo vacuum sewer design, including the City of Cape Town's O&M arrangements.

Appendix C provides the Barcelona Settled Sewerage Pilot project design criteria and proposed O&M schedule.

Appendix D has a list of the research items produced, presented and/or published.

2. Research methods

2.1 Introduction

The original objectives of the Water Research Commission (WRC) study on which this report is based (K5/1827) focused on the technical aspects of alternative sewerage technologies and how to offer tangible improvements to such applications in a South African context. During the course of the study it became evident, however, that there was a need to change the focus as the technical details associated with the three main alternative sewerage technologies under consideration (simplified, settled and vacuum sewerage) are well documented in literature. Another major component of the initially proposed research was to draw a comparison between conventional (gravity) systems with alternative technologies in South Africa in terms of advantages and disadvantages (which included the review of CCTV footage of existing sewers). The WRC has since published a technical report and guidelines by Van Vuuren & Van Dijk (2011a, b) on the existing national standards and recommended design and O&M specifications for simplified, settled and vacuum sewerage in South Africa (*Waterborne Systems Design Guide (TT 481/11) and Operation and Maintenance Guide* (TT 482/11)). The research team thus decided, in consultation with the study's reference group, to refocus this study on technical and social design considerations for alternative sewerage in informal settlements; in particular, to focus on the research gap regarding why sanitation applications in these settlements have been bedevilled with problems.

The study's revised scope resulted in a change of research methodology and objectives. The research team employed a variety of methods that ranged from desktop literature reviews of alternative sewerage applications and perusal of municipal project files for existing installations, structured interviews with users and service providers, and site visits to inspect facilities. Participant observation was also employed in order to observe how people behave on an everyday basis and to experience why people may act in a certain manner under their unique circumstances. This ethnographic method enabled researchers to amass information on the possible underlying issues that cause sanitation projects to fail. From this fieldwork the research team developed reports on perspectives such as what it is like to use toilets connected to the dysfunctional vacuum system in Kosovo; to climb into a flooded vacuum collection chamber and manually clean a blocked pilot sensor side-by-side with municipal O&M personnel; to 'hang out' in Barcelona where a pilot settled sewerage system has been planned and promised but long delayed in being implemented; to plan projects with municipal officials and observe them struggle to gain traction on projects that are supposed to address council's priorities; or to receive an angry rebuke from a user of a serviced facility when they received too little toilet paper to cleanse themselves. Participant observation has enabled the research team to offer critical insight on what project design improvements could be made for sanitation installations; all based on the way people use systems or manage projects. Through these interactions the research team has sought:

- To establish the technical benefits/strengths and pitfalls/weaknesses of existing alternative sewerage systems applications in South Africa, particularly in informal settlements.
- To document municipal sewerage provision approaches for informal settlements in the Western Cape. This encompasses more than sewerage as it has become obvious to the research team that sewerage cannot be observed separately from other basic services such as water supply, solid waste removal or stormwater drainage.
- To understand what factors make for successful/unsuccessful sanitation projects in the context of an informal settlement in South Africa.
- To create a guide for providing informal settlements with serviced flush toilets.

2.2 Method

In order to gain an understanding of simplified, settled and vacuum sewerage technologies, a desktop review was conducted pertaining to the design, implementation and management (including O&M) of these alternative systems in international and national case studies. The main purpose of the literature review was to inform the fieldwork, but the reverse also proved true. The literature review was conducted in conjunction with interviews and fieldwork, reflecting the topical shifts prompted by the researchers' experiences in various Cape Town informal settlements and conversations with fellow researchers or interviewees.

Interviews and site visits were conducted with CoCT, Overstrand and eThekwini municipal officials directly involved in the design, implementation and/or O&M (ranging from plumbers, maintenance managers, technicians, engineers and managers) of simplified sewerage in Hangberg informal settlement (Cape Town), settled sewerage in Hermanus (Overstrand), vacuum sewerage in Kosovo informal settlement (Cape Town) and settled sewerage in Barcelona informal settlement (Cape Town). In addition interviews were conducted with design consultants and the construction contractors of the Kosovo vacuum sewer system, an independent vacuum sewer expert and the design consultant for settled sewer systems in a number of South African towns. In each interview the researchers sought to investigate the main considerations that the interviewee had taken into account in designing, constructing or managing the systems for use in a South African context, and the lessons they reportedly learnt from their experiences. Lastly, users, such as settlement representatives, were also interviewed to understand their role and responsibility throughout the project planning process, and how their first-hand experience with the systems could improve project design.

Site visits were made to numerous informal settlements in order to gain familiarity with the living conditions in these areas. The settlements that were visited in and around Cape Town included: Kosovo and Brown's Farm in Phillipi; Barcelona, Europe, Sheffield Road and Kanana in Gugulethu; Pooke se Bos in Rylands; Imazamo Yethu and Hangberg in Hout Bay; Witsand in Atlantis; Valhalla Park near Bishop Lavis; and ten sections in Khayelitsha.

Visits to Khayamandi in Stellenbosch, Zwelihle in Hermanus and Doornkop in Soweto (Johannesburg) were also conducted.

The remainder of this section outlines the specific methods used for each case study featured in this report.

2.2.1 Hangberg

Based on capacity constraints, the research team did not conduct an in-depth ethnographic study of Hangberg. A researcher conducted a number of site visits observing and participating in the interactions between residential leaders with four CoCT Housing municipal officials. In addition, approximately 20 residents – some users of the shared sanitation facilities, and others who had privately installed household toilets – were surveyed to get a perspective on municipal sanitation provision. Interviews were also conducted with the Development Action Group (DAG), a non-governmental organisation involved in the set-up of the housing upgrade project, the DAG Social Facilitator and three CoCT officials. Lastly, the research team reviewed documentary data prepared by CoCT and DAG.

2.2.2 Hermanus

Three postgraduate researchers conducted an interview with the then Hermanus' Area Operational Manager of Community Services Mr Dion van Vuuren, an engineer who at the time (May 2010) had managed the town's settled sewers for 17 years. Mr DeWet Nel, a municipal technician, also took the research team to see operating settled sewer installations and to view the communal sanitation facilities in the informal settlement Zwelihle. Finally, Mr Nel also provided information on the procedures for installing new settled sewer systems and specific challenges experienced in the Hermanus installation and the municipality's offering of caretaker services in informal settlements. A follow-up research fieldtrip was conducted with Mr Nel in April 2012, of which the present Area Operational Manager Mr Peter Burger and Mr Rolf Myburgh also shared their insights on constructing and managing the suburban settled sewer and Zwelihele's janitorial services.

2.2.3 Kosovo

The CoCT's attempt to trial vacuum sewerage in Kosovo informal settlement was of interest to the research team as it presented an opportunity to investigate the factors impeding the effective management of one form of alternative sewerage in an informal settlement context. In 2009/2010, UCT researchers began collaborating with the Water and Sanitation Informal Settlements Unit (WSISU) to review current procedures and identify ways to manage the vacuum sewer sustainably. In June 2009, a six-week long close-up ethnographic study was conducted amongst Kosovo residents in order to understand their views and experiences, and their impressions of the system some five months after it was first implemented. In May

2010, members of the research team spent time in the settlement observing and participating with WSISU staff for the purposes of investigating the O&M procedures that were undertaken (and evidently failing) in Kosovo at the time. In addition, the 2003-2009 municipal project files for the settlement were reviewed in order to understand what was described as a participatory planning process used by the project implementers, and to investigate why the municipality had not planned for the system's O&M. The lessons learnt from the Kosovo studies were taken into account when developing a strategy for implementing an alternative sewerage system in Barcelona.

2.2.4 Barcelona

The Barcelona Settled Sewerage Pilot Project (BSSPP) is an initiative undertaken as a collaborative effort by the UCT Urban Water Management group, the CoCT's WSISU and the Barcelona Street Committee (BSC) – a leadership group comprising Barcelona residents that serve as the BSSPP's main residential representatives and point of contact for the project team. Members of the research group provided project support by preparing a preliminary design for the settled sewerage system in conjunction with WSISU officials and residents. Attempts were made to ensure that CoCT officials and BSC representatives stakeholders were consulted on a regular basis during the initial eight-month preliminary design considerations phase when monthly 'think-tank' meetings allowed those present to express their views and comment on the design of the alternative sewerage installation for Barcelona.

During the preliminary design phase, regular project team meetings were also conducted between WSISU officials and UCT researchers, and progress reports provided to residents or other interested parties by e-mail, telephone or in person through a research team member. A postgraduate researcher also conducted ethnographic research in Barcelona to gain an understanding of residents' perspectives and opinions of the sanitation situation. Another postgraduate researcher worked side-by-side with CoCT officials preparing critical project documentation (*e.g.* supply chain management applications) in order to provide insights into the municipal challenges that constrain service delivery.

2.3 Research limitations and scope changes

Only simplified, settled and vacuum sewerage were investigated as part of the present study's research scope. Any reference to 'alternative sewerage' in this report thus refers to these three systems. The study was also limited to concern only those system components that generally fall within the boundaries of serviced properties/facilities and the sewer network that transports sewage. The final treatment of wastewater conveyed by the sewer network – or, in the case of settled sewerage, the sludge removal from the interceptor tanks – was considered as being outside the study's scope.

As the study progressed, further research limitations became evident which prevented the research team from achieving its objectives. By 2010, the research team had completed the technical component of the literature review and the background data for the initial pilot studies (the existing alternative sewerage installations in Hangberg (simplified) and Kosovo (vacuum), and a proposed settled sewer in Barcelona informal settlement. In 2011, a literature review focusing on social processes was also conducted in light of the need to understand the various socio-political factors that made for successful or unsuccessful sewerage projects internationally and in South Africa.

The research team intended to prepare case studies on three alternative sewerage projects that were implemented in the Cape Town informal settlements of Hangberg, Kosovo and Barcelona, but the following project constraints that were beyond the control of the research team required additional scope changes:

- Broken promises between municipal officials and Hangberg residents literally halted the settlement's planned incremental housing and services upgrade in 2009 and erupted into a violent, nationally-publicised confrontation between 'the city' and 'the community' in 2010. An independent mediator (paid for by the municipality) was appointed in early 2011 to arbitrate the dispute between the CoCT officials and Hangberg residents; however, it was not possible to conduct a technical review of Hangberg's simplified sewer system when servicing negotiations resumed in mid-2011.
- As regards Kosovo's dysfunctional vacuum system, senior municipal managers, elected officials, community leaders and residents had not decided on a way forward to improve the system in the period 2009 to 2011, despite repeated attempts by junior municipal officials and the research team to motivate either rehabilitation or replacement of the system. In October/November 2012, after the majority of this report was written, CoCT officials from the Water and Sanitation Department stated that the municipality would not attempt to re-commission the non-operating system and that they were considering non-sewered alternatives to replace the toilets connected to the vacuum system.
- Lastly, the construction of the Barcelona Settled Sewerage Pilot Project (BSSPP), which the research team had anticipated would be a pilot alternative sewerage case study, has been delayed by two years, and looks likely not to begin until September 2013. The reasons for the delay appear to be issues with the set-up of the partnership approach that was used to manage the project, the need to change the initially proposed technical designs and the long supply chain management (SCM) timelines. Lessons learnt from the BSSPP also indicate that CoCT is still in a state of transition and has yet to establish clear procedures for introducing and managing infrastructure.

Although the occurrence of the above issues has prevented the research team from reflecting on the first-hand practical implementation of the three technologies in informal settlements, each case study offered a wealth of reasons for where and why blockages to service provision come to occur and important pointers for improving key areas. As a result of the delays in implementing a settled sewer in Barcelona informal settlement, this report draws on

Overstrand municipal officials' experience when improving their implementation and management systems of settled systems in middle-income private residential and holiday homes in Hermanus. Overstrand officials also shared their insights on implementing and managing public sanitation facilities (connected to conventional sewers) with janitors in the town's informal settlement Zwelihle. The research has:

- Identified a number of benefits to and pitfalls of existing alternative sewerage installations in Hangberg (simplified), Kosovo (vacuum) and Hermanus (settled);
- Documented the basic service provision approaches used in City of Cape Town (CoCT), Overstrand and eThekwini municipalities;
- Reviewed major socio-political and on-the-ground risks encountered in Cape Town and Hermanus alternative sewerage projects; and
- Initiated a settled sewerage pilot project in partnership with CoCT municipality and Barcelona residential leaders. The municipality has committed R2 million in capital costs to pilot and thus test the viability of settled sewerage in Barcelona (a discontinued solid waste dump site). In October 2011, the CoCT had appointed consultants to finalise designs and to prepare tender documentation for the pilot project.

2.4 Summary

This chapter presents a description of the research scope and methods employed in this study. The research team used a mixed approach to collect data. The various research methods described were used to develop an understanding of what technical designs, O&M strategies and management arrangements have worked in South Africa's Western Province. The methods included elements of participant observation and documentation of existing services in informal settlements, drawing on site visits and meetings with the various stakeholders involved in service provision or who require such services. The next sections will present: (a) the international and South African literature reviewed on alternative sewerage technologies and the methods used to implement them, and (b) case studies of four Western Cape alternative sewerage schemes/approaches.

3. Literature review

3.1 Introduction

This chapter provides a brief background of simplified, settled and vacuum sewerage technology and presents information about international and South African experiences of such systems described in currently available literature. It also includes an outline of key lessons learnt from these studies. As detailed design specifications for each alternative system are already well documented and widely available (EPA, 1991; Mara, *et al.*, 2001; Van Vuuren & Van Dijk, 2010a, b) they are not replicated here. Summaries of the key design and O&M specifications for simplified, settled and vacuum sewerage systems are provided in Appendix A.

One of the original intentions of this report was to include a section on participatory design and management for each of the three technologies, but the literature review revealed that only simplified sewerage had a complementary participatory approach – through the condominial model. Condominial systems are commonly referred to as a type of simplified sewerage. For that reason, a discussion on the condominial approach is integrated into the section on simplified sewers. A brief review of the partnerships approach also follows the vacuum sewerage discussion.

3.2 Simplified sewerage and the condominial approach

3.2.1 Background

Simplified sewerage and the condominial approach were conceived in the 1980s by a team of sanitary engineers led by Jose Carlos de Melo, who sought an innovative way to provide waterborne sanitation to Brazil's high-density peri-urban areas at a lower-cost than conventional methods (Watson, 1995; Mara & Guimaraes, 1999). Simplified systems (as with conventional gravity sewerage) rely on gravity to transport wastewater. Mara (1998: 25) describes simplified sewers as "*conventional sewerage stripped down to its hydraulic basics*". Simplified sewer specifications are based on the re-evaluation and subsequent relaxation of conventional gravity sewerage design standards, which many engineers had deemed to be excessively high in cost due to design standards that were more conservative than operationally required (Mara & Guimaraes, 1999; Melo, 2005).

Many professionals commonly refer to simplified sewerage as 'condominial sewerage' through its early use in Brazil where groups of dwelling or housing blocks that were connected to the simplified sewer system were referred to as 'condominiums'. According to Watson (1995: 14) this system was inspired by condominium apartment systems in that a simplified sewer line "*mimics a horizontal apartment building*", which the various households are meant to collectively own. Originally, Melo (2005) had only referred to a specific layout of simplified sewers (backyard) as a condominial system (Mara, 1998), but subsequently this has been expanded to include all simplified sewers. More recently, Melo (2005) and Mara & Alabaster (2008) refer to ‘condominial systems’ as both physical ‘sewer systems’ and ‘participatory approaches’ that involve neighbourhood units (or ‘condominiums’) in the project design process and the simplified sewer construction and management. A facilitator from the public utility (or an external group such as a non-governmental organisation) usually coordinates the process. However, it is important to distinguish the technology from the participatory process because:

- Not all simplified sewers are designed, constructed or managed using a condominial approach, as discussed in the upcoming sections (3.2.3 and 3.2.4) on Brazilian and South African case studies.
- Failing to distinguish between the technology and the process has created confusion for a number of professionals; such as World Bank urban planner Gabrielle Watson (1995) who mistakenly states that ‘condominial sewerage’ is a different ‘technology’ to simplified systems.

In this report ‘simplified sewerage’ refers to a technology where the usual design parameters employed for conventional sewerage have been deliberately relaxed in a bid to save money without unduly compromising sewer function or O&M, whilst the term ‘condominial sewerage’ is reserved for the approach or model where users are deliberately engaged in the installation and operation of simplified sewerage. Simplified sewerage is also commonly known as ‘shallow’ or ‘small-diameter’ (or ‘small-bore’) sewerage because the pipes are generally laid at shallower depths using smaller-diameter pipework when compared to conventional sewers. However, Mara (1998: 249, 252) notes that settled sewers (a system with interceptor tanks; see Section 3.3) could also fit this description. In contrast to settled systems, simplified sewers are designed to convey sewage without first settling the majority of the solids in interceptor tanks; thus Mara, as does this report, distinguishes the two technologies by this characteristic.

The way households connect to the sewerage network is frequently another distinguishing characteristic of simplified sewers. In conventional systems, individual households are generally connected to the municipal sewerage in the road reserve via a direct ‘feeder’ sewer (Mara, 1998; Melo, 2005; Figure 3-1). Household units are only responsible for maintaining their connection. Thus issues such as blockages are not problematic for households outside the property borders because municipal authorities are expected to take responsibility for them. Simplified sewerage, in contrast, generally comprises of a number of neighbourhood units each comprising many households (*e.g.* condominiums) linking into the sewer trunk via a single connection point (Melo, 2005). As for conventional sewerage, users are expected to maintain their household connections (Watson, 1995), but in condominial systems this usually extends to the next household (Watson, 1995; Melo, 2005). The service provider, however, still maintains those sewers constructed through public property as for conventional systems (Watson, 1995). However, simplified sewerage systems do not have to be condominially managed; they can be directly linked into the municipal system.

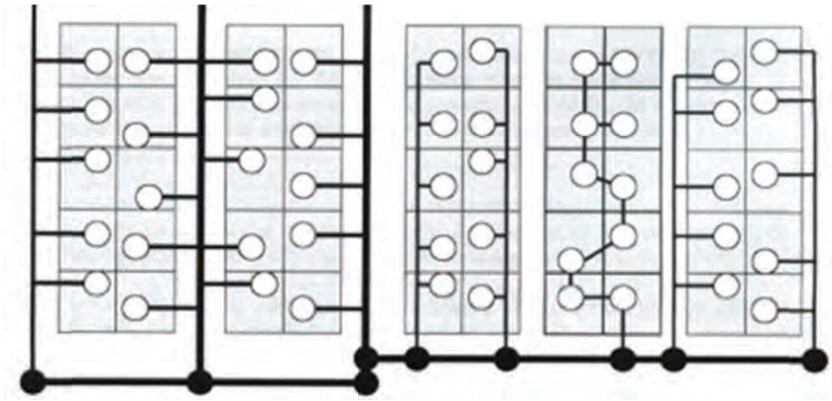

Figure 3-1: Difference in layout between a conventional system and versions of simplified sewer branches connected via the households' adjacent yard or sidewalk (after Watson, 1995)**.**

Whether the user or utility is responsible for maintaining the branch sewer is critical because problems such as downstream household blockages can cause sewage back-ups for upstream households. Blockages need to be dealt with immediately by those users closest to the point of blockage by either manually unblocking the sewer themselves, or reporting the problem to the utility for their action. Watson (1995: 17) notes that in the condominial model, users are expected to "*cooperate… to remove obstructions within the block feeder lines*" (*i.e.* do it themselves), or by hiring plumbers, masons or community members to address such issues if necessary. Having users accept responsibility for such O&M tasks is meant to reduce their monthly utility sewerage fees (Melo, 2005), an incentive to make the service more affordable for low-income households. In Brazil, condominiums (*i.e.* all households linked together by a single sewer) often get to choose which layout they prefer as they are expected to assume the installation and servicing costs (Melo, 2005). Of the three, sidewalk connections have the highest installation costs and servicing fees. Backyard connections, in comparison, are "*significantly cheaper*" to build due to the shallower excavation depths and shorter lengths required (Melo, 2005: 15) as households are directly interlinked to the main sewer. Watson (1995) and Melo (2005) comment that sewerage tariffs for backyard connections should also be lower than sidewalk installations because utilities normally expect users to maintain the branch sewer running through their property themselves, as they likely could not access it. Users with front yard connections, on the other hand, could choose to either manage the branch sewer themselves, or to outsource its O&M to non-household members as access to the sewer is not restricted.

The next section focuses on the benefits and limitations of simplified sewers and condominial arrangements as experienced internationally and in South Africa. Issues with the simplified sewer construction and management, and its impact on design, will be discussed in further detail in Sections 3.2.3 (Experience in Brazil) and 3.2.4 (Experience in South Africa).

3.2.2 Experience with simplified sewers and the condominial approach

Bakalian *et al.* (1994), Watson (1995) and Mara (2006) report that simplified sewerage installations have had great success in Pakistan, Australia, India, the United States, Zambia and throughout South America, particularly in Brazil. In fact, Mara *et al.*, (2001) and Melo (2005) recount that a number of Brazilian utilities have widely implemented simplified sewers using the condominial approach, with some now having adopted simplified systems as their preferred alternative to conventional gravity systems. A number of articles also point to successful applications outside Brazil; *e.g.* Zaidi (2001) and Komives (2001) seemingly support Melo's and Mara's assertions of the condominial approaches' potential when implemented in conjunction with simplified sewer installations in Orangi, Pakistan and El Alto, Bolivia. In both instances, Zaidi (2001) and Komives (2001) claim that the service providers' consultation and communities' participation not only reduced labour costs as compared with conventional installations, but also created a sense of ownership for the simplified sewers, and as a result users were more likely to use and maintain them appropriately.

By adopting simplified sewers, Melo (2005: 6) argues that municipalities could save on capital costs of up to half the length of a sewer system and a quarter the length of a water service because the public network did not need to run through every street or plot of land. Moreover, municipalities could also possibly save on servicing costs by devolving maintenance responsibilities for feeder branch lines from utilities to the residents (Watson, 1995: 35). Yet, Watson (1995: 35) notes, "*this [shared O&M] arrangement has not worked well*" due to "*residents lack[ing] the skills and knowledge to perform complex maintenance tasks and [failure] to cooperate*" with each other, which is exacerbated by the municipality's lack of support to struggling residents. Watson (1995) and Melo (2005) both document that municipal officials and residents were having a number of issues with simplified sewer construction and maintenance arrangements throughout Brazil. Utility officials from Belo Horizonte also confirmed similar findings to the research team. This has resulted in some municipalities accepting responsibilities for services such as sewer rehabilitation and feeder line servicing, thereby not necessarily reducing their O&M costs (Watson, 1995).

Watson (1995) and Melo (2005: 6) believe that cooperating would encourage the two parties to mutually "*facilitate service expansion and adap[t] to local needs and constraints*", through which officials, unfamiliar with working outside a supply-driven framework, would learn how to address the needs of the urban poor. According to Nance & Ortolano (2007: 284), these beliefs were guided by literature from a number of international organisations (including the World Bank) and universities. Such professionals had stressed, "*community participation would contribute positively to project effectiveness*" in their lessons learnt from failed infrastructure projects (Nance & Ortolano, 2007: 284), which were usually installed by service providers and international aid organisations without users' consultation or financial support. A community participation method advocated by some of these groups was co-production, which Joshi & Moore (2004: 1) define as "*the provision of public services…*

through a regular long-term relationship between state agencies and organised groups of citizens, where both make substantial resource contributions".

Co-production aptly describes the aims of the condominial approach as the service provider and groups of users developing and managing a simplified sewer together. Advocates such as Watson (1995), Melo (2005) and Mara (2006; Mara & Alabaster, 2008) focus on the condominial approaches' potential to empower service providers to become skilled negotiators, and users to become vocal constituents. Watson (1995: 10 & 49), in particular, argues that condominial systems are novel "*customer-centred*" approaches to urban sanitation because: (a) municipalities' performance is based on their "*responsiveness to customers*", and (b) users as "*condominial customers play an informal regulatory role, pushing for improved service provision*". After participating in the condominial scheme, Bakalian *et al.* (1994), Watson (1995) and Mara (2006) report that users felt uplifted and developed a sense of co-ownership amongst those involved in the design process, and who contributed monetarily or with 'sweat equity' (*i.e.* free labour) to the project. As a result, Mara & Alabaster (2008) comment that users have been mobilised to make decisions collectively and to project manage as a cooperative.

Watson (1995), Mara *et al.*, 2001 and Melo (2005) promote the condominial approach as an effective and low-cost way to introduce simplified sewer services at-scale. In particular, Watson (1995: 51) states that users' participation and negotiation with agencies "*ultimately improve[d] both the quality and appropriateness of services and the performance of service providers*". Nance & Ortolano (2007), however, point out that simplified sewer services were not always 'enhanced' by a condominial approach in their study of seven such installations in the Brazilian cities of Recife and Natal. In fact, Nance & Ortolano (2007) argue that although interaction between users and utility officials aided the mobilisation and decision-making phases of the condominial approach, this did not necessarily extend to sewer construction or maintenance.

This report builds upon some of Nance & Ortolano's (2007: 287) arguments on how the condominial approach's supporters have 'oversimplified' users' interactions with utilities as resulting in enhanced sewer performance. As Nance & Ortolano found, the Brazilian and South African case studies written up by Watson (1995), Melo (2005), Mara & Alabaster (2008) and Eslick & Harrison (2004) suggest that the condominial approach was effective in eliciting interest in implementing an alternative sewerage service between utilities and users, and facilitating agreement to build. Yet shortcomings in the condominial approach's 'co-production' logic are evident in poorly built and neglected sewers, thereby suggesting construction or management under the condominial model may not be effective. The following sections highlight how users' decisions and actions in Brazil (Section 3.2.3) and South Africa (Section 3.2.4) have sometimes resulted in poorly performing simplified sewers despite implementing the technology with a condominial approach; thus unskilled or uninterested parties should perhaps not be expected to construct or maintain infrastructure. Such data suggests the need for a re-evaluation of where and why the condominial approach has succeeded, and what aspects need to be critically rethought.

3.2.3 Experience in Brazil

After several decades of innovation and modification in Brazil, Mara (1998: 252) propose simplified sewers as the "*most appropriate [technology] in high-density, low-income housing areas which have on-plot level of water-supply (i.e. one tap or more per household) and no space for on-site sanitation pits or for the solids interceptor tanks of settled sewerage*." Yet, both Mara *et al.* (2001) and Melo (2005) state that the uptake of the technology in Brazil has extended beyond the urban poor; for example, the public water and sewerage utility of the nation's capital (Brasilia's Companhia de Saneamento Ambiental do Distrito Federal, or CAESB) considers simplified sewerage as its "*standard solution*" for both rich and poor areas (Mara *et al.*, 2001: 16). The residents of the affluent Brasilia neighbourhoods Lago Norte and Lago Sul have also demanded waterborne sewerage because the area's original sanitation system (household septic tanks) were insufficient for the burgeoning population's needs, which resulted in raw sewage polluting the local lake. Thus, CAESB, in consultation with residents, decided to introduce simplified sewers in Lago Norte and Lago Sul, using the condominial approach for negotiations.

Melo (2005), in his case study of Brasilia's citywide application, also shows how the condominial approach mobilised large numbers of users to interact with the public utility, and collaboratively determine their level of servicing. From 1993 to 2001, Melo (2005) reports approximately 680,000 people living in more than two dozen rich and poor peri-urban neighbourhoods – all previously unserviced areas – that benefitted from 188,000 simplified sewer connections. During this time an estimated 57,000 users attended 5,000 condominium meetings with CAESB, the public utility. These meetings were generally held near the neighbourhood being served (in a school or one of the member's homes), in the evenings when most people were expected to be able to attend (Melo, 2005). At the meetings, residents were given the option of installing sewers themselves or having them installed by the utility company, with users' expected to pay the full cost of installing the condominial sewers in either arrangement and assisting with maintenance (Watson, 1995). As a result of this effort, Melo (2005: 7) reports the city had rapidly achieved universal sewerage access at "*very low financial cost to the utility*" across a "*wide socioeconomic spectrum*" by installing simplified sewers implemented through a condominial approach.

Yet, Melo (2005), in his support of the condominial approach, did not analyse how users' decisions actually indicated their preference for the government to manage the simplified system, which contradicts one of the key co-production aspects of the condominial approach. Melo (2005: 15) notes condominiums in poor neighbourhoods "*usually… weigh[ed] economic savings against the inconvenience of assuming responsibility for maintenance*" when selecting where to lay the branch sewer. Melo's statement infers that residents might be willing to pay higher capital costs to avoid the trouble of managing the branch sewer, which seems to be evidenced in CAESB's statistics (Melo, 2005: 16): users living in three low-income areas had simplified sewer branches installed chiefly in sidewalks (51% at US$85) or front yards (43% at US$59). This is significant to note because such connections were considerably more expensive than backyard installations (US$47).

Melo (2005: 15) does not elaborate on why users had the above preference, but he mentions some believed sidewalk branches "*confer[red] a higher social status*." Melo's statement infers that intended users in poor peri-urban areas believed a sidewalk system – which is supposed to deliver the 'same results' as the front or backyard connections – is somehow better. This, however, may be linked to the type of sanitation service found in the majority of Brasilia's middle- and high-income neighbourhoods that these users wanted as well: a full-flush facility in one's home that drains waste via a connection running underneath the property's front yard into a receiving sewer maintained by the local utility.

Of course, this is only a hypothesis, but, when comparing the relative merits of each system, it seems logical that users in poor neighborhoods often believed sidewalk systems were superior to backyard or front yard connections because they offered the sanitation service they wanted. As stated earlier, the service provider is responsible for maintaining sidewalk branch sewers (Watson, 1995) as in conventional systems. Users could also conveniently outsource management of front yard branch sewers because it would be easy for non-household members – such as CAESB, a private contractor or a condominium member – to access. The backyard connection, on the other hand, restricts branch sewer access thus increasing the likelihood that individual households would be wholly responsible for the branch sewer running through their property. This latter option would have necessitated users to unblock sewer lines, a 'dirty' task which many users were willing to pay more to avoid. Interestingly, Melo (2005: 15) notes that Lago Norte and Lago Sul residents had opted to route branch sewers through their large backyards to avoid inconveniently replacing the expensive paving in their front yards. Melo (2005) does not mention whether O&M duties factored into the residents' decision to install backyard connections; yet these residents probably paid contractors to service their septic tanks, thus making it unlikely that they would have objected to outsourcing this responsibility again.

If the above is true, it shows that project planners and advocates of the condominial approach may not have understood that 'poor' Brasilia users wanted a sanitation service that is found in upper-income neighbourhoods, suggesting they did not want O&M sewer responsibilities. Such an analysis can perhaps also be extended to several instances documented by Watson (1995: 17) where simplified sewers were not managed as the project planners had envisioned. For example, in the State of Pernambuco, the public utility had hired full-time maintenance contractors, which were funded through a special levy added to users' monthly service tariff (Watson, 1995). Watson (1995) also notes that State of Ceará officials outsourced O&M duties as well by hiring a condominium member to maintain the system, though it is unclear how many individuals were employed, and how large a sewer network he or she was responsible for. Of course, there were instances where condominium members had maintained basic sewer O&M without the assistance of external providers. Watson (1995:17) reports that in Natal (the capital city of the state Rio Grande de Norte), one resident on each block was given a rod that all condominium members shared to remove blockages, though it is unclear whether users actually shared the rod to maintain the branch sewer. Nance & Ortolano (2007: 291) also found that "*even when residents tried to do maintenance, they often lacked the skills or tools to succeed and needed professional support* *from the responsible sanitation agency*." Moreover, some of those interviewed told Nance & Ortolano (2007: 291) that they "*had previously agreed to handle maintenance on their own, [but now] refused to do so because they believed that maintenance was the government's responsibility*." Thus findings from Melo (2005), Watson (1995) and Nance & Ortolano (2007) show that many users' actions indicate they do not want to manage the branch sewer, which suggests aspects of the condominial model need to be critically rethought.

Watson (1995: 36) also states that simplified sewer management was oftentimes complicated in low-income Brasilia neighbourhoods as these areas had "*high resident turnover and high rates of house expansion and construction*", which made cooperative management logistically difficult. "*New residents [were] not always aware of the network's existence, or [oftentimes were] not advised properly about operation and maintenance*" (Watson, 1995: 36), thus there was an increased risk of misuse and mismanagement. Watson does not distinguish who – the old residents, a condominium member or the utility – is responsible for training and informing new residents, thereby noting another major risk of expecting users to maintain branch sewers. Watson also notes instances where a 'condominium manager' was identified to troubleshoot problems; however, this, too, was sometimes ineffectual because the 'manager' moved, or residents forgot who was assigned the task. Moreover, Watson (1995: 17) says a number of Brazilian simplified sewer installations had suffered because residents had "*difficulty cooperating*" with each other. The constant flux of household compositions and users' difficulty in resolving O&M issues highlights a major long-term risk that has not been adequately addressed in the condominial approach. When these O&M tasks were unfulfilled the service provider oftentimes had to assume these duties (Watson, 1995), thereby the public utilities absorbed the servicing costs. Thus, in light of all of the above problems and risks, project planners need to ask themselves: should disinterested or unskilled users be responsible for the branch sewers? Or should these critical tasks be permanently outsourced to skilled providers? If project planners choose the latter option, they will also have to consider who is most appropriate to perform the tasks.

In addition to people struggling with sewers due to poor O&M, Watson (1995), Mara *et al.* (2001), Melo (2005) and Nance & Ortolano (2007) also report on users' and local authorities' troubles with poorly built sewers due to construction and limited construction supervision. Simplified sewers are at a high risk of blocking because shallow gradients are employed, hence good sewer design and construction quality control are critical. Unfortunately, though, Watson (1995) found numerous examples of poorly constructed sewers built by unskilled labour with limited monitoring, thereby affecting the reliability of the sewer system. To ensure functionality, Mara *et al.* (2001: 93) suggests that service providers train small contracting companies as a means of avoiding major operational problems due to poor construction. Furthermore, Melo (2005) notes that physical constraints (such as an area's topography) often require specialised construction methods; experience which condominium members generally cannot provide. In these situations, Mara & Alabaster (2008) suggest that users be limited to excavating the trenches to reduce labour costs, thus limiting unskilled tasks for condominium members to the construction phase. Such tasks deviate from the condominial approach in which users are encouraged to build their own sewer connections to reduce labour costs (Watson, 1995), and supports the idea that only skilled personnel should build and monitor construction.

Whether or not users participate extensively in the planning, decision-making, construction and/or operational phases, Melo (2005) and Mara & Alabaster, 2008) still recommend the condominial approach as a way for users to share the capital and servicing costs, as well as O&M responsibilities, for new simplified sewerage installations. The condominial approach seems to be an effective facilitation tool for mobilising interest in the infrastructural campaign, and including users in deciding what layouts they prefer; however, the benefits as regards the construction and O&M of the system when employing the condominial approach seems to be questionable as Nance & Ortolano (2007) found. If anything, the success of the condominial method is not managing new infrastructure, but introducing an effective platform that can facilitate the negotiation between the service provider and users regarding the design.

3.2.4 Experience in South Africa

The applicability of simplified sewerage in South Africa was investigated in a late 1990s WRC study (Report TT 113/99). In this report, Pegram & Palmer (1999) identified the following types of South African settlements as best for introducing simplified sewerage:

- Low- to middle-income formal and informal settlements with existing on-plot sanitation but no sewer connection, where users are willing to finance the project and take responsibility for construction and operation of branch sewers; and
- Low-income informal settlements with access to capital grant financing and where users are willing to take responsibility for block sewer construction and maintenance.

In these instances, Pegram & Palmer (1999) argue that the users needed to take responsibility for construction and maintenance of simplified sewer installations. The following section describes two simplified sewer schemes undertaken in South Africa. The first was facilitated by eThekwini Municipality for the low-income housing developments of Emmaus and Briardale in Durban. The eThekwini case studies are comprehensively discussed in the WRC report *Lessons and Experiences from the eThekwini Pilot Shallow Sewer Study* (Eslick & Harrison, 2004); a short account of the key findings from the pilot, including reflections on implementing the condominial method and financing the scheme, is recounted below. The second simplified sewer scheme is in Hangberg, an informal settlement in Cape Town where users privately extended the municipally provided sewer system. It is presented in Section 4.2. Both case studies show the significant roles users and service providers have in the uptake and management of simplified sewer systems.

A public-private partnership was established between eThekwini Water Services (EWS), Water and Sanitation Services South Africa (WSSA) and the WRC in order to ascertain whether simplified sewerage would provide a viable alternative waterborne sanitation system to the urban poor in dense settlements in South Africa with the "*self-help*" condominial model (Eslick & Harrison, 2004: 2 & 29). Eslick & Harrison (2004: 21) report that the three organisations had divided "*responsibilities based on their individual expectations and objectives*" as follows:

- EWS was responsible for identifying settlements for the pilot study, designing the sewerage system, providing water supplies to the pilot installations, researching and administering the household tariffs, the systems' commissioning, and specific maintenance tasks that would be identified during the project's implementation;
- The technical experts WSSA were responsible for general project management. A Program Manager from WSSA had previous experience implementing the condominial approach and installing simplified sewers in Bolivia and Brazil, thus he helped facilitate the pilot projects, and conducted handover trainings for the municipality and users; and
- WRC-funded researchers were responsible for data collection and research dissemination.

In 2000, EWS identified Emmaus and Briardale housing developments as 'suitable' sites to pilot the simplified sewers projects because both were located near existing conventional sewerage points and were earmarked for either municipal servicing or provincial housing upgrades (Eslick & Harrison, 2004). Furthermore, Eslick & Harrison (2004: 34) report that "*both communities had expressed great desire and willingness to participate*" in the study and had "*ranked sewerage provision in their top three development priorities*". Emmaus is a housing development with 94 homes on individual plots. The Emmaus residents had originally installed septic tanks but they could not empty the tanks when they were full. Eslick & Harrison (2004) do not elaborate on whether residents could not afford the expense, or whether the septic tank designs prohibited desludging; nevertheless, Emmaus residents "*had approached EWS to solve their sanitation problem*" (Eslick & Harrison, 2004: 33).

Emmaus residents and EWS then began negotiating potential low-cost sanitation alternatives for the housing development. However, the Emmaus residents' situation was complicated because they had already used their housing subsidies, which meant they did not call on government funding to connect to a sewer (Eslick & Harrison, 2004: 33). The Briardale housing development, in contrast, had 155 families who hoped to include sewer connections as part of their housing subsidies. The People's Dialogue, a non-governmental organisation who wanted to facilitate and manage the greenfields housing project, assisted Briardale residents with their applications for Provincial Housing Board subsidies (Eslick & Harrison, 2004).

Eslick & Harrison (2004) note that the project's condominial approach was adapted from a model the WSSA Project Manager had reportedly implemented in La Paz, Bolivia. The implementation of the pilot was divided into eight steps (Eslick & Harrison, 2004: 30), as follows:

1) ***Institutional and community arrangements***: Initial agreement between the project team (EWS and WSSA), the researchers, and Emmaus and Briardale residents on the project scope, how each party would be involved and what resources each would contribute.

2) ***Cadastral and social characterisation***: The project team conducted socio-economic surveys and initial technical and geo-hydrology assessments.

3) ***Health and hygiene education and community strengthening***: The project team offered residents health and hygiene awareness training and developed community participatory tools to increase interaction between the project team and residents. Condominium representatives were also selected during this stage.

4) ***Definitive design, task planning and agreements***: The project team consulted with residents and agreed upon a layout, design, works schedule and draft legal agreements together. It was assumed the "*community [would make] an informed decision about the type of services they want and are willing to pay for*". During this phase WSSA and EWS also organised training for personnel and residents who would construct and maintain the system.

5) ***Works implementation***: The intention was that the "*community construct… the condominial branches of the system, ha[ve] ownership of, and understand… the proper use of and implications of abusing the system, having received operation and maintenance training*".

6) ***System consolidation***: Residents would construct the simplified sewer household connections and started to use/manage the system. The project team would evaluate the system at this stage and work with residents to resolve any problems. "*[A]t the end of this phase, the houses should have functional wet cores that drain into the [simplified] sewer system. All training would have been completed to enable the people to maintain the system themselves*".

7) ***Systemisation and final evaluation***: The project team would collect results from the pilots and analyse the technology and method.

8) ***On-going social maintenance***: Residents would bear the costs for maintenance, including the materials and tools, whilst the EWS would be responsible for sanitation services management, such as any further social intervention, assistance with maintenance, retraining, *etc*. deemed necessary.

According to Eslick & Harrison (2004: 42), Emmaus and Briardale residents initially accepted the project's approach with enthusiasm, particularly in Briardale where some residents adopted the condominial model to manage 'community finances'. Through the first four steps of the process, WSSA, EWS and residents primarily interacted in community meetings and workshops. At one of these initial meetings, residents were grouped into *amaqoqo* (singular = *iqoqo*), a term used in this instance as a Zulu equivalent for condominiums (Eslick & Harrison, 2004: 35). As part of Step 4, EWS drafted memoranda of agreement (MOAs) to establish clear and legally binding roles and responsibilities between *iqoqo* members, *amaqoqo* and eThekwini Municipality. In the legal agreements:

- Each *iqoqo* member was meant to own "*the section of pipe that connects the[ir] house to the condominial sewer*" (Eslick & Harrison, 2004: 147).
- "*Communities were expected to install [branch sewers]*", "*connect to the sewer [main]*", and be jointly responsible (in an assumed community of interest) for a branch sewer that the members of the *amaqoqo* collectively owned (Eslick & Harrison, 2004: 38).
- Finally, the local authority was meant to be responsible for constructing and maintaining the sewer main (Eslick & Harrison, 2004).

In other words, as in the Brazilian condominial management schemes, each owner was supposed to be responsible for the construction, operation and maintenance of 'their' property.

Furthermore, according to a draft of the project MOA between an *iqoqo* member and the service providers (Transitional Metropolitan Council of Durban, undated: 1 & 4), the legal agreement was meant to ensure that both parties understood that piloting the experimental simplified sewer system "*necessitates the imposition of conditions generally not contained in the [municipal] bylaws*", and the protocol if the pilot project was deemed a failure. Users, service providers or an eThekwini Health Department official could determine if the pilot failed, though no details were included on how anyone would assess this. Nonetheless, if the pilot technology was deemed a failure, the Council was meant to provide users with a replacement of an "*equivalent level of sanitation to each dwelling unit at no cost to the owner*" (Transitional Metropolitan Council of Durban, undated: 4), within five years of the contract's commencement date.

Eslick & Harrison (2004) report that, eventually, all but one condominium (of 17 houses) in Emmaus had agreed to the MOA terms. Described by Eslick & Harrison (2004: 40) as the more affluent members of the community, the 17 Emmaus households had wanted a full pressure water supply, but the majority of the community preferred a semi-pressure as a cost saving. EWS' policy was to supply "*only one level of service*" and they could not reach consensus, thus the 17 households unhappily withdrew from the project (Eslick & Harrison, 2004: 40).

By November 2000, Eslick & Harrison (2004) state that the pilot project was running on-schedule despite the above negotiation issues, and EWS essentially completed the construction of the main simplified sewers. EWS was ready for *iqoqo* members to connect; however, soon after Eslick & Harrison (2004: 3) report that the schemes came up against community pressures beyond the project planners' control, resulting in limited household connections to the sewer mains. In Emmaus, election promises of free basic water by an aspiring local councillor candidate (who was later elected) led residents to understand that their homes would each be provided with free water and sewerage services – that is, all internal plumbing, connection and consumption costs. This resulted in the majority of Emmaus residents refusing to "*uphold their side of the [project] agreement*" (Eslick & Harrison, 2004: 39) because they did not want to assume the construction, connection and servicing fees themselves. WSSA tried reinvigorating interest in the project with Emmaus *iqoqo* members, but by March 2001 the project team "*realised that the implementation was not going as planned*" (Eslick & Harrison, 2004: 134). WSSA eventually chose to withdraw from the project due to residents' apathy (Eslick & Harrison, 2004). After WSSA's withdrawal, EWS decided to continue monitoring and evaluating users' perceptions of simplified sewers for the sake of the research study, but they no longer pressured the community and allowed them "*to connect as and when they wanted to*" (Eslick & Harrison, 2004: 40). Ultimately, Eslick & Harrison (2004: 39) report that only 24% of Emmaus households (approximately 23 out of 95 *iqoqo*) connected to the water supply, and 11% (an estimated 10 out of 95 *iqoqo*) installed sewer connections.

Briardale residents also had financing problems because the NGO developer People's Dialogue failed to obtain subsidies for the housing scheme. This meant residents no longer had funding to build their own homes, let alone water and sewerage connections. People's Dialogue had tried to remedy the situation by offering loans, but Eslick & Harrison (2004) report that the owners of 65 houses (about 42% of the planned 155 homes) had primarily used their personal savings to build instead. WSSA did, however, assist Briardale residents with loans and in-kind donations of materials, tools and plumbing support to increase household connections. In all, WSSA eventually assisted 48 households (74% of the 65 houses) in building water and sewerage connections, and an additional seven homes with water supplies only (Eslick & Harrison, 2004). Despite belated efforts by People Dialogue to find alternative means to fund the housing project, Eslick & Harrison (2004: 40) state that their failure to secure the subsidies had irreparably undermined the community committee, which essentially caused the "*collapse*" of both the housing and simplified sewer pilot projects. Consequently, Briardale residents withdrew their support and barred EWS staff from entering the site (Eslick & Harrison, 2004). Thus, as in the Emmaus project, a lack of subsidised support ultimately resulted in lower than expected connections, jeopardising the research project's aim to test whether simplified sewers could be a viable alternative to conventional systems.

The various events above led EWS to consider whether they could apply the MOA terms *iqoqo* members had previously signed. An assessment by eThekwini Municipality's Legal Department in August 2001 came to conclusion that this was impossible because the MOAs were not legally binding contracts. Their review, included as an appendix in Eslick & Harrison's report (2004: 48), points out a number of "*legal shortcomings and incompatibility between the [simplified] sewer technology and South African legislation… relate[d] to land issues, contractual issues and… the National Building Regulations*". In essence, it seems as though the fundamental principles behind the condominial approach – namely sweat equity and collective ownership – conflict with national legislation. The Legal Department's main contractual and technical issues are summarised below, as well as how the condominial method conflicts with South African legal policies:

- ***Non-binding agreement***: A MOA signatory had to "*acknowledge that they are independently liable for all charges imposed in respect of any service rendered by the Council"* (Eslick & Harrison, 2004: 148). Yet the Legal Department state the municipal officials could not legally bind Emmaus and Briardale residents because it was not an encumbrance or servitude included in their title deeds. Furthermore, the Council could not bind a third party, such as a future homeowner, for agreements made between *iqoqo* members and EWS.
- ***Collective ownership***: The notion of having collective ownership of infrastructure in South Africa is flawed because a condominium is not a legal entity, thus cannot have ownership rights. In this situation, the titleholder, not the *amaqoqo*, for example, owns the segment of branch sewer laid in their property. According to the Legal Department, *amaqoqo* could register condominiums as non-profit Section 21 Companies (Eslick & Harrison, 2004), but the set-up costs – (an estimated R3,000 per *iqoqo*) at the time of the evaluation – are cost-prohibitive for low-income households.
- ***Collective encumbrances*** (*i.e.* debt or liabilities): The MOA had stipulated that all costs undertaken by EWS were to "*be borne jointly… by the members of the condominium*" (Transitional Metropolitan Council of Durban, undated, 1). However, according to the Legal Department, individuals could only be held accountable for servitudes attached to their title deed. The plots of land were owned by households, not the *amaqoqo*, thus encumbrances can only be billed individually (Eslick & Harrison, 2004).
- ***National Building Regulations (NBR)***: The NBRs for sewerage are based on conventional systems that do not allow innovations for simplified systems such as pipe diameters smaller than 100 mm. Moreover, the NBR "*prohibits people from undertaking work on the drainage system unless they are licensed*" (Eslick & Harrison, 2004: 149). WSSA had trained *iqoqo* members on how they could construct and manage their branch sewers; however this training would not meet the construction or plumbing licensing standards. Thus, the condominial approach's sweat equity principle directly conflicts with NBR specifications.

Following the Legal Department's findings, EWS officials accepted that they could not compel residents to participate in the proposed scheme. The Legal Department had stressed that sewerage standards could be relaxed if a *Government Gazette* on simplified sewer specifications was released (Eslick & Harrison, 2004: 151); however, EWS found they could not easily overcome the contractual and tenure issues. Thus the condominial method – not simplified sewers – is seemingly impossible to implement in South Africa at present because it is incompatible with national policies that are based on historical ideas of private property. In retrospect, Eslick & Harrison (2004: 146 & 63) acknowledge that the attempt at social intervention failed in some ways, but considered that a "*reduced standards sewerage system*" should "*be developed and promoted as the 'standard' or norm for low-cost and high density subsidised housing systems*" in South Africa. This conclusion is similar to Pegram and

Palmer’s (1999) findings, except Eslick & Harrison (2004: 63) recommended the simplified sewers be owned and operated by the local authority instead of users. In other words, Eslick & Harrison (2004) espoused local authorities accept responsibility for the sewerage systems and sanitation services of informal settlements and low-income housing developments.

Eslick & Harrison (2004) also note that the researchers could not reach firm conclusions on the technical feasibility of simplified sewers in South Africa because of the insufficient number of connections due to the various socio-political and financial problems described. In their conclusion, Eslick & Harrison (2004: 7) feel that the condominial method “*in its pure form*” was “*not applicable to the country in general*” because:

- The self-help tenet contradicts the “*communities’ expectation that the government will provide*”;
- National government’s desire for rapid infrastructure development does not correspond with the negotiation processes necessary for community engagement;
- The various legal issues, such as the conflict between private land tenure and communal ownership, contradict the collective principles of the condominial method; and
- eThekwini institutional structures do not promote collaboration between the community liaison department and the technical staff required for infrastructure projects.

Although the pilot project did not elicit the results project planners had wanted, EWS officials nevertheless had additional confirmation that the previous development policy for supplying sanitation services to the urban and rural poor needed to be critically rethought. Various interactions with eThekwini officials, including interviews or correspondence with personnel (Gounden, 2010; Harrison, 2012) indicate that the simplified sewer project was one of many case studies that contributed to EWS accepting full financial and management responsibilities for sanitation services to the poor. In particular, officials restructured the department and recruited new staff to overcome the non-collaborative government silos that plagued a number of community consultations. EWS’s new basic services model, based on the notion of ‘partnerships’, will be discussed further in Section 3.5.3.

In a follow-up e-mail, Harrison (2012) notes that the eThekwini Municipality Housing Department had eventually accepted responsibility for the Briardale housing development and subsequently replaced the simplified sewers with “*full waterborne sewers to appease the community*”. In contrast, the Emmaus simplified sewers are still technically operational, but some of the households in Emmaus “*have connected badly*” to the sewer main, using pedestals without water traps (Harrison, 2012). Consequently, residents are complaining of odours and “*blaming it*” on the simplified sewer system. Emmaus residents have since petitioned a Ward Councillor to replace the simplified sewers with conventional mains and connections at the municipality’s cost. Harrison interestingly notes that the Emmaus simplified sewer pilot continues to run in spite of “*the ignorance of the [new] home owners*” who do not realise that their opposition to the system may be enough for the project to finally "*fall to pieces*". Furthermore, Harrison acknowledges that residential turnover (coupled with informal densification in the form of backyard dwellers residences) has complicated the existing simplified sewer *iqoqo* O&M arrangements because new owners of connected homes have not been trained. Watson (2005) notes similar O&M problems caused by residential turnover in a number of Brazilian simplified sewer applications, thus once again indicating a shortcoming of the condominial approach.

3.2.5 Lessons learnt

Simplified sewerage and its linkage to the condominial approach have reportedly enjoyed success internationally (Mara *et al.*, 2001; Melo, 2005). However, after further analysis, Watson's (1995) and Melo's (2005) assertions of the potential for users and utilities to save on construction costs, monthly sewerage tariffs and/or maintenance are likely overstated. Available literature has shown the condominial approach has been an extraordinary participatory planning tool towards consensus building, but has had mixed results when it came to construction and long-term management of the facilities. Harrison (2012) found that users' dissatisfaction of the system stemmed primarily from poorly constructed connections when *iqoqo* members did not follow the municipality's design specification. This finding supports the recommendation by Mara *et al.* (2001) that contractors be specifically trained and strictly supervised to construct simplified sewers for the purpose of avoiding major operational problems due to poor construction as a result of supposed cost savings.

The success of the condominial approach may not be so much about sharing capital or labour costs and responsibilities between overwhelmed local authorities and the urban poor, but rather introducing a service provider led participatory method that is acceptable to involved users thereby allowing the two parties to design and set-up a new technology together. Further analysis should be undertaken to understand what tenets had made the approach attractive to condominium members. In addition, future research should also query why condominium members so often chose sidewalk connections serviced by the municipality, rather than backyard or front yard connections. Such studies will likely show that the urban poor want the convenience and prestige of a fully serviced sewerage system, not just the technology. In essence, they want a similar level of service to that which is 'standard' (*i.e.* expected) in higher-income, formalised areas, specifically: an arrangement where users only manage their full-flush toilet and their household connection to the collection main inlet. Ultimately, such evidence should lead service providers to ask: why create a different level of service for the urban poor to the one which people living in developed areas expect?

The eThekwini study suggests that – as one CoCT official put it – "*we cannot govern the 'third world' South Africa with 'first world' laws and systems*". The condominial method was shown in eThekwini to have major social problems and legal repercussions that made it difficult to implement and manage in a South African context. Eslick & Harrison (2004) ultimately come to the conclusion that due to various socio-political and legal constraints, the condominial approach is unsuitable for a South African context. In particular, the explicit pressure for *iqoqo* members to contribute was shown to be problematic. Thus they recommend that local authorities should adopt and manage simplified sewers themselves rather than expecting users to maintain branch sewers.

Harrison (2012) notes that users commonly blame the technology for what is wrong whenever a system fails. This statement can also be extended to include the poor planning, installation or management of sanitation professionals, municipal officials, political officials and users who – likely in an effort to avoid culpability – are unwilling to accept responsibility for how their actions (or inactions) will influence whether a project succeeds or fails. This topic will be revisited several times throughout the report, particularly in discussions regarding Cape Town's vacuum system in the informal settlement of Kosovo (Section 4.4).

3.3 Settled sewerage

3.3.1 Background and description

Settled sewers were first designed in Northern Rhodesia (modern day Zambia) in the 1960s (CSIR, 2005). Like conventional and simplified sewerage, settled systems rely on gravity to convey effluent to a wastewater treatment works (WWTW) via a reticulation network. Furthermore, similar to simplified systems, costs can be relatively low for settled sewers because they require only shallow excavation depths, small-diameter pipework and simple inspection units in place of large manholes (Mara, 1998: 252). However, they also require the insertion of interceptor tanks immediately downstream of toilets, baths and showers, but upstream of each connection point to the main sewer line – which must be periodically de-sludged. This allows for effluent with minimal amounts of total suspended solids to be conveyed to the treatment facility whilst the settleable matter is collected in the interceptor tank. Thus, settled systems are sometimes referred to as 'solids-free sewerage' (Du Pisani, 1998a). Mara (1998) recommends settled systems as a low-cost sewerage alternative for areas where housing densities have risen to a point where sewers have become necessary.

There are two variations of the system: Septic Tank Effluent Pumping (STEP) and Septic Tank Effluent Drainage (STED). Both systems settle solids in interceptor tanks, but the two systems transport effluent to the WWTW differently. STEP systems have submersible pumps installed in the interceptor tanks to pump the sewage via pumping mains to suitable disposal points – and clearly require an additional energy source such as electricity (Figure 3-2). The United States Environmental Protection Agency (EPA, 1991) also refers to STEP systems as low-pressure sewerage. In contrast, STED systems (also known as small-bore, small-diameter gravity, solids-free sewerage or sewered interceptor tanks) convey effluent by gravity (Otis & Mara, 1985; EPA, 1991). A variation of a STED system where the tank is located directly or slightly offset from below the pedestal (toilet) is called an aqua-privy (CSIR, 2005, 11). In this variation, toilets discharge directly into the tank via a vertical pipe that maintains the water seal by ending some 100-150 mm below the surface of the tank's water instead of the usual U-, S- or J-shaped trap (CSIR, 2005: 11).

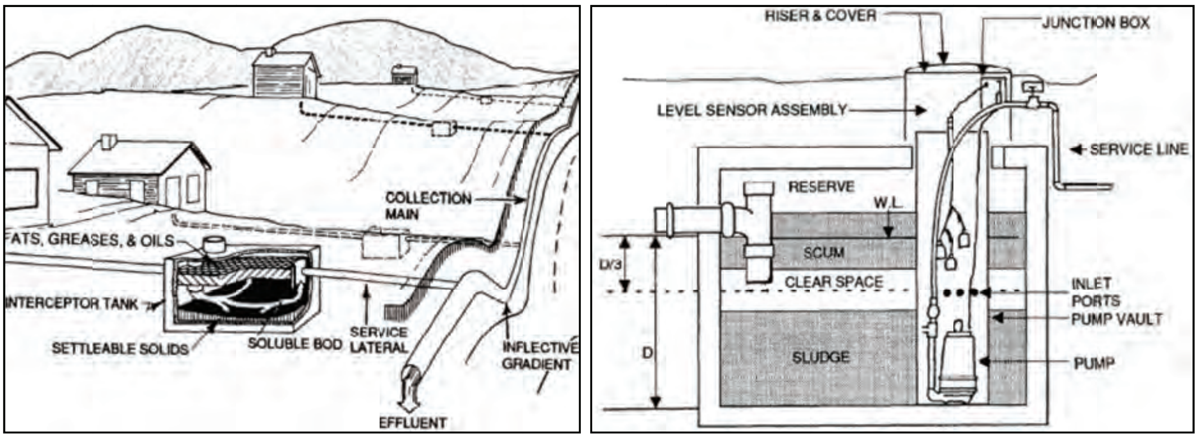

Figure 3-2: STED system (left) and a STEP system (right) (EPA, 1991)**.**

As the majority of effluent drawn from the middle of the tank is free of large solids (reducing the risk of settlement in the pipes) and the tank provides temporary storage (reducing the peak flow), smaller diameter pipes than are generally used in conventional systems can be installed. Furthermore, since the majority of solids are removed prior to reticulation, if there are blockages, they are usually easily flushed or rodded. Additional advantages accruing from the removal of large settleable solids are the possibility of negative gradients for short lengths of pipe (the hydraulic gradient must remain below the surface), and a reduction in the amount of water required for sewer cleansing. Du Pisani (1998a) and the EPA (1991) note that these differences compared to conventional gravity systems make settled sewerage particularly useful in areas where water supply is limited or unreliable, with flat or undulating terrain and where deep excavations would be problematic due to underlying hard rock, unstable soils or high groundwater tables. Settled sewers are also well suited to remote areas where houses are far apart from each other allowing for effluent, free of large solids, to be conveyed over long distances in relatively small diameter pipes with minimal hydraulic losses.

The main challenge with settled sewerage revolves around the operation and maintenance of the interceptor tanks: regularly monitoring the accumulation of solids and periodically de-sludging and transporting the sludge to a treatment facility. Otis & Mara (1985) point out that blockages leading to sewage spills will occur if the interceptor tanks are not de-sludged before full. For emptying purposes, the tanks should be accessible by appropriately equipped vacuum tankers (Du Pisani, 1998a: 5). Seabloom *et al*. (2005) warn that the retention of sewage for extended periods of time (interceptor tanks are generally sized with a mean hydraulic retention time of 24 hours) will result in a greater production of hydrogen sulphide (H_2S) and methane gas than is common in conventional systems. This is problematic as these gases are corrosive and explosive respectively. Another challenge noted by EPA (1991) for STEP systems is the reliance on electricity to pump sewage.

The following sections will primarily reference Du Pisani's (1998a) review of international and South African case studies of settled sewer systems. Once again, there is limited sociological data. Moreover, although Du Pisani provides guidance regarding O&M, there are few details on how the settled sewer systems in Zambia or South Africa were financed, constructed and planned. Nevertheless, Du Pisani's findings show settled systems' potential for servicing sparsely populated areas.

3.3.2 International experience

Settled sewers have been built and operated in Zambia, the United States, Australia, Nigeria, South America and South Africa (Otis & Mara, 1985). The EPA (1991) reports that settled sewerage are used primarily in low- to medium-density peri-urban areas. Du Pisani (1998a) and Austin (1996) state that one of the advantages of settled systems for local authorities and users is their low installation costs, particularly when septic tanks or conservancy tanks exist and can be modified to serve as settled sewer interceptor tanks.

According to Du Pisani (1998a), the attraction of settled sewers stems from the fact that they seem 'robust' and require minimal and non-specialised O&M. The communal aqua-privy systems and settled sewers in Zambia were still partially operational after nearly 40 years despite poor O&M due to lack of manpower and equipment (Du Pisani, 1998a: 6 & 21). Settled sewers also require little specialised training for personnel beyond a basic knowledge of sewer system operation and tank de-sludging (Du Pisani, 1998a: 21). Where some Zambian systems failed, Du Pisani (1998a) concludes that the majority of problems encountered resulted from improper operation of the interceptor tank. Frequently tanks had not been timeously emptied thus the high sludge levels obstructed effluent from draining. Furthermore, users complained about odour problems when the water-seal for aqua-privy systems was below the water chute due to water shortages. Aqua-privies – like all sewerage systems – are clearly unsuitable for areas with unreliable water supplies. Bakir (2001) suggests that when interceptor tanks are properly maintained, settled sewerage will provide the same convenience and reliability as any other waterborne sanitation system.

Despite the various O&M problems experienced with the aqua-privy systems and settled sewers in Zambia, Du Pisani (1998a: 20) notes that most were "*immediately alleviated by emptying the tanks of sludge*" and "*could be restored to full effectiveness [if] adequate maintenance was carried out*". Furthermore operators of systems in the United States and South Africa report that settled sewers had "*proven to be largely trouble-free with low maintenance requirements*" (Du Pisani, 1998a: 20), thus making the system seem all the more attractive to local authorities interested in finding a low-cost and low-maintenance sewerage 'solution'. A summary of the experience with ten South African settled sewer installations is discussed next – which is mostly similar to that reported in the United States (EPA, 1991) and Zambia (Du Pisani, 1998a).

3.3.3 Experience in South Africa

Amongst the alternative sewerage systems that are the focus of this study, settled systems – in particular STED systems – have seen the most widespread adoption in South Africa. The first

STED system in South Africa was commissioned in 1989 as a result of the Council for Scientific and Industrial Research's (CSIR) interest in settled systems. The CSIR, from 1988 to 1992, conducted a number of workshops and collaborated with local engineering consulting companies in an effort to construct pilot settled sewerage schemes (Du Pisani, 1998a). Many of the STED systems installed in South Africa were originally isolated conservancy and septic tanks with soakaways that were networked by modifying the tank's inlet and outlet configurations (Austin, 1996). According to Austin (1996) and Du Pisani (1998a), in some instances the design and construction specifications normally used for conventional sewerage had been over-relaxed. This resulted in some instances of haphazard construction that did not have acceptable minimum sewer diameters, minimum sewer gradients and/or maximum intervals for maintenance access inspection points. Furthermore, Austin (1996) notes that the high capital and O&M costs for the interceptor tanks have been a problem for settled systems in low-income settlements.

In order to assess the performance of operating settled systems in South Africa, Du Pisani (1998a) interviewed municipal water and sanitation personnel, design consultants and users of nine rural and peri-urban settled sewer installations in five provinces (Eastern Cape, Free State, Gauteng, Northern Cape and Western Cape) in 1996 to understand their understanding and perceptions of the systems. Furthermore, she inspected a number of tanks connected to both private and commercial properties, and a few pump facilities; notably, none of the tanks were shared. The various systems had been operational for periods ranging from eight months to seven years, averaging two years. She focused primarily on the technical O&M aspects and did not include socio-economic data such as where funding was obtained for the settled sewer installations and which departments managed the systems.

Du Pisani (1998a) comes to the conclusion that settled sewerage is most suitable in areas with pre-existing conservancy or septic tanks located on individual properties (*e.g.* domestic units) and where those are subsequently upgraded by connection to a municipally installed and maintained sewer line. The existence of tanks reduces the high capital costs that would otherwise be associated with settled sewerage installations in areas that do not have such existing infrastructure. The technical problems experienced with existing South African settled sewerage systems seem to be mostly related to poor construction and blocked tank outlets. Settled sewer systems located in middle- to upper-income rural and peri-urban settlements have generally worked well, albeit with some minor problems arising from poor preparation of maintenance personnel and/or inadequate quality control during construction and maintenance activities. On the other hand, unforeseen densification in poorer peri-urban areas – for example from backyard shack construction to accommodate extended family – has resulted in interceptor tanks becoming overburdened thus limiting anaerobic digestion and the tanks' efficiency to settle out solids. Furthermore, pipes have collapsed under the weight of concrete foundations, inferring that project planners need to consider the risk of unauthorised building before implementing an alternative sewer system with shallow sewer lines. Watson (1995) and Mara *et al.* (2001) report similar challenges with Brazilian schemes. In addition, like Austin (1996), Du Pisani (1998a) suggests that the operators' and users' poor understanding of the technology has likely affected the performance of some settled systems, thus suggesting improvements when the role players have learned how such systems should function. For example, Du Pisani (1998a: 78) states that the Krugersdorp Municipality operators and users needed more "*education… to ensure that this system does not fail*", inferring education and awareness, rather than behaviour change, is enough to have people adapt. Du Pisani (1998a: 37) considers that verbal explanations given during the field inspection "*by technically orientated people would not be sufficient to transfer an understanding of the system to the users*", which prompted her to create a pictorial guide for Community Leaders (Du Pisani, 1998b). The guide is a 15-page document that simply explains how settled sewers function and should be managed. However, as Nance & Ortolano (2007) would say, Du Pisani's report and guide 'over-simplifies' the link between misuse of toilets and lack of information, particularly for failing systems in low-income areas. Indeed, Du Pisani (1998a) herself considers that financial motivations (*e.g.* resulting in Marselle residents removing the outlet tee-piece), or the users' circumstances (*e.g.* Lusaka II users having to collect water for pour-flush toilets) may have also influenced their behaviour.

3.3.4 Lessons learnt

International examples of settled sewerage applications suggest that the system could offer a reliable service at a potentially lower cost than a conventional system due to: shallower excavation depths, smaller diameter pipework, the use of inspection chambers rather than manholes, and fewer – and less serious – pipe blockages. Based on her observations of Zambia's 'robust' settled sewers, Du Pisani (1998a) thus suggests that overloaded and financially strapped local authorities should seriously consider the technology as it requires minimal and non-specialised O&M. However, Du Pisani (1998a) also notes that it has mainly found application in areas that have pre-existing conservancy or septic tanks located on individual residential (domestic unit) sites as this reduces the high capital costs that would otherwise be associated with settled sewerage installations. On the other hand, the capital costs of installing the interceptor tanks and connecting them to the network, coupled with the high on-going operational costs associated with emptying them, may make them too expensive for low-incomes areas (Austin, 1996).

At least in so far as the literature consulted has thus far indicated, it has yet to be demonstrated conclusively that settled sewerage is appropriate for communal facilities in South Africa. Du Pisani (1998a) also notes the risk of shallow pipes collapsing due to uncontrolled construction activities, inferring that the use of shallow pipes in informal settlements may be a problem.

3.4 Vacuum sewerage

3.4.1 Background and description

Vacuum sewers are often thought of as a 'new' technology, but their use in Europe and the United States dates back over 100 years (EPA, 1991). Petrešin & Nekrep (2008) state that a vacuum sewer system was first developed for the city of Haarlem (The Netherlands) in 1866 and for Amsterdam in 1906. A commercial application was also developed and tested in a residential district of Stockholm by the Liljendhal Corporation of Sweden in 1959. Nevertheless, its development has lagged behind other wastewater collection technologies and it is commonly referred to in literature as a 'last resort' (PDHEngineer, undated). More recently, however, several companies have entered the world market for vacuum sewer systems (EPA, 1991). Within the last decade, vacuum sewers have even become viewed as a viable alternative to waterborne sewerage, with the lessons learnt from early systems resulting in improved design and operation guidelines (EPA, 1991). By 2004 there were over 1,000 vacuum sewerage systems operating around the world in the United States, Germany, Botswana, Namibia and Australia (Little, 2004). The Water Corporation in Western Australia is considered the largest single owner of vacuum systems in the world with over 30 schemes operating under its jurisdiction.

Vacuum systems use differential air pressure to propel sewage through their own dedicated pipes to the main sewer network in an area. Unlike conventional, simplified or settled sewerage, vacuum systems do not rely entirely on gravity flows for wastewater conveyance and are thus less limited by topographical constraints. Vacuum sewers can be laid at considerably shallower gradients than those required for gravity-driven systems and can even transport sewage uphill for short lengths. The large velocities at which wastewater travels through the pipes also reduce the risk of blockages.

Whilst other sewerage technologies are generally more economic where the terrain can accommodate gravity systems, the EPA (1991) says that vacuum sewers may be more cost-effective where unstable soils or hard rock, flat terrain, high-water tables and/or restricted construction conditions impede the provision of gravity-driven sewerage. Under such conditions, the use of vacuum sewers may result in substantial reductions in excavation, material and treatment costs. According to Little (2004), the requirement to maintain air-tightness also makes vacuum sewers particularly useful in environmentally sensitive areas, as leaks are immediately detectable. Vacuum sewerage is, however, limited by the fact that it is a mechanised system that requires a reliable supply of electricity to the vacuum station. It should thus be generally limited to areas where a conventional gravity system would require numerous lift stations (Little, 2004).

3.4.2 International experience

The use of vacuum sewers has increased substantially over the last 30 years, resulting in the introduction of waterborne sanitation in areas that would be difficult to service using gravity-dependent systems. Although early systems were fraught with numerous challenges (EPA, 1991), operating experience and advances in technology have allowed the development of more efficient and robust systems. On the other hand, the use of vacuum sewers in Southern Africa is potentially problematic because the lack of local experience can lead to poor construction and inadequate O&M (Little, 2004).

Three installations in Sub-Saharan Africa are reviewed in this report, all of which substantiate Little's assertions. The first two (Shoshong, Botswana and Gibeon, Namibia) were installed in rural villages, and are presented in this section. The third vacuum sewer scheme (Kosovo, an informal settlement in Cape Town) is presented as one of the study's case studies in Section 4.4.

Buxton-Tetteh (2009) describes some of the challenges experiences by the Shoshong District Council and contractors during the construction and O&M stages of the continent's first vacuum system. The Gibeon write-up is based on three newspaper articles from Namibian periodicals. Though the texts inadequately explain the social dynamics when planning, using and managing the systems, the case studies nonetheless offer interesting insight into problems encountered when applying the novel systems in rural Sub-Saharan Africa. Unfortunately, the focus by the authors on the negative aspects makes it difficult to give a balanced assessment of the technology.

3.4.2.1 Shoshong, Botswana

Shoshong, located 40 km west of the Botswana Railway headquarters of Mahalapye, is a livestock-farming village of 12,000 people administered by the Central District Council (Buxton-Tetteh, 2009). It was selected as one of five villages to benefit from a water supply and sanitation upgrade funded by the national government, though it is unclear when this decision was made or the upgrade was meant to occur. Prior to the upgrade, the majority of residents used pit latrines. Officials from the Department of Water Affairs and the Central District Council struggled to decide how to provide a sewerage system for Shoshong as the sprawling settlement had an average ground slope of less than 0.5%. Preliminary work carried out in 2001 indicated that a conventional system would have cost as much as USD$9.5 million at that time (approximately R83 million at the 2001 $1USD = R8.75 exchange rate) primarily because it required a minimum of ten lift stations (Buxton-Tetteh, 2009: 2) to transport the sewage over long distances of relatively flat terrain. The high capital costs prompted officials to consider alternative wastewater collection systems. A vacuum sewer seemed like an ideal system for the area's flat terrain as its estimated capital cost (at only USD$5.2 million or R46 million) and estimated associated running costs were considerably lower than a conventional system (Buxton-Tetteh, 2009: 3).

Despite the lower capital and O&M costs, government officials still had mixed feelings about installing the first vacuum sewer in Africa (Buxton-Tetteh, 2009). After a year of discussion, the National Government and District Council officials eventually decided to install vacuum sewers in only the half of Shoshong west of the Mpalo River, which bisects the village. The majority of the slopes here are less than 0.5%. In contrast, Shoshong's eastern half was to be serviced with conventional gravity sewers as it had slopes averaging 1-1.2% (Buxton-Tetteh, 2009). Construction for the vacuum sewer commenced in 2003 and 54 kilometres of sewers, 500 collection chambers, 100 buffer tanks and two vacuum stations (with three 5.5 kW pumps and 11.5 kW discharge pumps each) were built in ten months. Its final cost was USD$2.6 (R22.75) million, whilst the conventional system (which had one lift station) cost USD$3.6 (R31.5) million.

According to Buxton-Tetteh (2009), the project planners had anticipated they would have various technical and social challenges with implementing Africa's first vacuum system. They reportedly tried to proactively address the issues related to procurement, construction, management and gaining users' acceptance prior to construction commencing in 2003 as follows:

- ***Vacuum parts supplier:*** There was no local supplier of vacuum systems in Botswana, just the agent of one international supplier – the German-based Roediger (Buxton-Tetteh, 2009: 4). A sub-contract was thus arranged with this agent to procure and install: the collection chambers (including the housing, interface valves and sensors), all vacuum sewer pipe-fittings, the division valves and the vacuum station vessels and associated pumps.
- ***Skilled personnel:*** The construction contractor was unfamiliar with the pipe jointing method (solvent-welding) necessary in vacuum sewers. Thus, a skills training session was organised for the contractor's personnel and supervisory staff prior to construction commencement. Furthermore, due to O&M under-capacity at National Government level and the Council's lack of familiarity with the new system, Council officials appointed a maintenance contractor to operate the vacuum system for two years. The Council also had one of its employees trained to assist with the system's management.
- ***"Community sensitization and education"***: Public consultations as part of the project's environmental impact assessment (EIA) process were used to "*promote community enthusiasm*" and gain project support.

Yet, despite such efforts, there were still a number of construction and operation challenges (Buxton-Tetteh, 2009). The contractor's poor construction (such as pipe jointing, trenching and compacting) and inadequate care for equipment (*e.g.* pipe caps, collection chambers) resulted in leaky or distorted system components, most of which the contractor had to repair and re-install. The contractor also supposedly "*ignored the constant advice of the supervising team to keep sewers free of debris*" (Buxton-Tetteh, 2009: 8) so pieces of building rubble damaged the vacuum vessels' protective lining. The vessel then had to be removed, re-lined and re-installed. Buxton-Tetteh (2009) extensively highlights the construction contractor's poor quality control; however, he fails to mention the construction supervisor's role in ensuring the system was built according to standard. He does not state who was responsible for this task.

The Shoshong vacuum system also quickly ran into problems because the project team had poorly prepared for the system's O&M. The project planners had intended for the maintenance contractor to work in conjunction with the trained Council employee; however, this arrangement did not work as envisioned because neither party knew "*where their responsibility began or ended*" (Buxton-Tetteh, 2009: 13). According to Buxton-Tetteh (*ibid*.), the "*maintenance contractor appeared to know nothing about vacuum technology*", suggesting that perhaps they should not have been appointed without specialised training. As possible consequences of the lack of experience and inaction, several lines were damaged and one of the vacuum pumps failed. Furthermore, leaks on the system went unattended for several months because the Council had not procured the test balls necessary for leak detection. Why Roediger, their Botswana agent, or the Consulting Engineers had not been able to persuade the Council to procure such an inexpensive but critical item in advance, however, is not discussed by Buxton-Tetteh (2009). The O&M plan for Shoshong's system should have elucidated distinct roles and responsibilities for the various operators, and essential O&M equipment should have been purchased as part of the initial parts order.

Buxton-Tetteh (2009) also notes that the Council's connection rate was well below what they expected. This indicates that there was minimal support from the prospective beneficiaries despite their being encouraged by the Council to be connected (Buxton-Tetteh, 2009: 5). The system was commissioned in 2004; after five years only 18% (approximately 356) of the 2,000 targeted households had connected to the network. During this period, Buxton-Tetteh (2009) also notes that the Council made no "*specific attempt... to explain the functions*" of the vacuum system to the users. Perhaps the low connection rate and limited user engagement was linked to the social mobilisation process erroneously being a part of the EIA. EIAs ideally should only be used to review how an engineering project might potentially affect the natural (*not* social) environment. The Council should perhaps conduct a survey for the purpose of understanding why the prospective beneficiaries have chosen to not connect, thereby informing the Council of whether they may need to adapt their policies and procedures.

In retrospect, Council officials should have immediately addressed the low connection rate as it may have affected the lifespan of the vacuum vessels. Buxton-Tetteh (2009) notes an inspection of the vacuum vessels in January 2008 had shown that the tanks' internal protective liner was deteriorating. This was later attributed to the build-up of hydrogen sulphide gas that formed because sewage was retained for long periods of time as a result of the low connection rate to the system in the village. In summary, the project's engagement tools, mobilisation and O&M strategies need to be critically rethought as each may have contributed to the Shoshong vacuum sewer's low connection rate and the system's slow deterioration.

In spite of the all the challenges, Buxton-Tetteh (2009) nevertheless contends that the Shoshong operation has functioned reasonably well and was still more cost-effective than the implementation of a conventional gravity system in the given circumstances.

3.4.2.2 Gibeon, Namibia

In contrast with the operational system in Shoshong described in the previous section, 5,000 exasperated villagers of Gibeon and their Village Council officials would like nothing more than to have their overflowing vacuum system decommissioned and replaced by a conventional gravity sewer (Cloete, 2011a, b; Goeieman, 2011). The news articles written by Cloete (2011a, b) and Goeieman (2011) describe users' dissatisfaction and the Council's frustration with the unfamiliar technology. Though the newspaper articles have related few of the technical details and sociological information such as demographics and why Gibeon was one of five villages selected to trial the system, the various accounts of people's experience that Cloete (2011a) and Goeieman (2011) critically highlight the consequences of introducing an alternative system that users and O&M personnel are not familiar with.

The vacuum sewerage system, with components supplied by Roediger (Cloete, 2011a), was introduced in an attempt to eradicate the bucket system. Since its installation, approximately 300 households have connected to the N$80 million system (N$80m = R80m). In a follow-up article Cloete (2011b) reported that there were technical problems with the vacuum system, though he does not explain what these specifically were. As a consequence, Cloete (2011b) said that residents complained of "*continuous*" sewage overflows into the village's streets, creating "*sewage rivers and pools*". The sewage overflows were a public health problem because the roads were "*breeding ground[s] for mosquitoes*" and nearby groundwater wells are contaminated (Cloete, 2011b). The Council said that the consistent network problems were caused by: (a) poor workmanship, (b) lack of expertise to repair the system, (c) lack of money to repair it and (d) "*abuse of the system by residents*" (Cloete, 2011b; Goeieman, 2011). The lessons learnt and recommendations for preventing and redressing poor construction and expertise have been extensively addressed in literature (Watson, 1995; Mara *et al.*, 2001; Melo, 2005; Buxton, Tetteh, 2009), therefore only the last two assertions will be discussed – in reverse order.

With regard to his comment on residents' purported abuse, Goeieman (2011) said, "*people are apparently throwing solid matter into the system*". Cloete (2011a) further elaborated that such acts of abuse include "*the use of newspaper as toilet paper*" and "*vandalism*", thus prompting the Council to "*launch an awareness campaign… to educate residents*" on how to use vacuum toilets (Cloete, 2011a). The notion that residents' ignorance and malice can be addressed through education drives is common in sanitation literature and practice. However, this is often a baseless statement that exaggerates the relationship between people's education and action. It also disregards other causes for why toilets are used for rubbish disposal (such as inadequate solid waste removal services or users' inability to afford toilet paper). Project planners need to assess the underlying reasons by conducting a socio-political analysis, as 'education' may be inappropriate to redress the problem.

Both Cloete (2011a) and Goeieman (2011) reported that rehabilitation costs – namely parts and labour – were high. For example, a sensor valve for the collection chamber cost the Council N$6,400 (R6,400) each in 2011 (Cloete, 2011a). The sensor is only manufactured by Roediger, and must be imported from Germany, explaining the item's high cost. This suggests that there will also be problems accessing replacement parts, necessitating a stock of spare critical items in cases of emergency. Furthermore, the Council paid between N$12,000-N$32,000 (R12,000-R32,000) each time the engineers and maintenance contractors attempted to fix clogged sewer lines or restore the system. However, each measure has only been a temporary remedy as the system starts to overflow again after several days. This suggests that perhaps the underlying causes contributing to the system's dysfunction are being inadequately addressed. Project planners need to bear in mind the risks of implementing a technology that requires parts that are not locally available and cost-prohibitive, as these two factors suggest that such a technology may be inappropriate and financially unsustainable for governments with limited budgets.

Cloete (2011b) also noted that bureaucratic red tape has prolonged delayed repairs. For example, the Council had to tender, *i.e.* advertise projects and request bids from vendors to prevent corruption, to repair problems such as the faulty pumps (Cloete, 2011b). Cloete (2011b) did not elaborate on how long this process can take for the Village Council, but CoCT officials often complain that such a process averages six months in their municipality. Thus, the procurement process has seemingly hindered service delivery for this situation. It highlights the need to include rehabilitation and O&M components as part of the original infrastructure tender, or at least tender for system repairs of new technologies a minimum of six months before capital infrastructure is commissioned.

According to Goeieman (2011), the problems with Gibeon's system then prompted the Village Council to appeal to the national government to replace the dysfunctional sewer with a conventional system. Gibeon's Village Council eventually learned from the National Ministry officials that all six pilot vacuum sewers trialled in Namibia were failing (Goeieman, 2011). The widespread dissatisfaction with the vacuum system experienced by three other Village Councils and two Town Councils elsewhere in Namibia supposedly prompted Ministry officials to organise a workshop with Roediger Engineers "*to find solutions*". Goeieman (2011) said the outcome of the workshop in November 2011 was to replace the vacuum system. He significantly did not indicate who was involved in this decision. Despite the November 2011 decision, Cloete (2011b) indicated that Gibeon's Village Council advertised a tender for the repair of its vacuum system's faulty pumps in December 2011. Dr Patrik Klintenberg (2012) clarified in an e-mail that the regional government had eventually allocated funds for the repair of the vacuum system, which was done by the original contractors. Klintenberg, the Research and Training Coordinator of the NGO Desert Research Foundation of Namibia, helped to organise the national government's vacuum sewer workshops. Though Klintenberg could not clarify whether the system was fully operational or what repairs were done, he stated that local authorities were not involved originally in the decision to install the vacuum sewer. He thought that this decision was likely undertaken by central or regional government, "*who commonly lack the understanding of the conditions on the ground*". Klintenberg's assertions indicate a complex socio-political dynamic between local authorities, regional and national government that needs to be unpacked and contextualised to understand how the authorities' relationships may have contributed to the vacuum system's failure.

3.4.3 Experience in South Africa

At the time of writing, the researchers were aware of only one installation in the country: in Kosovo, an informal settlement in Cape Town. The Kosovo system is featured in an in-depth case study in Section 4.4.

3.4.4 Lessons learnt

The challenges faced in Botswana and Namibia highlight the need for: (a) knowledgeable and skilled contractors, construction supervisors and operators; (b) strict construction supervision and quality control for installation and management of vacuum systems; (c) timeous procurement of parts and services not covered by standing tenders (*e.g.* spares that are not locally available or contingency rehabilitation works); and (d) clearly specified maintenance arrangements if vacuum sewerage is to be successfully adopted and managed. Both examples corroborate Little's (2004) findings that lack of local expertise with vacuum sewers has resulted in inferior facilities being constructed and service providers outsourcing O&M responsibilities to (sometimes equally inexperienced) contractors. Furthermore, the Shoshong example indicated a need for manufacturers of vacuum systems to include all O&M equipment, such as test balls for leak detection and a supply of locally available spares, as part of their tender contracts. What the two experiences also suggest is that the propensity of government contracts to divide capital and operation costs for tendered projects itself needs to be reviewed – especially for services and technologies that require immediate operational management or rehabilitation once installed. There is also a need for proper training if new technologies are implemented.

Most of the texts reviewed focused on the technical aspects and service providers' or agents' actions (or inactions) during the construction or management phases. Future research should also assess whether vacuum systems were the right choice for either settlement. In particular, there needs to be an analysis of the social, political and economic factors that influenced the project's planning, implementation, construction and management that was inadequately addressed by these authors. For example, Shoshong officials' misunderstanding that an EIA is an engagement and education tool shows they have limited understanding of what are appropriate facilitation or awareness methods.

3.5 Participatory design

Recently, participatory approaches to service provision have been proposed as an avenue for fighting poverty and circumventing the shortcomings of top-down approaches that have previously been in place. For example the South African Government in its *White Paper on Basic Household Sanitation* (DWAF, 2001) clearly prescribes community involvement in decision-making. This premise is generally accepted in South Africa as a necessary component of any developmental intervention; however, activist groups, residents and municipal officials have hotly debated what form it should actually take. In earlier experiments with alternative sewerage in South Africa, community participation was very limited, rarely going past the use of local labour and the hosting of a limited number of poorly-attended community meetings to inform residents of predetermined solutions. Residents were rarely ever engaged or included in the design processes.

Participatory methods often emphasise that users of new infrasturcture must be given opportunities to personally contribute to the process, which many (Lagardien & Cousins, 2005; Melo, 2005; Mara, 2006) assume reduces the likelihood of the system failing and critically develops users' skills to improve their situation themselves. Considering South Africa's high incidence of toilets malfunctioning shortly after facilities have been installed and commissioned in informal settlements (Mjoli *et al.*, 2009; Schaub-Jones, 2010), municipalities across the nation have started to employ participatory approaches in the hopes of reducing high rehabilitation costs for damaged infrastructure. The damaged infrastructure is reportedly due primarily to residents' and the municipality's poor management – suggesting that an alternative approach to sanitation delivery, operation and maintenance is required.

Finding a suitable approach to engage both residents and municipal officials on sanitation issues presents a major challenge. Popular international 'best practice' principles for demand-driven, grassroots approaches – such as Community-Led Total Sanitation (CLTS; Kar & Chambers, 2008) – are often inherently undermined in South Africa by the state's free sanitation policy (Eslick & Harrison, 2004), which leads to previously marginalised individuals feelings of entitlement to free services from government and their demand to be regularly informed and consulted – something they consider to be their constitutional right. A partnership approach has been suggested (Eales, 2008; Hazelton, 2009) as a possible way forward.

3.5.1 Partnership approaches

Partnership approaches are generally accepted as being strategic alliances with partners complementing each other's strengths (Lee *et al*., 2000; Schaub-Jones, 2010). Available literature does not have a precise definition of what a 'partnership' means, but in practice, it tends to be a loose term that describes the relationships between two or more parties based on mutual aims and interests, and the assumption that the partners cannot accomplish the task on their own (Schaub-Jones *et al.,* 2006).

Eales (2008: 1) discusses the potential of partnerships between government, civil society, and non-government service providers as an effective way to overcome a number of servicing challenges, such as: municipal capacity constraints, "*mistrust, disengagement, poor accountability and the fragmentation*" of toilet construction, waste collection and disposal that often characterise the sanitation sector. However, Eales (2008: 1) also significantly notes that partnership arrangements are "*not a substitute for action by the government, nor do they absolve government of responsibility*". Nevertheless, the various stakeholders should be involved throughout the numerous stages of a project to strengthen relationships between the involved parties and leverage the acceptance of new installations (Eales, 2008).

Although each partnership necessarily needs to be set up distinctively with its own unique aims, the main intention is that the partners pool their resources, with each contributing to specific aspects so that the partnership achieves mutually agreed objectives. In Cape Town, such a 'partnership' approach has been adopted by a number of municipal departments, residential associations, NGOs, private companies, universities and other research groups in an attempt to improve conditions in the city's informal settlements (Bolnick, 2010; CoCT, 2011). The next two sections discuss experiences with partnership approaches both internationally and in South Africa.

3.5.2 International experience

Schaub-Jones *et al.* (2006: 2) note that partnerships observed in international case studies tend to have a diverse group of stakeholders that take joint decisions and that the arrangements were usually semi-formalised to enable the flexibility for re-negotiation and adaptation as "*the context changes and partners learn to work together*". Eales (2008) contends that government-civil society partnerships meant to benefit the urban poor generally have succeeded when the involved parties: (a) acknowledged their need for each other to accomplish their aims; (b) recognised and respected the different contributions and strengths of the different partners; and (c) clarified tenancy rights when working in informal areas.

In the 2006 UN Human Development Report, Watkins (2006) says that "*some of the most conspicuous success stories in sanitation are the product of partnership between governments and communities, with a wide range of civil society organisations as a bridge*". Eales (2008) affirms this statement by noting that NGOs often supported end-users (or their community-based organisation (CBO) representatives) in successful partnership arrangements across the African and Asian continents in her review of sanitation partnerships between government and civil society. Furthermore, Eales found that end-users (or their CBO representatives) tend to be directly involved in negotiations with local authorities, the latter of whom were open to trying alternative approaches.

3.5.3 Experience in South Africa

In the case of South African municipalities, Hazelton (2009) considers the approach to be useful to reduce informal settlement service provision backlogs. However, Schaub-Jones (2010: 5) notes that collaborative sanitation service approaches are undermined by the state's "*pressure to deliver on ambitious targets*" that has led increasingly to a state-dominated supply-driven approach because the time constraint restricts the ability to establish strong relationships and to re-negotiate arrangements when the need arises. Eslick & Harrison (2004), as discussed in Section 3.2.4, also found that National Government's priorities have induced a supply-driven approach with severe time constraints and minimal opportunity for the municipality to engage intended users throughout the project design process. In addition, as mentioned earlier, the Free Basic Services policy has discouraged users from contributing their own resources to supply or manage new sanitation infrastructure.

In recognition of the fact that eThekwini Municipality needs help to deliver sanitation services to residents in informal settlements, officials have innovatively adapted a partnership model in which they facilitate projects between a number of residential and NGO groups and private companies. eThekwini's participatory process has purportedly resulted in significant progress on collaborative rural and urban sanitation projects with a diverse range of 'partners'. Roma *et al.* (2010), Schaub-Jones (2010) and Kees & Gounden (2011) discuss eThekwini municipal officials' partnerships with: users during the design stage; local micro-entrepreneurs for service provision; NGOs; national entities (such as the government's Expanded Public Works Programme (EPWP)) for job creation; and the University of KwaZulu-Natal (UKZN) to evaluate projects. As a result of its collaborative approach, eThekwini Municipality successfully negotiated with residents to provide 'Community Ablution Blocks' (CABs) to 350 urban informal settlements servicing over 35,000 households (approximately 115,000 people). The municipality pays for the capital and management costs for CABs and employs a local resident to be the facility's 'caretaker'. The caretaker maintains the facilities and distributes toilet paper to users. Kees & Gounden (2011) reported that the projects have been so successful that "*no mass delivery protests have been experienced*" since the scheme was first implemented in 2009-2010.

Interestingly, the municipality has pronounced that CABs are only temporary sanitation options for informal settlement users because, as Kees & Gounden (2011) noted, the municipality expected that all residents would be relocated to formal housing schemes in the next 10-15 years. Thus, building upon Eales' (2008) argument that successful sanitation partnerships had clear tenancy rights, eThekwini officials' clarification of the users' housing situation has likely made it easier for both the municipality and users to negotiate a mutually agreeable arrangement for temporary sanitation services. Furthermore, eThekwini has innovatively negotiated incentives for users to participate in sanitation services by creating a number of job opportunities for local residents. Supplementing the coveted CAB caretaker positions, the municipality has trained, supported and provided start-up materials for a number of community-selected residents as brick-makers. This opportunity has created micro-entrepreneurs who have started localised brick-making facilities that continue to be employed in the rollout of eThekwini's new sanitation infrastructure, and are expanding their markets to supply other building services (Schaub-Jones, 2010).

3.5.4 Lessons learnt

Partnership approaches have the potential to overcome many of the constraints that have plagued municipal service delivery in the past. In most of these partnership arrangements, Eales (2008) noted both users and local governments (supported by NGOs) are empowered through the partnership and their working relationships are enriched through extensive negotiation processes.

eThekwini Municipality's partnerships with users, academics, micro-entrepreneurs and national government officials demonstrate how a local authority can also be an innovative facilitator and legitimate driver of a partnership process. eThekwini Municipality, without the assistance of a bridging organisation, created trust through their direct interactions with users and likely gained buy-in for the new infrastructure and partnership arrangement by being transparent, particularly with regard to residents' tenancy rights. Moreover, the creation of unskilled and skilled jobs has incentivised users to be engaged in the partnership in order to continue developing skills and generate potential sources of income for the impoverished communities. Despite some criticism that eThekwini Municipality's approach is first supply-driven then demand-oriented, it is important to bear in mind that eThekwini Municipality is also a partner that has objectives that need to be addressed. What is interesting about eThekwini's approach is how officials have successfully negotiated sanitation partnerships in its urban informal settlements where mutual partners' aims are achieved despite the constraints created by the State that generally undermine partnership approaches in South Africa. As the partnership is still new, further research should be conducted to assess the sustainability and benefits of eThekwini's partnership approach after some time has elapsed.

3.6 Conclusions

The reviewed literature has shown that various alternative sewer systems have been developed as a means of overcoming the topographical constraints that can make the installation of conventional sewerage difficult and often costly. These constraints – which include high groundwater levels, unstable and sandy soils, hard-rock and extremely flat or undulating terrain – can sometimes be accommodated more economically by alternatives to conventional sewerage. However, both international and local experience has highlighted the importance of good management from project inception to decommissioning, for the purpose of avoiding significant cost implications – not to mention user dissatisfaction. The choice of sewerage system in informal settlements needs to be particularly sensitive to the long-term O&M requirements as well as the involvement of users.

Participatory approaches have the potential to overcome many institutional and social constraints that plague current sanitation provision endeavours, such as the need to provide the disadvantaged residents of informal settlements with opportunities to contribute their energy and opinions. Yet careful consideration must be taken by implementers into *how* this will be done, as the negotiation of the relationships and tasks necessary to achieve a meaningful participatory process is easier said than done. In eThekwini Municipality's partnership approach and a number of condominial projects in Brazil, the clear assignment of roles and responsibilities by specific parties – particularly the leading or facilitating party – was critical to successfully implementing projects. Documenting the processes eThekwini Municipality followed in assigning roles and responsibilities was deemed to be outside the scope of this project, however, future research that encompasses participatory planning as regards infrastructure development should document how roles and responsibilities are assigned and negotiated, particularly in light of overcoming conflict.

Of the two participatory approaches discussed in this report, condominial approaches as designed in South America are incompatible for South African legal frameworks and the socio-political situation. Furthermore, as Ortolano & Nance (2007) showed, condominial approaches might facilitate residential mobilisation or negotiation between the service provider and the ‘community’, but there this was no guarantee of ‘improved’ service delivery as a result of the process. In particular, service providers need to carefully consider when adopting participatory approaches whether they are appropriate for long-term O&M given the limited success in evidence-based research. This also suggests a gap between theory and practice with regards to operating and managing alternative sewerage systems. Service provision needs to emphasise four major outcomes when implementing infrastructure: (1) design, (2) construction, (3) O&M and (4) training.

Partnerships, on the other hand, have been widely implemented in South Africa because the looser arrangement and flexible process can be adapted to any setting as it is mostly based on identifying priorities and achieving the interests of involved stakeholders. The literature reviewed on partnership approaches did not specify any particular methodology to be followed in the provision of sewerage in informal settlements. It seems clear, however, that implementers (and project partners) should clearly distinguish the main facilitator and driver for the initiative, such as eThekwini Municipality determined from the onset of its partnership arrangement. In addition to strong leadership, it seems that transparency of policies and actions, clear tenancy rights and desirable employment opportunities are also critical features that can determine whether or not a project succeeds or fails.

Whatever participatory approach is implemented, it should aim to establish and nurture relationships between the involved stakeholders, and it needs to grapple with a far wider range of issues beyond sanitation. Notably, discussion around tenure insecurity in informal settlements and desirable employment opportunities will need to be discussed and clarified at the beginning of any project in order to mobilise and sustain interest.

Lastly, much of the literature reviewed were technical texts that gave little information as to how the decision to implement the technology was made, what other parties were involved in project management, what the quality of construction was and who was using the toilets. Such data is critical to assess whether the service delivery process was effective.

4. Case studies

4.1 Introduction

This chapter introduces three Western Province alternative sewerage schemes: simplified (Hangberg, Cape Town), settled (Hermanus) and vacuum (Kosovo, Cape Town) systems. It will also present the project team's approach when providing the systems, and examine the lessons learnt when addressing technical, institutional and residential issues during the planning, design, construction and O&M phases of both the successful and unsuccessful projects. The unfolding events discussed in the Hangberg and Kosovo sections will demonstrate the need to define the roles people have in the service delivery process – in particular, clarifying whom the ambiguous 'community' and 'city' are. By way of contrast, the Hermanus review explains how the settled sewer scheme was successfully implemented because the management process was appropriately matched to the people supporting it. A similar conclusion is made with regard to the approach used when implementing janitorial services in Hermanus' Zwelihle informal settlement's sanitation facilities.

The Hangberg and Kosovo situations are particularly telling in how CoCT officials have encountered a number of socio-political constraints when attempting to upgrade the informal settlements without clearly defined municipal procedures for urban upgrade projects. Without a clearly articulated municipal process, CoCT officials have tried to address urban upgrades stage-by-stage, defining the next step according to what the moment dictates. This method has resulted in an ad-hoc implementation process that handicaps CoCT officials from effectively coordinating a holistic servicing plan for informal settlement residents. Furthermore, various socio-political constraints have negatively affected upgrade projects by causing unnecessary delays when delivering sorely needed housing and services in Cape Town's informal settlements. Both Hangberg and Kosovo projects are driven by the principles of *in-situ* upgrading, meaning the aim was to cause as little disruption as possible in the existing informal settlement whilst incrementally developing new services and housing. However, in-situ upgrades require careful negotiation with residents, which many officials admit they were not equipped for. Thus, 'Social Facilitators' were engaged to include community leaders as part of a public participation process for the purpose of guiding the development of their settlement according to the needs of greater 'community'. The Hangberg Social Facilitator (SF) was a NGO called the Development Action Group (DAG), who used their own funds to facilitate their interaction. The Kosovo SF, on the other hand, was a consultant that was appointed by the municipality. A discussion on how having an independent SF can further complicate the already complex upgrading process will also be discussed in the Hangberg section.

4.2 Simplified sewers in Hangberg (Hout Bay, Cape Town)

4.2.1 Background and description

Figure 4-1: Photographs of Hangberg. From top clockwise: (a) dwellings located beneath the '*sloot*' (ditch) with views overlooking the harbour, (b) a dwelling in neighbouring Dallas section and (c) informal dwellings built behind a row house (Photos by Taing, 2011**).**

Nestled on the slopes of the Sentinel Mountain, Hangberg overlooks the Hout Bay harbour (CoCT, 2008; Figure 4-1). In 2007, Hangberg residents (with the DAG SF and CoCT officials) conducted a community register and established that the sprawling 3.7-hectare informal settlement had 302 dwellings. The 1,200 residents refer to their homes on the slopes of Sentinel Hill as 'bungalows' (CoCT, 2008). According to Ackelman & Andersson (2008), residents originally built the bungalows in response to the lack of low-income housing in the area. In the 1940s, one of the municipal predecessors to City of Cape Town Municipality (CoCT) had provided walk-up flats (often referred to as row houses) near the present-day Rhode Vos and Karbonkel Roads as low-income accommodation for the labourers in Hout

Bay's fishing industry (Figure 4-1c). The council flats soon became overcrowded as the occupants' families grew, and new residents – attracted to nearby employment opportunities – moved in. Interestingly, Soeker & Bhana (2011: 9) claim "*the municipality… allowed residents to occupy land behind the council flats, on condition that they not erect permanent structures*". The UCT researchers could not corroborate Soeker & Bhana's (2011) statement of whether 'the municipality' – which presumably refers to the local authority that existed prior to the formation of the current CoCT Municipality in 2001 after three local government restructurings (OECD, 2008) – had given Hangberg informal settlement residents permission to temporarily live there. Nevertheless, there is sufficient evidence that there had been insufficient formal housing in Hangberg for many years by the time it was incorporated into the CoCT.

Over the decades, residents have seemingly overcome the challenges of living on the Sentinel's steep slope; a significant number of dwellings – some with second or third stories – have been constructed from brick, timber or mountain rock (CoCT, 2008), which Winter *et al.* (2008) credits to residents' ingenuity, skills and collaborative networking. In addition, DAG and CoCT (2008) claim that the residents' "*greater disposable incomes*" allowed them to build dwellings "*above [the] average standard*" of those generally seen in Cape Town informal settlements. Kapembe (2007) estimated that over 50% of Hangberg's residents had some form of employment, with average household monthly incomes being approximately R2,600 in 2007. Ackelman & Andersson (2008) reported that the bungalows ranged in size from 9-150 m^2, with plot boundaries sometimes demarcated by residents with fences (CoCT, 2008). There are also several local businesses, such as shops and take-away restaurants, shebeens, a church and a dance hall registered in the survey (CoCT, 2008).

4.2.2 Hangberg's simplified sewer system

In 2001, the CoCT provided Hangberg residents with 37 tap-stands and 39 shared full-flush toilets (Ackelman & Andersson, 2008). The toilets were supplied and drained by simplified sewers because conventional sewerage was unsuitable for the settlement's sandy and rocky soils. Gravity-driven sewers could be laid because the settlement has a steep slope (1:3 to 1:5) (Winter *et al.*, 2008). According to Ackelman & Andersson (2008), the shallow (now frequently exposed) water supply pipes and waste- and stormwater sewers were meant as a 'temporary' measure because, at the time, the settlement was earmarked for an upgrade. Some residents – through their innovation, plumbing know-how and cooperation – subsequently improved their water and sewerage services by making private household connections without CoCT's assistance.

Neither municipal officials nor residents indicated during interviews conducted in 2011 that they were unhappy with the simplified sewer service. In fact, none seemed to know the difference between a conventional or simplified system. That does not mean there were no problems with sanitation in Hangberg informal settlement – officials and residents reported technical issues related to the size of the feeder and receiving sewers and poor facilities management. Officials also claimed that the residents' unauthorised connections to municipal pipes had caused a number of water leakages and environmental pollution problems. The following section presents the technical and management issues experienced with the Hangberg simplified sewer primarily based on interviews with Hangberg informal settlement residents and CoCT officials in 2010-2011. This is followed by an account of the problems CoCT officials and users have had in the incremental housing development project to show how social issues can severely disrupt service delivery in an informal settlement.

4.2.3 Sanitation management and technical sewer challenges

Hangberg's simplified sewer mains, often laid underneath dirt paths, comprise of 160 mm diameter pipes. However, the 160 mm pipes are incompatible with the 110 mm conventional sewer that it connects into off Rhode Vos Road. Blockages have since occurred where the two pipes join, with raw sewage seeping from a nearby manhole. Fortunately, residents are not inconvenienced by the overflow as the area that floods is at the back of the Hangberg Advice Office, a municipally-owned two-roomed building that functions as an office for Hangberg community leaders' meetings. Nevertheless, many residents that were interviewed by Ackelman & Andersson (2008) said they were unhappy and inconvenienced with the conditions of the facilities provided by the municipality. Apparently, CoCT officials and users had expected or wanted the other party to manage the tap-stands and toilets, but neither ultimately accepted responsibility. So, over time, doors and toilet seats disappeared (Figure 4-2), taps and cisterns broke and the sandy soils on which the toilet structures were placed eroded as a result of stormwater run-off and the wind. Eventually, in a 2011 inspection of the settlement by CoCT officials, a municipal contractor and residents, all parties decided that all the shared toilets installed in the past decade would be replaced at the municipality's cost.

Dissatisfied with the municipally-provided facilities, some residents stopped using them altogether after they built or paid a skilled neighbour/contractor to connect their homes to the simplified pipe network. By 2006, over 40% of the residents had installed toilets in their homes (Figure 4-2), while close to 80% had connected to the water supply network (Kapembe, 2007; Ackelman & Andersson, 2008). It is significant to note that some residents have taken it upon themselves to 'upgrade' their services independent of subsidies from South Africa's Free Basic Services policy. This is one of only two instances observed during the study where informal residents had built their own sanitation alternative. (Some Barcelona residents have also constructed private pit latrines in their yards; See Section 5.2.2). By installing their own service, residents thus assumed responsibility for maintaining the household connection themselves. One resident said she had paid to have a private toilet installed in her two-bedroom home so that her three young daughters would not have to walk outside to a shared facility at night to use the toilet. Whenever a blockage occurred downstream of her connection she unblocked the sewer "*on [her] own, without the assistance of a man*".

Figure 4-2: Photos of municipal and private sanitation facilities in Hangberg informal settlement. From top left clockwise: (a) a shared toilet without a door, (b) a toilet with an unstable structure due to an eroded base, (c) a bathroom in a resident's bungalow and (d) an unauthorised private connection to the exposed sewers (Photos by Ashipala (2010) & Taing (2011)).

The Hangberg residents' self-sufficient approach to providing one's own sanitation needs – financed and driven without any government subsidies or assistance – would generally be commended in international circles. However, despite the benefits residents expressed from having their own personal toilet – which many proudly showed the research team – the interviewed CoCT officials clearly had mixed opinions on the unauthorised connections. Although they applauded residents' initiative, the considered the connections to be technically 'illegal' and residents 'stealing' by not paying any of CoCT's water supply and sewerage rates, though it is unclear whether the officials had accounted for the residents' right to their Free Basic Services allocation. The unauthorised connections have nevertheless affected the integrity of the water supply and sewer service for the shared toilets; for example, municipal officials have no doubt that problems such as low water pressure are due pipe network leaks caused by shoddy plumbing.

In addition to leaks caused by poor jointing, a municipal contractor was also concerned about where some residents were discharging their waste. The municipal contractor, responsible for installing a new sewer line to additional toilets in the upper reaches of the informal settlement, said he was surprised during a site inspection in 2011. Whilst walking through the settlement, he had wondered aloud, "*Where are they connecting to? There's no wastewater sewer there!*" He had suspected that many of the households were draining their waste into stormwater outfalls.

The interviewed CoCT officials commented that the 'illegal' connections should be disconnected because the reliability of the shared water supply and sewer network was affected, and the environment likely polluted. An in-situ upgrade project (which is briefly discussed in the next section) was meant to improve service connections using municipal funding, thereby incrementally ensuring that all connections fit accepted engineering standards. Delays in the commencement of the upgrade project have, however, meant that Hangberg residents continue to install their own connections so that they have private facilities to use in their homes. Officials, when walking around Hangberg, can see the tell-tale pipes and ponding pollution from poorly installed or drained unauthorised connections, but they say they feel helpless in stopping them. They claim to be afraid of sparking unrest and criticism that they were preventing residents from improving their water and sanitation service in light of their unhappiness with the public facilities. Officials turning a blind eye to unauthorised connections of any basic service in informal settlements are not uncommon. Whether in Atlantis in the north or Khayelitsha in the east, officials from the Housing, Water and Sanitation and Electricity Departments frequently said they turned a blind eye to unauthorised connections of any basic service in informal settlements. They recognised that such connections – in particular, the scary webs of electrical lines above the shacks – were major fire hazards. One official explained that he could 'not take away' these services because he feared sparking large-scale riots. He said he also risked his personal safety if he 'angered' the community as he regularly visited informal settlements in his section alone. The interviewed CoCT officials said the municipality only had two options when providing private connections according to engineering standards and municipal by-laws: CoCT had to upgrade the settlements in-situ, or move residents to greenfield developments. In highly populated areas with limited open land, officials felt that in-situ upgrades require both approaches; some residents need to be moved to new developments to reduce the housing density. Whatever option is taken, as Eslick & Harrison (2004) note, the municipality needs to address the legal issues concerning the installation of private connections where residents may not have land titles or servitudes. In the instance of Hangberg, CoCT officials have tried to address the illegal connections issue by formalising the settlement, but a number of socio-political conflicts between residents, CoCT officials and the DAG SF have delayed the project.

The following section will discuss some of the challenges the project team and residents have reported concerning the Hangberg in-situ housing development project. Although the housing upgrade is officially a separate issue from service delivery, the Hangberg case study shows how the two provisions are intrinsically linked in CoCT because the same CoCT officials working on the housing upgrade also coordinate basic services for the settlement. The lessons learnt from the Hangberg in-situ development case study also show how people and their interactions during project planning may determine whether a process is successful. In particular, the conflicts between the seemingly cohesive 'Hangberg community' and the CoCT Project Manager (PM) and DAG SF will be discussed.

4.2.4 Housing and intermediate servicing project challenges

Figure 4-3: Hangberg residents resist the City of Cape Town's demolition of nine structures by throwing home-made petrol bombs (Molotov cocktails) and stones at police (Photo by Michael Walker as cited in Soeker & Bhana, 2011)**.**

On 21 September 2010, a simmering conflict between the Hangberg 'community' and the 'city' finally erupted into a violent showdown as a consequence of broken promises. The residents interviewed by the research team referred to the confrontation between the Cape Metropolitan Police (on behalf of the CoCT) and the Hangberg community as 'the War' because the police, armed with guns firing rubber bullets fought residents armed with stones and home-made petrol bombs (Figure 4-3) over the existence of nine structures built on the upper reaches of the settlement.

The proximate start of 'the War' was when CoCT officials from the then Housing Department (now restructured and called the Human Settlements Department) wanted to demolish the nine structures built above the *sloot* (a man-made ditch along the informal settlement's northern boundary), whilst Hangberg residents adamantly protected the bungalows. CoCT officials contended that erecting structures above the boundary was a fire hazard because the *sloot* is meant to function as a firebreak that protects both residents and the adjacent nature reserve in case a blaze were to spread in the area. CoCT officials and

Hangberg informal settlement residents had been negotiating and planning a low-income housing upgrade since 2007, but the project was still delayed thus the Hangberg residents living above the *sloot* claimed that they felt compelled to meet their own housing needs as the local authorities had 'failed' to accommodate them as 'promised'. In addition, an intermediate sanitation project planned in 2009 by residents with the NGO DAG had not come to fruition either, further shaking interviewed residents' confidence in 'the city's' interests in providing services to them. Thus, as CoCT officials had failed to meet their housing and servicing needs, they felt they had little choice but to build homes for themselves.

NGO activists (Tissington & Royston, 2010; Soeker & Bhana, 2011) and filmmakers (Kaganof & Valley, 2010) have since depicted what has happened in Hangberg as evidence of the city's inability to address the needs of the urban poor. In contrast, this report highlights some socio-political issues that have plagued efficient and effective housing and service delivery in Hangberg. The following section describes the proposed Hangberg housing upgrade project and how the dynamics between involved and excluded parties ultimately undermined it.

In resistance to local government's proposal to resettle 45 km away from their jobs and homes in the Cape Flats, residents lobbied CoCT officials to formalise Hangberg's informal settlement so they could retain their livelihoods and social networks (Ackelman & Andersson, 2008). In March 2007, their efforts paid off: the Cape Town Mayor had announced "*an in principle commitment*" (CoCT, 2008) to upgrade the informal settlement in partnership with Hangberg residents and the NGO DAG.

According to the DAG SF, DAG coincidentally approached CoCT officials in late 2006 or early 2007 to facilitate a participatory approach for upgrading an informal settlement. DAG (2010: 2) describes itself as a specialist in South African low-income housing issues with the explicit aim of "*ensuring that communities engage in, and lead, their own development*". In this arrangement, DAG was meant to be a 'support organization' for both Hangberg residents and CoCT officials (CoCT, 2008). The DAG SF, for example, critically assisted in the project by collecting data and preparing key project documents, such as a Business Plan, from 2007-2008.

Interviewed officials and residents said the Hangberg in-situ Development Association (HiDA) was established in March 2007 as the 'community' representatives. The purpose of their involvement was to ensure residents were involved in the planning and design of the settlement upgrade. A former HiDA member explained that Hangberg residents (with the assistance of DAG and CoCT) identified the 302 households (CoCT, 2008) in Hangberg informal settlement that would be included in the in-situ upgrade. The 302 households were then divided into six blocks (with approximately 50-60 bungalows in each), with the intention that each block would then elect HiDA representatives who were meant to address and promote their block's needs and interests when designing the upgrade with CoCT and DAG.

CoCT municipal officials stated that the housing development in Hangberg was a 'big deal' because it was CoCT's first *Upgrading of Informal Settlements Programme* (UISP) project. UISP is a CoCT housing programme that endeavoured to develop the informal settlements in line with the National Housing Department's upgrading programme entitled *Breaking New Ground: A Comprehensive Plan for the Development of Sustainable Human Settlements* (DoH, 2004). The four-phased UISP approach (CoCT, 2008: 5) was broken down accordingly:

- Phase I: Application for funding through the submission of a business plan by the metropole to the Provincial Department of Local Government and Housing (PDLGH).
- Phase II: Pre-planning documents – which included technical designs, community registration and the "*letters of right to occupy, provision of interim services and the acquisition of land*" from the government, and feasibility assessments – to be approved by PDLGH.
- Phase III: A final business plan to be approved by PDLGH that included specific project implementation outcomes, such as "*the establishment of project management capacity, a detailed town planning process including surveying, establishment of a Housing Support Centre, land rehabilitation, permanent municipal engineering services and the construction of social amenities, economic and community facilities*" (CoCT, 2008: 5).
- Phase IV: An incremental upgrade of dwellings in the settlement by the residents or local contractors with qualifying residents being entitled to housing subsidies.

From the project inception, CoCT officials, HiDA, and DAG had intended an *in-situ* upgrade in line with the UISP framework (CoCT, 2008). As stated earlier, residents had resisted the CoCT's proposals to relocate them. The DAG SF noted that an *in-situ* upgrade was widely supported by Hangberg residents because the *Breaking New Ground* (BNG) policy proposed "*relocation only as a very last resort*" (CoCT, 2008). On 18 July 2008, the documents for Phases I and II were approved (CoCT, 2008). However, the three partners were not able to complete Phase III due to two broken promises: CoCT's inability to accommodate residents in a reasonable time frame and HiDA's inability to prevent the erection of new homes. The two broken promises critically show that CoCT's housing and servicing approach needs some adjustment. What follows presents the dynamics between four critical stakeholder groups (the 'city', HiDA representatives, the 'community' and the facilitating NGO DAG) in an attempt to show how their inability to support each other resulted in the project impasse. Understanding how each group's role influences the project outcome is critical in assessing how to modify procedures for future housing upgrades.

Municipal officials involved in housing and service delivery have said that engineering *in-situ* services for informal settlements is difficult. They noted that housing developments of this nature generally attract opportunists who – in an effort to be included in the upgrade – erect new homes in the settlement to benefit as well. Officials said such buildings also sometimes obstructed the delivery of new services by constructing new homes on land planned for roads or public spaces. Thus, according to a CoCT official, a building moratorium was proposed by CoCT in October 2007 which HiDA representatives had agreed to in order to prevent household ‘creep’. Also known as ‘freezing’, such a moratorium is common in in-situ upgrading to assist in the planning of improvements and to denote residents’ commitment to the process (Abbott & Douglas, 2001). As part of the agreement, HiDA representatives were asked to enforce the moratorium by preventing new erections, or reporting new building to CoCT. This seemingly simple request, however, became the “*biggest headache*” for HiDA representatives (DAG, 2008) who could not stop the erection of new structures. Three HiDA representatives that had been interviewed by DAG in 2008 had said that “*die vrot appels*” (rotten apples) in the informal settlement had continued building despite HiDA’s requests to stop. The HiDA representatives had explained these “*people have their own agenda and don’t care about the rest of the project*”.

Yet being called a ‘rotten apple’ could extend to anyone on the housing waitlist who would not benefit from the housing project. CoCT officials acknowledged in hindsight that major project risks were not accommodating the housing and servicing needs of the overcrowded council flats; backyard dwellers residing behind the Council flats and residents in Hangberg’s informal ‘pockets’ (the settled tracts of public land dispersed in between formal housing). The HiDA representatives reported that they had problems gaining community buy-in and support (DAG, 2008) because so few would immediately benefit from the housing upgrade. Overlooking their needs had critically impaired the project: one resident in the Council flats noted during a tour of the settlement in late 2011 that her daughter was an occupant of one of the nine contentious flats built above the *sloot*. The woman, who was not a HiDA member, claimed she tried dissuading her daughter from violating the moratorium, but she said her daughter insisted upon having her own home to raise her children. This telling story shows that a housing development where only a few benefit can divide a seemingly cohesive ‘community’. In the future, CoCT officials need to consider whether a building moratorium is a reasonable condition given the existing housing shortage, the delay in housing delivery and the dynamic change of settlements on a day-to-day basis.

Another critical issue that impeded progress in the housing project was the conflict between the CoCT PM and the DAG SF. The CoCT PM had been assigned to the Hangberg housing project in late 2007 after the original PM was promoted and left the department. In interviews conducted in 2010 with the DAG SF and the CoCT PM, both acknowledged having difficulty establishing a working relationship with each other, unlike the rapport that the DAG SF had claimed she shared with the CoCT PM’s predecessor. One critical issue that neither noted was DAG’s role beyond support to CoCT or HiDA. In reality, the DAG SF – motivated by her enthusiasm to effect change and DAG’s limited funding that afforded a tight project timeframe – was managing the project in order to minimise delays. In this capacity, as Eales (2008) warned in partnership arrangements, the DAG SF had essentially ‘absolved’ the municipality of responsibility by undertaking the PM role, and became the ‘bridge’ between the ‘community’ and the ‘city’. It was also problematic for the DAG SF to be the *de facto* PM as she ultimately did not have responsibility for authorising CoCT funding for the upgrade and mediating the conflicts between HiDA representative and Hangberg residents, nor could she control the lengthy municipal processes that delayed the project. Ultimately, having DAG as the PM was an 'on-the-ground' risk that eventually caused the project to crumble when the organisation had to withdraw in late 2008 as DAG no longer had funding to continue independently supporting the upgrade project. This caused another long delay because CoCT officials and HiDA representatives then had to establish a new relationship without an intermediary. The CoCT PM said later that the DAG SF had done a 'phenomenal job' in mobilising interests and organising project documentation; however, in hindsight what he ultimately needed was for DAG to concentrate on gaining broader community acceptance for the project which was a task beyond his ability (as an engineer) to negotiate. Situations such as these highlight the need for flexibility in roles and responsibilities in partnerships.

In 2011, CoCT officials and Hangberg residents established the Hangberg Peace and Mediation Forum (HPMF) with the assistance of an independent, municipally-appointed mediator. The HPMF is a 39-member committee representing the ratepayers, informal settlement residents and backyard dwellers living in Hangberg and is meant to represent the interests of all Hangberg residents. As a result of negotiations with the HPMF and mediator, the CoCT PM said in December 2011 that he was preparing a tender for in-situ earthworks to commence in 2012. However, a major struggle that CoCT officials are still coping with is how to address the housing moratorium violations, which continually strains negotiations between CoCT and the general Hangberg populace, causing further delays to an in-situ upgrade.

4.2.5 Lessons learnt

As of 2012, Hangberg residents and CoCT officials were seemingly satisfied with the simplified sewers in the settlement. Unlike with eThekwini simplified sewer installations, Hangberg residents had installed the branch sewers and household connections at their own cost without the assistance of the municipality. Residents installing their own services would usually be viewed as desirable for struggling municipalities; however, eThekwini's problematic connections in Briardale and CoCT officials' trouble with Hangberg's unauthorised connections have shown how the integrity of a sewer network can be compromised when connections are carried out by unskilled builders. Ideally, only skilled labourers should be used to construct sewage systems, whilst the issue of unauthorised connections in informal settlements needs to be addressed, particularly sewers are shallow and easily accessed.

The Hangberg case study shows how people and their interaction while planning the upgrade project determines if a process succeeds or fails. In particular, the housing development project shows how the seemingly cohesive Hangberg 'community' was divided according to who would benefit from the upgrade and who would not. This socio-political constraint ultimately contributed to the HIUP's failure and forced the involved parties to renegotiate the project aims and process on a different platform. Furthermore, the relationship break-down between the municipality and the NGO Social Facilitator highlights the need for the following in a partnership approach: (a) clear roles and responsibilities between the project team, particularly the service provider and any supporting organisations; (b) setting realistic expectations based on the constraints of the involved parties; and (c) the need for PMs of large infrastructure projects to possess project facilitation and negotiation skills. The Hangberg project management dilemma particularly illustrates the necessity of having able negotiators when planning informal settlement upgrade projects. This task is often outsourced by CoCT officials to supposed 'expert' supporting organisations with little consideration of how long the arrangement will last. Such arrangements have had disastrous consequences during negotiations between informal settlement residents and CoCT officials, as demonstrated by DAG's withdrawal in the Hangberg project. Service providers need to consider whether it is pragmatic to employ independent organisations in the facilitation role given that project delays and prolonged time frames could preclude them from providing this critical service from a project's beginning to its end.

4.3 Settled sewers in Hermanus (Overberg, Overstrand)

Overstrand officials built the first settled sewer in Hermanus in 1993 (Du Pisani, 1998). According to Van Vuuren (2010), the Hermanus settled systems (commonly referred to as small-bore sewers by municipal officials and Overstrand residents) were only installed in middle-income suburban homes or businesses. The recommendations that follow (Van Vuuren, 2010; Nel, 2010a; Burger, 2012; Myburgh, 2012; Nel, 2012a) are thus based on the Overstrand officials' experience of designing, constructing and managing settled sewers in such conditions. Details are also given for the municipality's janitorial service for the communal sanitation facilities (drained by conventional gravity sewers) in Zwelihle informal settlement. Contractors, users and janitors of sanitation facilities in Zwelihle were interviewed in 2012 during brief site visits but no settled sewer users were contacted due to time constraints.

4.3.1 Background and description

Hermanus has grown from a small seaside resort town into the economic and administrative hub of the Overberg District with a population of approximately 49,000 people. The town, which falls under the administration of the Overstrand Municipality, is spread along a 25 km stretch of coastline between the Bot River lagoon and the Klein River estuary. In 2008 the town was made up of 14,164 residential stands comprising approximately 13,726 permanent and 438 holiday homes and 650 commercial properties (Overstrand Municipality, 2009).

4.3.2 Hermanus' settled sewerage system

According to van Vuuren (2010) and Nel (2010a), there are three sanitation systems in Hermanus: conventional sewerage, conservancy tanks and settled sewerage (Table 4-1). The conventional sewers only service the central business district and the city's informal settlement Zwelihle. Settled sewers, on the other hand, are mainly located in suburban areas. In 2010, 5,272 properties were serviced by settled sewerage in the suburbs of Vermont, Voëlklip, Onrus, Sandbaai, Santa Claire, Kitbroek, and Hemel n' Aarde estate (Nel, 2010a). Du Pisani (1998: 73) notes that a settled system is suitable for the town's conditions, namely flat slopes and shallow rock and sensible considering the town has "*widely varying flow volumes throughout the year*" due to Hermanus being a seasonal holiday town. Hermanus has shock periods of high usage during the summer holidays.

Table 4-1: Breakdown of household sanitation types in Hermanus (Nel, 2010a).

Sanitation system	Conventional sewerage	Conservancy tank	Settled sewerage	Total
Number of households served	6,725	5,513	5,272	17,510
Percentage of total	38.4%	31.5%	30.1%	100%

The settled sewer network was initially installed because it was considered to be less expensive than a conventional system (Burger, 2012). According to Du Pisani (1998), Hermanus' settled sewer system was 30% cheaper than building a conventional system, though she did not clarify if the savings were for the municipality or the user. According to Myburgh (2012), Hermanus is situated on 'solid rock' about one metre below the surface on average and officials wanted to avoid the expense of deep trenching into rock. Furthermore, there was a benefit for property owners with existing conservancy or septic tanks as they could modify these to serve as interceptor tanks. The interceptor tanks could then be connected to shallowly laid sewers installed by the Municipality.

Individuals who intended to develop properties in areas that are served by settled sewers are required to connect to the network (Nel, 2010a). Such properties are required to have 5 kℓ interceptor tanks with 63 mm outlets and suction pipes to municipal specifications. Nel (2010a) and Van Vuuren (2010) reported that interceptor tanks constructed from brick and concrete were generally the most popular because such tanks had lower capital costs than plastic and precast concrete tanks (the latter being the most expensive). A number of residents have also experienced problems with plastic tanks rising and floating out of the ground due to high groundwater levels: in one instance an attempt to anchor a plastic tank down by placing concrete over it resulted in the tank's collapse. Municipal officials generally prefer clay-brick tanks as they can inspect construction quality. They also prefer these tanks because the tank geometry is one that is dictated by the municipality and has been shown to efficiently reduce sludge volumes.

After the interceptor tank installation is built, inspected and approved by an Inspector from the Overstrand Building Department, the developer or property owner requests a water-tightness test, which is conducted by municipal personnel (for the cost of R800 in 2010) (Nel, 2010a). If the tank passes this test, the municipality sends out a contractor to install a filter on the tank outlet and connect it to the settled sewerage system (for an additional R800) (Nel, 2010a, 2012a). Myburgh (2012) informed the researchers that the municipality installs a specially made filter for the 63 mm outlet (Figure 4-4) to manage the overflow and prevent solids from getting through, which should be cleaned regularly by the homeowner. The settled sewerage collection mains consist of small diameter (90-110 mm) Class 4 PVC pipes laid at small gradients (some as small as 1:330). Points for future house connections are installed on the network.

Figure 4-4: The 63 mm outlet filter (left) that is installed in Hermanus' properties. The middle photo is of a filter on a new tank that was just commissioned and the photo on the right is of a settled tank that has been in operation for several years (Photos by Ashipala (2010) and Taing (2012)).

Dividing the O&M responsibilities and financial costs for settled systems between the property owner and Overstrand municipal officials is also a straightforward process (Nel, 2010a) as it is similar to previous sanitation arrangements when the owner was responsible for maintaining their conservancy or septic tanks and would contact the municipality to de-sludge them when necessary. The municipality charged R200 in 2010 for the first call-out in a month, and R180 thereafter (Nel, 2010a). Officials said that a 5 kℓ tank is generally pumped every 4-5 years (Myburgh, 2012; Burger, 2012). Two municipal teams are responsible for emptying the tanks and maintaining the settled sewer collection mains extending up to the tank outlets, and both are experienced and familiar with the system (Nel, 2010a).

Overall, Nel (2010a) considers settled sewers as a good system that is easy to construct and manage. Van Vuuren (2010) notes that the system reduces the immediate and long-term loading at the treatment facility, and that settled sewers can be designed with low water consumption fittings – thereby reducing water demand. Nevertheless, Van Vuuren

(2010), Nel (2010a, 2012a) and Burger (2012) also report a number of social and technical challenges since the system's initial wide-scale rollout in 1993, which required prompt action and, on occasion, changes in procedures by Overstrand municipal officials. The following section summarises some of these.

4.3.3 Technical challenges and sewer expansion

4.3.3.1 Residents' acceptance and responsibility

According to Van Vuuren (2010), residents had been apprehensive about installing settled systems when the municipality first initiated the transition from the conservancy / septic tank system to a settled sewer network. The Overstrand municipal departments thus undertook an awareness campaign targeting households and local schools. It appears as though Overstrand officials likely used a top-down, engineering-driven approach. In other words, 'professionals' decided what they considered was the most sensible way to introduce waterborne sewerage, giving residents little choice as to whether they wanted a conventional or settled sewer. In this instance, this seems to have been a positive move as Overstrand officials have seemingly converted seven suburbs with few complaints. In interviews conducted in September 2012 in Onrus and Vermont, it appeared that those who had lived in areas that were not reticulated generally said that settled sewerage was an improvement upon the conservancy and septic tanks they had used previously. However, those who had previously lived in areas with conventional gravity systems – *e.g.* Pretoria or Cape Town – preferred conventional over settled sewerage because they had more operational problems and responsibilities with settled sewerage.

Upon reflection, the high levels of acceptance by users and Overstrand officials alike are not surprising because there has been little change to the operation of the sanitation system. Residents – and businesses – call the municipality whenever their tanks must be de-sludged. Those already familiar with the maintenance of conservancy and septic tanks need not change their behaviour in any way when converting to a settled sewer system. One issue that should perhaps be addressed is users' awareness that they are using an alternative sewerage system. Some residents living in the Onrus/Vermont areas in September 2012 were not aware of the technology used by the municipality to drain their suburb. Two people whose homes were connected to the settled sewer system thought that they only had French drains or septic tanks. This suggests that the municipality may have to have a communications campaign to alert those connected to settled sewerage and inform them of management responsibilities.

4.3.3.2 Construction issues and responsive troubleshooting

For the first three months after the system was implemented on a wide-scale, the municipality had to constantly address a number of technical problems that caused sewage overflows. Van Vuuren (2010) said municipal officials had allayed residents' distrust of the system by immediately responding to complaints. In addition, Van Vuuren reported that his teams principally dealt with improper connections to the network by tightening up construction quality control. In hindsight, Van Vuuren (2010) said he expected difficulties when trialling new technologies, but – more importantly – he also realised the municipality had to aggressively troubleshoot such problems by finding the cause of problems, adapting municipal procedures accordingly and training teams on how they could effectively address technical problems. Van Vuuren (2010) stated that after the first three months, the settled sewer O&M teams generally had fewer problems than the conventional sewer teams, though this may however have more to do with settled systems having been introduced primarily in low-density areas with holiday homes (thus infrequently used).

4.3.3.3 Stormwater diversion, inspection points and pipe material

The main problem municipal officials have experienced with the settled sewerage system has concerned users directing stormwater to the collection mains (Nel, 2010a; Van Vuuren, 2010; Burger, 2012), which has resulted in wastewater backing up from some properties' interceptor tanks. Illegal stormwater connections pose a greater risk for settled sewer systems than conventional sewerage as the small diameter sewers are not designed for stormwater inflow and groundwater infiltration and thus have less capacity than conventional systems.

Nel (2010a) also raised concerns about the number of maintenance access structures (cleanouts), which were originally kept to a minimum on the sewer lines in order to reduce stormwater ingress. The current numbers of inspection points are now proving to be too few to allow access for maintenance work to be carried out. Furthermore, Van Vuuren (2010) advised against using concrete pipes in cases where settled sewerage discharges into conventional sewerage because these are susceptible to corrosion induced by the H_2S generated from the partially degraded sewage.

4.3.3.4 Expansion

Overstrand officials reported that the settled sewer network was extended to the properties along the edge of the lagoon in Onrus in 2010. Properties with leaking conservancy tanks had their tanks repaired and connected to settled sewerage in order to prevent pollution of the lagoon. Currently Overstrand officials are reluctant to use settled sewerage in Hermanus' informal settlement Zwelihle because of the high risk of inert items being disposed in the system. If this were to occur, then, according to Van Vuuren (2010): (a) biological processes occurring in the interceptor tanks might be interrupted, thus requiring the tanks to be emptied more frequently as waste would not efficiently degrade and (b) the objects may block tank outlets. Van Vuuren (2010) reported that the O&M teams regularly unclogged blockages caused by bricks, rags and sticks found in the informal settlement's conventional sewers whilst Nel (2010b) noted that the contractor finds "*a lot*" of rags, paper and sand during monthly cleanings of the seven sewerage pump stations servicing the informal settlement Zwelihle, at a cost (at that time) of about R204,000 annually. By way of comparison, Nel

(2010b) also mentioned that the same contractor also cleans 25 other pump stations servicing formal areas quarterly, at an annual cost of approximately R200,000 (in 2010). Unfortunately it was not clear what proportion of the waste going to these 25 pump stations came from properties occupied year-round and connected to conventional sewerage and which came from settled sewerage servicing infrequently used holiday homes, but the inference was that the potential for blockages at pump stations servicing Zwelihle were higher than those serving formal areas. Burger (2012), who also was not supportive of installing a settled sewer in an informal settlement, noted however that many of the 'items' (*e.g.* baseball caps, broomsticks, plastic bottles and – sadly – a ½-metre long deceased baby) found in Zwelihele's sewer lines were likely deposited via manholes as these could not have been flushed down the toilets. This suggests the need for more solid waste disposal services and that perhaps installing interceptor tanks at least before the pump stations may catch some of the rubbish that blocks the pumps and connecting pipes.

4.3.4 Informal settlement janitorial services

Nel and Van Vuuren both commented in their 2010 interviews that they began outsourcing janitorial services for Zwelihle informal settlement's communal sanitation facilities (drained by conventional gravity sewers) in mid-2009. Zwelihle, the only informal settlement in Hermanus, is home to 5,384 people (Nel, 2012b). In the past, the communal toilets were handed over to residents to manage, but the municipality struggled with high maintenance costs associated with the constant blockages in toilets and sewer lines, and replacement costs when facilities broke-down (Nel, 2010a). For the purposes of reducing such costs, officials engaged a number of local contractors to arrange a daytime janitorial service for the communal toilet blocks in Azazani, Transit Camp, Bekella, Sphunzana, Wag 'n Bietjie, Tsepe Tsepe, Blou Kerk and Mandela Square sections. In order to encourage local labour job growth, Overstrand officials only allowed "*residents of Zwelihle*" to submit quotations for the contract work at the ablution blocks (Overstrand, 2010; 2012).

According to Nel (2010a; 2012a), janitors are available from 7:00 to 20:00 every day of the week. The Overstrand (2010; 2012) tender specification states that the janitors are responsible for cleaning the facilities, reporting broken or blocked toilets or basins on a daily basis to the municipal help desk, and distributing toilet paper. Interestingly, the tender specification also includes collecting refuse 10 m around the toilet blocks, thus making each janitor responsible for some solid waste removal duties (Overstrand, 2010; 2012). Cleaning materials are to be provided by the contractor (Overstrand, 2010; 2012); but the municipality pays for the toilet paper (Nel, 2010a; 2012a). Notably toilet paper was not in the toilet stall nor did on-site janitors distribute it when the researchers visited the Zwelihle facilities in 2010. According to Nel (2010a), residents were expected to know who they were and approach them directly in the person's home to get toilet paper prior to use. By 2012, however, this arrangement had changed and on-site janitors (discernible to the research team as they held a roll of toilet paper) were distributing approximately 25 1-ply toilet paper sheets to each user (Figure 4-5).

Figure 4-5: A janitor shows how much toilet paper she distributes to users. The two janitors interviewed said they wrap the paper five to six 'times', which is about 25 sheets of 1-ply paper (Photos by Taing, 2012)**.**

The contractor is required to employ a minimum of twelve residents to clean the 106 toilets (Overstrand, 2010; 2012). According to Burger (2012), a minimum level of service was advertised so that local contractors did not undervalue their quotations. Burger (2012) said "*some prospective tenderers [had] ridiculously low*" quotations, such as "*quoting 1/5 of the price of what we knew was realistically needed*". Therefore, Overstrand Municipal officials established the minimum number of janitors they thought was needed to clean the sanitation facilities, however, contractors "*are free to employ more*" (Burger, 2012). In addition, officials provided guidance to the contractors that attended the compulsory site meeting, such as tips on how to fill-out the document and how to do the calculations (Burger, 2012).

According to Nel (2010b), Overstrand Municipality spent R220,584 for janitorial services (excluding toilet paper purchases) in 2010. In Nel's interview (2010), he justified the servicing costs because the users he had met previously said they were satisfied with the services, and were happier because the municipality was more responsive to their sanitation problems than in the past. Furthermore, in terms of facilities management, Nel (2010b) noted municipal officials had "*more control*" over the facility's condition, because janitors were available on-the-ground to assist with preventative maintenance or report problems immediately. In the past, officials had to "*phone people directly*" to learn of any problems. This previous method was also more time-consuming for technical officials because they would then have to manually input the complaint. In the new system, janitors call-in O&M problems more or less on a daily basis to the municipal help desk personnel – who immediately log the complaints into the electronic work order system. The municipal O&M teams then address the complaints and 'close' the work orders when they have completed the repair work. From 1 July 2008 to 1 July 2009, Overstrand Municipality reported that 1,263 service requests from Zwelihle were logged and closed. The figure increased to 1,508 the following year (1 July 2009 to 1 July 2010), which Nel (2010b) did not think was due to an increase in misuse but rather the addition of janitors' daily maintenance reports, which was an advantage as it helped address issues in a preventative manner.

4.3.5 Lessons learnt

In summary, the advantages of Hermanus' settled sewers over conventional systems are: reduced municipal capital costs for public sewerage infrastructure, reduced maintenance costs for residents when existing conservancy or septic tanks are converted, coupled with potential water savings for both the municipality and users (Du Pisani, 1998; Nel, 2010a; Van Vuuren, 2010; Burger, 2012). After inspecting the Hermanus installations and interviewing both maintenance crews and one resident, Du Pisani (1998: 75) concluded that the "*lack of problems at Hermanus was due to good design and construction, driven by the [local authority's] understanding… of the technology*". Du Pisani's comment however oversimplifies why Hermanus' system has fared well. In fact, Overstrand officials' extensive planning, adaptive management, troubleshooting and preventative maintenance (in particular, the Operation team interviewed) have produced a well-designed and operated settled sewer system from a municipal perspective. Van Vuuren (2010), Nel (2010a, 2012a), Myburgh (2012) and Burger (2012) all discussed at length their departmental roles in selecting tank specifications for efficient bio-digestion, checking that contractors correctly connected interceptor tanks to the collection main and promptly troubleshooting any problems. In other words, Overstrand officials ensured good technical design, construction and management of the system by constantly turning previous mistakes into training sessions and lessons learnt, thereby using an adaptive approach to produce both technical settled sewer specifications and a step-by-step procedure for setting-up Hermanus' effective settled sewer service.

The Overstrand officials' good design also extends to how they expected users to behave. Overstrand officials (perhaps unknowingly) had more or less ensured their settled system would be successful by not having settled sewer users adopt out-of-ordinary steps, such as users having to, for example, rake their waste when using ecological sanitation toilets. Maintaining the same type of service for former septic or conservancy tank users (*i.e.* a private sanitation service that safely empties the tanks when full) and were thus familiar with essentially guarantees that there would be little resistance from users beyond the initial capital costs for the modification of the tanks. Overstrand officials also adapted sanitation services in the informal settlement Zwelihle according to user behaviour. Knowing that users were not going to take responsibility for O&M after several years of battling high rehabilitation costs in Zwelihle, a sanitation technology and service was chosen that would best achieve what residents and the Overstrand engineering department required.

Overstrand officials also took responsibility for managing informal settlement sanitation facilities by employing a janitorial service as a preventative maintenance measure, just like eThekwini Municipality. The facilities have had municipally financed janitors available to distribute toilet paper and clean the facilities since mid-2009. There are still some problems – such as controlling foreign items likely introduced via manholes that clog pumps at the pump stations – but otherwise, the janitorial service has undoubtedly added value to residents who had opportunities to start their own cleaning business with a municipal contract or be employed as janitors (Nel, 2010b). The comment by Van Vuuren (2010) and Burger's (2012) that officials are wary of installing settled sewers in Zwelihle because the introduction of non-biodegradable items is difficult to control needs further interrogation though. Considering the anecdotal evidence from officials and contractors who clean the downstream pump stations, having interceptor tanks to trap the majority of the solid waste upstream may be more economical in the long term if the cost of maintaining the tanks is less than the cost of clearing the blockages in the pipelines and maintaining the pumps. It is also not clear why there should be such a concern about non-biodegradable objects in the interceptor tanks. As long as they do not interfere with the biological processes (*i.e.* are not toxic), the only real concern should be the reduced period between the de-sludging of the tanks.

4.4 Vacuum sewers in Kosovo (Philippi, Cape Town)

This section discusses the people and processes associated with planning and managing the country's first vacuum system in Kosovo from 2004 to 2011. The informal settlement's geotechnical, physical and social constraints had precluded the installation of a conventional sewer thereby necessitating the application of an alternative technology if the area were to be sewered. Interviewed CoCT officials said that the vacuum sewer was installed as part of a visionary 'integrated' settlement-wide basic service upgrade project planned in collaboration with Kosovo community leaders. The CoCT Water and Sanitation Department (W&SD) has however since struggled with the O&M of the system since it was handed over from the city's then Housing Department (now Human Settlements) in 2009. The W&SD adopted a trial and error approach, but this has proven to be ineffective because (as with the Gibeon, Namibia system; Section 3.4.2.2) the users' behaviours and operators' reactive practices that cause the system to malfunction were not redressed. Kosovo's unresolved vacuum sewer problem has become yet another example of how a seemingly technologically sound concept has failed disastrously once implemented because the people involved neither supported the processes in place, nor each other. If the system were to be rehabilitated, a number of institutional, technical and management adaptations to the current project planning, design and management processes would need to be addressed. Such process adaptations need to centre on CoCT repairing the system and employing residents as caretakers to help manage Kosovo's public facilities; however, as stated in the Section 1.1, CoCT officials have since elected not to rehabilitate the system and to instead replace the toilets connected to the dysfunctional system with non-sewered alternatives. Brief descriptions of the system's technical specifications and CoCT's previous O&M procedures are included as Appendix B.

4.4.1 Background and description

Kosovo is an informal settlement situated in the Philippi suburb of Cape Town. Interviewed CoCT officials said the privately owned farm was 'invaded' in 1999, and Kosovo's residents initially had limited access to municipal basic services because the local authorities did not have policies in place to service private land. In addition, the settlement's 'built environment' restricted vehicular access in emergencies. On 6 November 2002, an internal Cape Town Fire and Emergency Services memo (CoCT, 2002) sent to the Chief Fire Officer from the Assistant Station Officer described a shack fire in 'Kosovo Squatter Camp' on 4 November that razed over 100 shacks "*to the ground*". The Officer stated that fire crews were unable to access the settlement because new structures had "*gone up overnight blocking previous entry points*" (CoCT, 2002). In addition, overhead 'illegal' electrical wiring had barred access to the settlement as the risk of damage to 'conventional' fire engines entering the area was high. The emergency team's ability to address the fire was also hindered because the hydrants in the area were either 'vandalised' or never installed (CoCT, 2002). The project files unfortunately do not indicate whether the CoCT officials had been able to negotiate access roads into the settlement, or improve the electrical wiring situation. Yet the memo was the first of a series of internal communications between various CoCT departments showing interest in providing services to the privately owned Kosovo.

Recognising that private ownership of Kosovo and the settlement's dense layout restricted CoCT's ability to fulfil their obligations as part of the Free Basic Services policy, CoCT municipal and elected officials considered the purchase of land on which Kosovo was situated. The first document in the Kosovo servicing project's files (CoCT, 2003) which indicated high-level political and municipal interest in purchasing the land was a memo sent from the Executive Director (ED) of the Service Delivery Integration (SDI) Directorate to a local Councillor on 17 December 2003. The ED was one of the few senior CoCT officials that directly reported to the City Manager. In the memo, the ED explained the "*council… [had an] accepted practice of not purchasing occupied land… due to the precedent this would create*". However, less than three months later it seems the council's practice was somehow amended because the CoCT purchased the land from the property owners for R450,000 on 25 March 2004, thus making Kosovo perhaps the first settlement that CoCT had purchased with the intention of upgrading the settlement (CoCT, 2004a).

On 11 May 2004, SDI's Development Support Department (DSD) officials held their first servicing upgrade meeting with Kosovo 'community' members in the Samora Machel Community Hall (CoCT, 2004b), as minuted by a CoCT consultant who would later become the Kosovo upgrade project's Social Facilitator (CoCT, 2004c). The technical team also requested at the initial meeting for four residents to accompany the team's engineers to "*promote understanding of the area*", which would be incorporated into the project designs. Five months later DSD officials had a meeting introducing the Department's proposed Kosovo upgrade to officials from the following CoCT departments (CoCT, 2004d): Transport, Roads and Stormwater; City Parks; Disaster Services Management; Potable Water; Solid Waste; Electricity; and Sewerage Departments. The meeting minutes indicated that CoCT officials in attendance had agreed that the DSD team would facilitate the servicing upgrade project.

In 2005, CoCT officials applied for national subsidies to provide improved water, sewerage, roads, stormwater drainage, pre-paid electricity meters and improved solid waste removal to Kosovo, which by then was one of the city's most densely populated informal settlements (CoCT, 2005). Since its initial inhabitation in August 1999, Kosovo had also ballooned into one of Cape Town's largest with over 15,000 residents in 5,500 dwellings on 26.5 hectares of land (CoCT, 2006b; Goven, 2007). CoCT officials recalled that residents, upon consultation, had demanded full-flush systems after they widely rejected increasing the number of container toilets. However, consulting and municipal engineers deemed a gravity system as impractical because Kosovo's flat topography, high water table and sandy soils required three pump stations and up to eight-metre deep trenching (CoCT, 2009a; Dlamini & Hartung, 2010) between close residential structures where residents often were reluctant to move for fear of further marginalisation (Beauclair, 2010).

4.4.2 Kosovo's vacuum sewerage system

Dlamini & Hartung (2010), the consulting engineers for the project, said their firm suggested a vacuum sewer at almost the same capital cost as a conventional gravity system. According to a CoCT official, a group comprising of both municipal and consulting engineers had assessed vacuum sewerage in 2005 to be an ideal technology for many of Cape Town's dense informal settlements because it requires shallower trenching, fewer pump stations and less residential relocation than gravity systems (CoCT, 2006a). Dlamini & Hartung (2010) stated that the German manufacturer Roediger's *Roevac* vacuum system was selected as it had been "*successfully*" used in a number of different countries, including in rural areas of Namibia and Botswana.

Interviewed CoCT officials said contractors completed Kosovo's basic services upgrade in February/March 2009. Financed with both national subsidies (specifically Municipal Infrastructure Grants) and CoCT cross-subsidies, the final cost of the upgrade was R22,122,860.85, of which: R5,280,548.23 was for roads and stormwater drainage, R5,155,019.34 for the water supply, and R11,687,293.28 for the vacuum system (CoCT, 2010a). The new services consisted of paved main roads, stormwater drainage via a network of open channels and underground pipes and 354 toilets grouped in 42 communal clusters spread across the settlement; each block having a tap and collection chamber (Figure 4-6; Figure 4-7).

Each toilet cluster has between six and fourteen toilets, and is drained by a 110 mm diameter gravity sewer conveying wastewater to an adjacent 40-litre collection chamber sump. The collection chambers' 63 mm diameter interface valves connect to vacuum sewer mains which range from 90 mm to 250 mm in diameter. Pre-cast concrete rings with lockable lids were placed over the collection chamber / interface valve assemblies as a security feature to help protect them from damage.

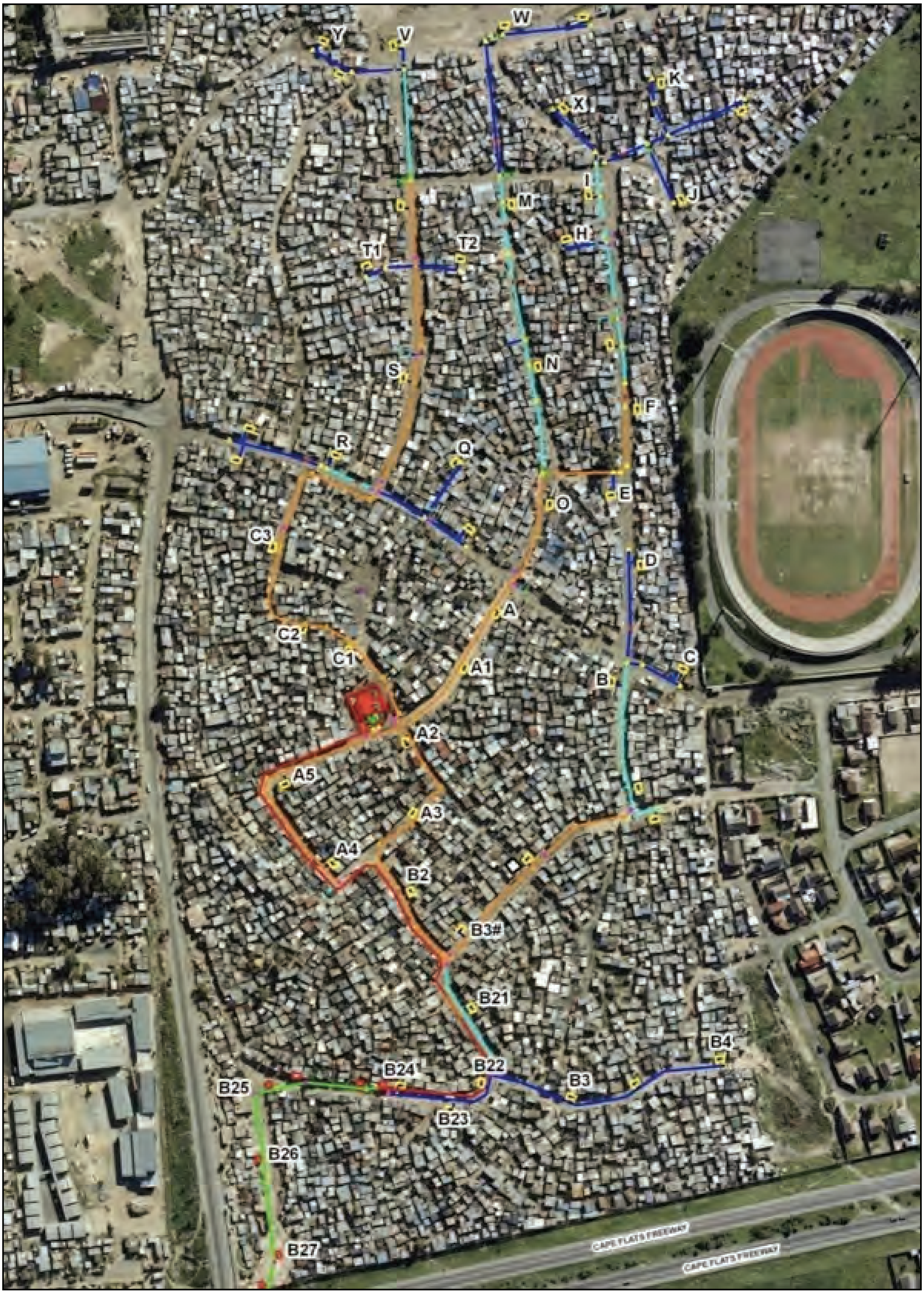

Figure 4-6: Location of Kosovo vacuum sewer system toilet clusters (CoCT, 2010b).

 

Figure 4-7: Open stormwater channel and drain (left) and communal toilets drained by vacuum sewer system (right) (Photos by Ashipala, July 2009)**.**

4.4.3 Technical challenges and institutional and social constraints

Since inception the system has been hampered by users' (Kosovo residents') and service provider's (CoCT's) poor management. Residents continually complained about how the system that they had been provided was of inferior quality and as a result got blocked very easily. For example, sewage overflows regularly emanated from the toilets and drained directly below the washbasins that had been installed at the communal toilets (Beauclair, 2010; Figure 4-8a). In some cases, the overflowing sewage flooded neighbouring shacks. Residents described trying to prevent sewage seeping from the open drains by covering them with wooden boards and bricks to no avail (Beauclair, 2010; Figure 4-8b). CoCT officials subsequently covered the drains with concrete slabs in an attempt to prevent solids and sand from entering the system at these points.

Nevertheless, blockages continued rendering most of the toilets completely unusable (Figure 4-8c). Residents' disposal of items such as cutlery (Figure 4-8d) and bricks (Figure 4-8e) into the system sometimes caused flooding when interface valve diaphragms, pierced by sharp objects, remained closed, and bulky items blocked sumps. Wastewater thus regularly inundated the collection chambers and seeped through the covering concrete rings into the local environment (Figure 4-8f). Sensor controllers also malfunctioned due to fats and dirt clogging pilot tubes, or were rendered completely useless from waterlogging; and the vacuum pumps were overworked due to air leakages in the vacuum line.

Residents have subsequently permanently locked the majority of the toilet blocks in order to prevent anyone from using them. CoCT officials have also found the water supply pipes to some of the toilets blocks have been cut, and a set of toilets destroyed, presumably as a sign of the residents' discontent with the system (Figure 4-8g).

Figure 4-8: Photos of Kosovo's vacuum system and connected toilets. Clockwise top: (a) raw sewage overflow from washbasin drain in June 2009, (b) attempts by residents to prevent spillage by covering drains with wooden boards in June 2009, (c) a used but disconnected toilet in November 2010, (d) a spoon piercing an interface valve diaphragm, (e) a brick in a sump, (f) a submerged collection chamber in a flooded concrete ring in June 2010 and (g) destroyed toilets in July 2010 (Photos by Beauclair (2009), Ashipala (2009), Cornelius (2010), Taing (2010, 2011) and Pan (2011))**.**

After the vacuum system first failed, the R17 million technology's collection chambers primarily functioned as a series of 40-litre conservancy tanks. In 2009/10, 26 tanks were regularly de-sludged thrice weekly at an annual cost of around R500,000. Calculated in terms of litres of waste collected and transported for treatment, the conservancy tank toilets have cost the CoCT's Water and Sanitation Informal Settlements Unit (WSISU) 18 times more than Kosovo's container toilets to service, and four times more than 'expensive' chemical toilets (Table 4-2). Residents have come to view the malfunctioning vacuum system as an inferior technology to conventional systems (Beauclair, 2010) and by 2011 were demanding alternative connections to gravity sewers or the system's complete replacement with the – generally detested – container toilets (Daily Sun, 2011), which at least 'safely' contain wastewater.

Table 4-2: Approximate 2009-10 servicing costs for Kosovo's sanitation provision (Jooste, 2010).

	Costs (1/7/2009 to 30/6/2010)	Number of units serviced	Number of servicing per week	Total litres of waste disposed	Cost per litres of waste disposed
Failed vacuum system collection chambers as conservancy tanks	R500,000	26 collection chambers	3	162,240	R3.08
Container toilets	R1,391,015	256 toilets	6	7,987,200	R0.17
Chemical toilets	R1,572,160	130 toilets	3	2,028,000	R0.78

All municipal officials familiar with Kosovo's vacuum sewer, including the project leadership, now acknowledge that regular blockages of the system by foreign objects and the municipality's lack of knowledge about how to manage vacuum systems suggest that it was an inappropriate technology for informal settlements as implemented. The research team argues further that Kosovo's vacuum system was bound to fail due to a number of institutional, residential and technical constraints that have paralysed effective municipal management. CoCT's responsibilities have been compromised by inter-departmental conflict and a lack of capacity in the municipality. High staff turnover, municipal restructuring and a lack of conflict resolution skills have resulted in inconsistent lines of project accountability that have made it difficult to hold any one person or department accountable for the system's failures or take responsibility for resolving the problems.

4.4.3.1 Institutional constraints

In 2011, interviewed officials stated that problems with Kosovo's vacuum sewer still persisted after three years in part because no one department or official has accepted responsibility for its management and rehabilitation. Officials said that the project's management often changed because of inter-departmental handovers and staff turnover. The events that led to this unfortunate situation are as follows. Development Service Department (DSD) officials initiated the Kosovo services upgrade project in 2004. DSD strongly believed in the coordinated development of roads, stormwater, water, sanitation and solid waste services in informal settlements. A small group of project managers had overseen the planning and construction of settlement-wide infrastructure provision – which was generally outsourced to engineering consultants and construction contractors. They had expected the Water and Sanitation Department (W&SD) to take responsibility for maintaining infrastructure in informal settlements upon contract completion and handover. Officials in both Departments have commonly accepted such a split approach to sanitation provision. For example, when DSD first consulted a junior W&SD official in June 2005 about the proposed vacuum system, the W&SD official unquestioningly assumed the W&SD would be responsible for its maintenance (CoCT, 2006c).

During interviews conducted in 2010/11, however, junior officials reported that W&SD senior management had become increasingly agitated by DSD’s implementation of new water and sanitation services. In an e-mail sent in late 2006, a W&SD senior official suggested that DSD should play a “*coordinating*” role between the city’s decentralised technical departments rather than initiate and provide new services (CoCT, 2006d). Further tension between the two Departments was revealed in W&SD senior management’s opposition to and lack of support for the vacuum system. In February 2006, two W&SD O&M officials submitted departmental applications to visit Botswana together with the DSD Kosovo PM and the vacuum system supplier in order to prepare for the system’s future O&M. The W&SD senior officials ultimately rejected the request because they reportedly felt other available technologies were “*more suitable*” for informal settlements (CoCT, 2006e), though they did not state in the report which alternative technologies they thought were appropriate. Moreover, a senior W&SD official noted on the case study application that the request had come earlier than expected, a factor that may be interpreted as reflecting some political pressure to install the technology. In addition, two O&M officials reported during interviews that W&S leadership advised them in 2006-7 that no special measures should be taken by O&M personnel to learn how to operate the infrastructure until such time as the system was commissioned. Thus, the WSISU ultimately found itself financially and logistically burdened with an O&M problem that previous leadership appeared to have chosen not to address.

The inconsistent line of management was further complicated because the project management had changed several times, obscuring who was responsible for the upgrade project and processes employed. The ‘champions’ (*i.e.* the personnel committed to the successful implementation of the project) who had initiated the project departed even before the system was fully installed and commissioned: the DSD Kosovo PM had joined another CoCT department in 2007 and the consultant Social Facilitator’s contract had ended in early 2009. The Social Facilitator had been appointed by Council to manage the public participation process. After the original Kosovo PM’s departure, the Kosovo upgrade project was subsequently “*inherited*” by the Housing Department PM in 2007, who eventually handed over the dysfunctional vacuum system’s O&M to reluctant WSISU officials in 2009.

The loss of the project champions was critical because interviewed officials have regularly stated that all successful CoCT projects require champions to lead and support initiatives. In the case of Kosovo, no CoCT official – elected or municipal – took responsibility for providing an operable sewer system to Kosovo residents. In 2011, frustrated WSISU officials tried to keep the system operational and grudgingly paid for emptying the collection chambers for nearly three years, but repeatedly asserted that Housing officials should be responsible for the system's expensive repairs and maintenance because the sewer was part of a "*Housing project*". Whilst the Housing PM empathised with WSISU officials' frustration, he maintained his department's budget was restricted to capital projects, thereby barring him from contributing to infrastructure O&M or repairs. Environmental Health officials, who regularly receive complaints from Kosovo residents about the system, also could not assist because infrastructure repair is beyond their responsibilities of health and hygiene awareness. One Environmental Health official recalled how humbled she felt when a mother from Kosovo had pointed out how hypocritical it was for CoCT to teach her about hygiene considering how unhygienic the CoCT provided toilets were. Environmental Health officials have said they have continuously reported complaints and made requests to WSISU to repair the vacuum system in the hopes that the W&SD will act – but to no avail. Indeed, interviewed officials from Housing, Water and Sanitation, Roads and Stormwater, Solid Waste, and Environmental Health officials all complained of their restrictive mandates and inability to enforce another department "*to do their job*".

Upon reflection, the above grievances all point to the entrenched silo management in CoCT planning and operation that has restricted inter-departmental cooperation and coordination at 'the city'. In CoCT governance, personnel are assigned specific job functions based on the focus of their departments' mandate. In this capacity, each official has a specific role (*e.g.* strategic planner, project manager or maintenance personnel) in the decentralised government. Yet, such narrow interpretations of responsibilities has had practical implications for O&M officials supporting municipal services because they rarely are involved in project planning, but would nevertheless be expected to cope with consequences of decisions in which they took no part. In fact, none of CoCT's services the research team learned about had the same officials working on them from the initial planning stages to the infrastructure's decommissioning. Furthermore, such decentralisation of infrastructure planning is nonsensical because it often has resulted in duplicated roles. For example, the W&SD should technically be the sole provider of sanitation services. However, as new housing development settlements require the installation of *all* basic services, the Housing (now called Human Settlements) Department has become a 'de facto' capital service provider, but must handover water and sanitation services because they do not have an operating budget. A senior W&SD official, recognising that CoCT's decentralised planning model will not likely change, has reportedly argued that the various departments must establish inter-departmental service agreements at the initial stages of project planning to negotiate each departments' responsibilities upon handover. This is yet to become CoCT protocol.

Similarly, silos may be restrictive because some personnel choose to not act beyond their job descriptions for fear of being liable in case something goes wrong. This is a particular risk when dealing with informal settlements because the municipality does not yet have agreed procedures for them, thus much practice is decided *ad-hoc* with few protections for officials if a mistake is made. Without proper procedures for servicing informal settlements, many officials feel they are at professional risk if the *ad-hoc* procedure they adopt is unsuccessful. Many municipal officials thus await explicit directions in writing from their managers – and the managers in turn wait for political directives – before action is taken in difficult circumstances such as fixing Kosovo's vacuum sewer.

Officials' reluctance to accept responsibility is disappointing, but unsurprising given the municipality's severely decentralised framework system that gives no indication of who should act and what they should do if projects fail, as well as the municipality's lack of support to train officials for tasks that have become necessary for them to fulfil their responsibilities. Astonishingly though, none of the interviewed officials pointed out CoCT Executive Management's responsibility in setting-up an "*enabling environment*" (DWAF, undated: 5); *i.e.* to have processes and systems in place to facilitate service delivery and to ensure municipal officials can overcome institutional constraints. According to DWAF (undated: 8), the Water Services Authority (WSA) is a "*municipality*" who: (a) "*has ultimate responsibility for ensuring that end-users have access to water and sanitation services within its area of jurisdiction*" and (b) can delegate sanitation "*responsibilities*" to service providers. The national government (DWAF, undated: 8) has defined a service provider to mean "*any person who provides water services to [users]*". The service provider often does this as part of their responsibility to the local authority. In regards to Kosovo, the Executive Management's overlapping delegation of tasks – from building a sewage system, to installing and managing sanitation facilities – has made it difficult to establish clear lines of responsibility because a number of officials from various departments have been involved throughout the project. This explains why many of the municipal officials interviewed for the research study are having difficulty coordinating across silos, and linking how they are supposed to intervene for lack of a process that defines how or when. Regarding Kosovo's vacuum system, CoCT Executive Management is and should be ultimately accountable for negotiating Housing's and W&SD's impasse; training staff to become able negotiators, project facilitators and operators; and managing a way forward.

4.4.3.2 Residential constraints

In addition to their hesitancy in accepting a failed project, municipal officials are wary of accepting responsibility for the vacuum system because the high levels of politicisation amongst Kosovo's residents required officials and the consultant Social Facilitators to exercise conflict resolution skills (Beauclair, 2010). Though not discussed in detail in this report, Beauclair (2010), Mpengezi (2010) and interviewed CoCT officials noted that bipartisan conflicts amongst Kosovo's community leaders had severely undermined the implementation of the upgrade from the beginning and caused massive project delays. The conflicts between the community leaders were supposedly related to job opportunities for Kosovo residents. CoCT officials said Kosovo's leadership had initially refused to collaborate with the elected Ward Councillor representing their area, because they claimed he would only appoint his friends for the construction works (Beauclair, 2010). Later, when this issue was supposedly 'resolved', Mpengezi (2010) said construction was delayed again over the contentious appointment of the project's Community Liaison Officers (CLOs) who were responsible for relaying information on the construction project to residents. Project documentation indicated that CoCT officials and Kosovo community leaders had tried several times to enact a fair process to appoint the project's two CLOs, yet the disputes over the limited employment opportunities ultimately contributed to what would become a two-year construction delay.

As noted in the chapter's introduction, many officials admitted in hindsight they felt ill prepared to negotiate with residents. CoCT officials were able to appoint a Social Facilitator for the Kosovo project; however, the majority of officials with technical backgrounds generally will not have such support. Some officials in technical positions even said, "*it's not a part of my job description*" to facilitate residential agreement and acceptance. Yet the same officials who contested this role have also been observed by the research team as actively facilitating the provision of new services with residents in informal settlements. The municipality does have Social Facilitators employed in the Economic, Social and Community Development Directorate, but – for reasons unclear to the research team – only one of the CoCT officials interviewed asked for their assistance when engaging residents in infrastructure projects. Some officials also involved the local Ward Councillor to engage 'the community', but most CoCT officials said involving elected officials have only 'politicised' projects in the past, thus preferred to contact Councillors only to inform them of new projects. Therefore, though technical staff reported being hesitant to engage residents directly, many officials have accepted this task in light of the need for it, and their inability to outsource it.

4.4.3.3 O&M and adaptive management

The lack of municipal experience to manage vacuum systems, departmental tension between W&SD O&M teams and the lack of capacity to ensure new technologies reliably operate are further reasons why the vacuum system was an inappropriate technology choice for CoCT as a service provider. WSISU personnel and pump station operators responsible for the vacuum system's O&M have claimed they were handed over a malfunctioning technology, did not receive adequate training for the pilot system and were not even given the O&M manual that the contractor supposedly had provided. In the absence of the O&M manual, the technical personnel said they had little choice but to learn how to operate the system through trial and error. The situation was aggravated by the fact that W&SD's 'pipes' and 'pumps' sections disagreed over who was responsible for the collection chambers, a major constraint as vacuum systems should not be managed by a series of uncoordinated O&M agents.

Eventually, when WSISU accepted responsibility for the chambers, its staff learned that damaged sensors and valves could not immediately be replaced because spares provision was omitted in the original tender. None were available locally thus these critical and expensive units had to be sourced directly from the German manufacturers at R11,600 per unit in 2010. Equipment for inspecting the system for air leaks had also not been procured, furthering inhibiting the WSISU team's ability to effectively troubleshoot the system. The lack of test balls (inflatable rubber balls inserted into the vacuum sewer in order to isolate sections of the sewer) and pressure gauges meant that if sewer failures were to occur there would be no way of determining the section along a vacuum sewer line it had occurred.

With the hindsight of W&S's limited knowledge of vacuum sewerage, the CoCT Kosovo Project Manager has conceded that the original tender should have included provisions for the system's daily O&M administration; the production of a Kosovo-specific O&M manual; and a thorough technical training and practical handover to a team of dedicated W&S O&M personnel (CoCT, 2009a). The lack of such an O&M plan contributed to the poor state of the vacuum system; however, there was also a lack of consistent monitoring and evaluation and consequent adaptive management to manage the infrastructure. In contrast, when nearby Overstrand Municipality had to cope with three months of sewage overflows during its wide-scale settled sewerage implementation in 1995, that municipality immediately investigated the problems and systematically adapted practices and procedures to resolve them (Van Vuuren, 2010; Section 4.3.3.2). Observational data with CoCT officials showed that the majority of CoCT's pilot sanitation projects do not receive such rigorous troubleshooting. This seems primarily due to the overwhelming workload placed on CoCT officials.

Recognising that institutional knowledge was a major gap, in April 2011, some 25 months after the system was commissioned, WSISU arranged a five-day technical assessment and skills training course for WSISU staff and pump operators. Simultaneously, consulting engineers provided O&M manuals. During this period, ten collection chambers were reinstated on Kosovo's southern vacuum line. Unfortunately, the entire system could not be restored due to the consultant's time constraints, the lack of replacement parts for damaged chambers, the lack of equipment to drain flooded chambers before inspection, and leakages on the sewer lines. Approximately six months after the training, all the systems were functioning as *de-facto* conservancy tanks again because residential and institutional management had not changed.

4.4.3.4 Residents' circumstances

Post failure, many interviewed CoCT officials and residents believe the vacuum system is an inappropriate technology for informal settlements because the system is too "*sensitive*" to conditions that prevail in such places. Some claimed they expressed concerns prior to its installation about the utilisation of inappropriate personal cleansing materials in the vacuum system as toilet paper is not commonly used in an informal settlement as well as the fact that solid waste is also indiscriminately disposed into the system. All municipal officials interviewed now believe that the vacuum system is more suitable for affluent areas that enjoy good solid waste disposal services and regularly use soft, biodegradable anal cleansers such as toilet paper, which many informal settlement residents cannot afford or refuse to purchase. Some even recommended that the vacuum system should be replaced with a conventional gravity sewer. Yet *any* sewerage system is susceptible to blockage by bulky objects and by the build-up of grease and fats. CoCT (2010c) reported that some 90,000 blockages occur annually metro-wide in conventional systems in part because people use sewage facilities for other than their intended purpose of conveying human waste and toilet paper. What distinguishes a vacuum system in this regard is that blockages tend to occur locally at collection chambers and result in the discharge of sewage on site, whereas blockages in gravity systems tend to occur further downstream – away from the users. Thus, whilst the downstream users may suffer the consequences of upstream users' behaviour, the blockage is someone else's problem and not that of the perpetrators.

Officials regularly complain that informal settlement residents misuse toilets by flushing foreign objects (rags, newspaper, stones and sharp objects), a practice they attributed to a variety of factors ranging from: residents' incomprehension about, and unfamiliarity with sewerage, intentional sabotage or the use of the area around the communal facilities as playgrounds by small children (as observed by Beauclair in her 2010 study), to the use of these materials for anal cleansing. Yet observational data suggest that it is more logically attributed to circumstance (Beauclair, 2010): residents have inadequate provision for solid waste removal – including food waste (Figure 4-9). Thus, service providers should bear in mind that perhaps circumstances such as the lack of adequate basic services – as well as users' little understanding of how a system operates – have induced residents to misuse sanitation facilities.

Figure 4-9: Evidence of greywater, food waste and solid waste disposal in Kosovo toilets connected to the vacuum sewer (Photos by Taing, 2010, 2011)**.**

CoCT officials repeatedly emphasised the need for behaviour change through education and awareness programmes to enable successful new technology uptake. Interestingly, despite claims that such behavioural education and awareness is critical, no education and awareness programmes were however ever initiated in Kosovo, whilst the posters indicating what can be disposed into a vacuum system were stored in the vacuum pump station and neither distributed nor displayed. On the other hand, the posters may have made little difference owing to the problem of insufficient waste disposal services and lack of toilet paper already described.

4.4.4 The need for janitorial services

It is unclear whether CoCT officials and residential leaders had prepared a facilities handover to residents. Nevertheless, officials have stated that organising 'community-owned' management schemes amongst households often "*don't work*" because some of the users do not clean after themselves or the toilets are appropriated for private use. In Kosovo, an official said the facilities operate today primarily as 'open' facilities – with no-one responsible for managing them. The 'public toilet' problem is not unique to Kosovo; CoCT officials repeatedly complained how residents – some of whom had initially agreed to facilitate a management schemes amongst users – "*did not take ownership*" for toilets they were given from the municipality. Harrison (2011), in reference to one of the key findings in eThekwini municipality's simplified sewer pilot project, said that residents likely did not accept accountability or responsibility for the infrastructure because of their demand for the right to sanitation *services* from the state, rather than a toilet facility. This suggests that, in regard to Kosovo's vacuum toilets, CoCT officials have to accept full responsibility for both the infrastructure's supply and service to ensure it is used, operated and maintained as intended. Both Overstrand and eThekwini officials have reported that employing residents as janitors at public sanitation facilities in all their informal settlements – to clean, maintain and guard facilities – reduced their rehabilitation expenses during the 2009-2010 financial year (Gounden, 2010; Van Vuuren, 2010).

In 2010, WSISU officials described their experiences of providing janitorial services for public sanitation facilities at seven toilet blocks in Khayelitsha and the MobiSan unit in Pooke se Bos informal settlement, lessons that can be incorporated into a caretaker plan for Kosovo. Each facility is open seven days a week, 16-hours per day (during summer) and two caretakers who are responsible for cleaning the facilities and reporting problems to WSISU. WSISU began employing residents as janitors at the Khayelitsha public ablution blocks in January 2009. WSISU's officials provide cleaning materials to janitors, but residents were expected to provide their own toilet paper. Residents, who were using the facilities when the researcher had visited, said they preferred having janitors to maintain the toilets rather than assuming these responsibilities themselves. There have been a number of problems with the facilities despite employing local residents as caretakers. Janitors and CoCT officials recalled reporting after-hour break-ins where the metal fittings were stolen at all the facilities during the municipality's 2009-2010 financial year. Such incidences reinforce the fact that municipal services are at risk of vandalism and thus need to have security measures in place to protect these assets. Janitors also reported occasional blockages when newspaper was used for anal cleansing (Figure 4-10). Consequently, WSISU has decided to renovate each facility after improving security (*e.g.* installing concrete palisade fencing and padlocked gates) and intends to provide toilet paper as part of the department's new janitorial services tender.

The Mobisan unit, an ecological sanitation technology that was designed by the Dutch Consortium group 'Partners for Water' (PfW), is managed by WSISU and was opened three months after Kosovo's vacuum system in May 2009. Despite not producing one batch of compost properly to date since its inception, the Mobisan still functions as a successful public sanitation facility after three years of operation. The Mobisan unit is secured behind a fence and locked gate with flood lighting, and two on-site janitors have distributed toilet paper to users since it was opened. A janitor said that he has not had any issues with theft, except when someone occasionally steals a bar of soap or roll of toilet paper when he is away from the entrance. However, he has stated that some of Pooke se Bos' 500 residents still preferred relieving themselves in the wetlands behind the settlement, which is also where residents threw out their night soil and greywater buckets.

Overstrand, eThekwini and WSISU's experience with janitorial services indicate public facilities with janitorial services are effective and durable sanitation options for the municipalities' informal settlements. Moreover, facilities in South African informal settlements should have the on-site janitors distribute toilet paper in addition to cleaning the toilets, whilst it is important to provide security at night when the facilities are closed.

4.4.5 Lessons learnt

In retrospect, it is evident that Kosovo's vacuum system was bound to fail as implemented because neither the municipality nor the users were adequately prepared for the technological and social challenges of managing the system. Without an enabling environment to effectively plan and manage the new technology, coupled with inconsistent project leadership that subsequently left no one immediately accountable for the infrastructure, it is little wonder that CoCT officials have struggled to manage and rehabilitate the now discredited vacuum system. Moreover, residential leaders have not eased the situation as their contestations over the project's limited employment opportunities caused a number of unnecessary delays to the servicing of one of the city's densely populated informal settlements. This suggests that service providers should allow extensive periods for monitoring, evaluating and troubleshooting problems when implementing unfamiliar technologies. The Kosovo experience – as with Hangberg – indicates that CoCT, as the WSA responsible for service delivery, needs to adopt new policies and practices for the provision of sewerage in informal settlements.

Figure 4-10: **Clockwise from top left to right: (a) evidence of infrastructural damage from a break-in at TR Section's ablution facility, (b) a toilet in TR Section where newspaper was used as an anal cleanser, (c) a janitor at the CT facility, and (d) a sign posted at the facility's entrance entreating users (in isiXhosa) to use toilet paper** (Photos by Taing, 2011)**.**

If vacuum systems are to be implemented in informal settlements in the future, service providers should critically assess how to control usage of the vacuum system. If a janitorial service and toilet paper cannot be provided, there will always be a high likelihood of rubbish being introduced into the system which could damage the interface valves and/or their operation. Under these circumstances, service providers should consider installing interceptor tanks between the toilets and collection chamber – in other words, creating a hybrid between settled sewerage and vacuum sewerage. Alternatively, the toilets can be installed over the interceptor tanks similar to an aqua privy system, with the tank outlets draining directly to the collection chambers. If such an approach is undertaken, then the service providers would also need to consider how often they would need to empty the interceptor tanks to ensure the vacuum system continues to operate optimally.

At the time of writing, CoCT officials have decided to decommission Kosovo's vacuum system and are assessing a non-sewered technology to replace the dysfunctional toilets. If the vacuum system is to be saved, the system would need to be rehabilitated, and some officials have advocated contracting a service provider for a year to operate and maintain it whilst the municipality builds its O&M capacity. Improved social management of sanitation assets in a service-driven informal settlement environment will also require janitorial services, and in Kosovo this has been recommended as part of a system rehabilitation programme that requires a holistic O&M strategy. Regardless of the technology, the CoCT Executive Management – not residential users – should provide janitorial services for all shared facilities. It is clear that the indisputable assignment of various O&M responsibilities is necessary to enable municipal officials and residents to hold each other accountable for the vacuum system's functioning and failures.

4.5 Conclusions

This chapter has contrasted the different conditions, challenges and processes used to service two informal settlements in Cape Town and portions of Hermanus. In each situation an alternative sewerage system was introduced to a previously un-sewered area, with mixed results. Of the three, Hermanus' settled sewer clearly was the best planned, not only from a technical standpoint, but also its O&M – including a regulatory framework for construction and supervision. Overstrand officials have been thus been able to provide their residents with sewerage more economically than with conventional sewerage. On the other hand, Overstrand officials are providing services to largely middle-class residents or upper-income holidaymakers who can afford to pay for sewage services. One key to their success appears to be that they provided a similar quality of service to that the users expected, and did not expect them to take on any extraordinary tasks other than simply calling the Council to empty the tanks when they are full – something that former conservancy and septic tank users were already accustomed to. Overstrand's settled sewer demonstrates how good technology design takes into account how people behave, how the project is set-up and what processes are in place to support the people who use it. In Zwelihle informal settlement, Overstrand officials inaugurated a janitorial service for the shared toilet blocks in 2009 in recognition that the municipality – *i.e.* not users – had to accept responsibility for managing the facilities. As a result of introducing janitorial services, officials claim that, not only are residents satisfied with the state of the sanitation facilities, but also the municipality is saving money on the maintenance of the system.

In contrast, CoCT – the largest municipality in the Western Province – struggles to meet the demands of informal settlement residents for sanitation facilities. Extending these responsibilities to include O&M has huge financial and capacity repercussions. Many officials noted that O&M costs are generally not budgeted for when sanitation facilities are provided, in part because of a belief that residents should 'own' the toilets as one would a private facility and in part because project responsibilities and therefore costs are divided among various municipal departments in an uncoordinated manner. Particularly in Kosovo, the expectation that the 'community' should 'own' shared sanitation facilities – rather than the municipality providing both a facility and service – has patently not worked. Kosovo residents and CoCT officials have consequently condemned the vacuum system as inappropriate for an informal settlement. In hindsight, it is evident that Kosovo's vacuum system was bound to fail as implemented because neither the municipality nor the users were adequately prepared to address both the technological and social challenges of managing this unfamiliar system. There was also no contingency plan in place in case of failure and, as a consequence, sewage leaking from the dysfunctional vacuum system directly impacts residents' health and the settlement's environmental condition.

It is significant that some of the reasons why the vacuum sewer failed – *e.g.* its improper use and users' and officials' lack of management – also contributed to the failure of the simplified system in Hangberg to work as hoped. Interestingly though, Hangberg residents and municipal officials do not claim that the technology was the problem in this instance.

The Hangberg and Kosovo studies both show how people and their interactions with each other when planning an upgrade project can influence whether a project will succeed or fail. In particular, they showed how divided both 'the community', 'the city' and 'the project team' are, thereby highlighting the need to reconcile these divisions when developing projects for informal settlements in the future. In future projects, roles and responsibilities should be realistically assigned according to the needs, expectations and capacity of the people involved throughout a project lifespan. Furthermore, Executive Management needs to ensure that the contributions of the different municipal units are properly coordinated – bearing in mind, it is they who are ultimately accountable for ensuring that a WSA fulfils its FBS obligation.

5. Barcelona settled sewer pilot project

5.1 Introduction

In this chapter the process for forming a partnership to provide a pilot settled sewer system for Barcelona, an informal settlement in Cape Town, is presented. The Barcelona Settled Sewerage Pilot Project (BSSPP) is a collaborative initiative between: the CoCT Department WSISU (the implementing partner), the Barcelona Street Committee (BSC; the representatives of the intended beneficiaries) and the UCT research group (the design, social facilitation and research partner). The UCT research group contains, *inter alia*, civil engineers and social anthropologists – with the latter being responsible for social engagement. Initially it was assumed that this social engagement would largely be with the residents of Barcelona. However, the anthropology research team soon realised that their ‘social facilitation’ role could not be limited to negotiating and consulting with residents, but had to be extended to facilitating the project itself owing to the lack of municipal capacity and various institutional constraints. They have also attempted to understand all participants’ perspectives, from the study’s inception through planning and design. This included clarification of the division of responsibilities between WSISU officials and UCT researchers. It is hoped that these activities will continue in the future to include the construction period (estimated to extend from September to December 2013), and subsequent monitoring and evaluation of daily operation and maintenance (O&M) activities (projected to be January 2014 onwards).

What follows are the research team’s reflections on events between April 2010 and December 2012, in particular what events have caused the extended delay in construction. A brief description of Barcelona’s physical characteristics, demographics and level of basic services is presented first. Following this is a discussion on the factors that encouraged the project team to select settled sewerage for the pilot study and a partnership approach for its implementation, and then the challenges that arose as the project progressed. Finally there is reflection on what has been achieved and learned through this partnership process with some recommendations on how service delivery can perhaps be improved in the future through the clear definition of the roles, responsibilities and expectations of all involved in a municipal infrastructure project from the outset. A description of the preliminary technical design is included as Appendix C.

5.2 Description of the study area

5.2.1 Background

Barcelona informal settlement was established in 1992 and is named after the Spanish city that hosted the 1992 Olympic Games (Lerato's Hope, 2009). The settlement is bordered by the N2 Highway to the north, Europe informal settlement to the east, Klipfontein Road to the south and the Lotus Canal and Kanana informal settlement to the west (Figure 5-1).

Figure 5-1: Aerial photograph of Barcelona informal settlement showing the contours (after CoCT, 2009b)**.**

Barcelona is founded on a discontinued solid waste dumpsite covering an area of approximately 30 hectares (Figure 5-2). The land is owned by CoCT and was first used in the 1950s and 1960s by local authorities for the disposal of a variety of solid waste materials including industrial waste. The Environmental Partnership (TEP, 2004), a consulting firm that studied the feasibility of developing low-income housing in the area on behalf of CoCT, found that the solid waste dumpsite's excavation went as far down as the ground water table would allow, averaging depths of up to eight meters. No protection measures such as lining the bottom of the solid waste site were undertaken in the establishment of the landfill sixty years ago, thus the discarded items are in direct contact with and even occasionally below the current groundwater table. The uncontrolled dumping of waste ceased in 1987 after which the site was capped with a thin layer of sand approximately 30 cm thick. In many areas the capping has completely eroded, exposing the solid waste below (TEP, 2004).

Figure 5-2: A shallow excavation in Barcelona revealing subsurface solid waste materials (left) and Lotus River canal along the Barcelona-Kanana boundary (right) (Photos by Ashipala, 2010)**.**

TEP (2004) describe the land on which Barcelona is currently situated as heavily contaminated, thereby "*unacceptable*" for human habitation. In particular, TEP (2004: 12) noted "*explosive*" methane levels tested at 14 out of 15 trial pits and records "*the presence of volatile organics, petroleum hydrocarbons, fluoride, nitrate, potassium and sodium*" in groundwater tests close to the Lotus River Canal. Furthermore, the dumpsite was not properly compacted, meaning that the area poses a "s*erious risk with regard to the stability of three storey buildings and the risk of damaging underground services*". This appears to preclude the construction of any kind of housing.

Despite the extensive on-site contamination, some 6600 people (2230 households according to CORC, 2010) currently call the former dumpsite home. The Community Organisation Resource Centre (CORC) is a NGO that conducted a door-to-door enumeration with Barcelona residents' assistance. They reported that 32% of households (714) had lived in Barcelona for over 11 years as at 2009. In 2010, the settlement had a shack density of 74 dwelling units (du) per hectare. Residents have primarily constructed their homes using corrugated iron sheeting and timber, though there are some brick structures. Like Hangberg, the houses range from single room dwellings to multi-roomed structures, which have often been extended through the years. Many residents have built stand-alone structures for their extended family. Some residents have demarcated their 'plots' by constructing fences around their homes.

Barcelona has a network of small footpaths and dirt access tracks that can accommodate single land traffic. The tracks' surfaces are uneven containing numerous localised mounds and depressions. There are three solid waste disposal containers ('skips') in Barcelona. No formal stormwater drainage system has been installed in the settlement.

5.2.2 Water and sanitation services

In April 2010, the UCT research team conducted a tap and toilet count in Barcelona. The survey was conducted to clarify discrepancies between WSISU and CORC's statistics on the settlement's water and sanitation services. WSISU officials said their contractor invoices indicated that 393 communal containers toilets were installed (Figure 5-3) and CoCT paid contractors to service these facilities three times a week. CoCT staff had also previously provided 21 standpipes. However, the March 2010 enumeration survey by CORC (2010) and Barcelona residents disputed these figures; they had counted 323 container toilets (of which 157 were deemed 'dysfunctional' because they needed maintenance), 160 pit latrines ('long drop' toilets over unlined pits) and 15 standpipes. CORC (2010) also reported that 87 residents had no access to a toilet at all, having to make use of the open areas around the settlement, particularly the road edges along the N2 freeway. The disparities in the CoCT and CORC figures motivated the UCT research team to conduct an independent survey in order to clarify the statistical discrepancy and gauge whether additional sanitation facilities were needed in Barcelona. This survey also presented an opportunity for the research team to better understand the settlement by interacting with Barcelona residents with respect to their needs, expectations and practices around water and sanitation services.

The UCT sanitation and water survey found the following:

- A total of 524 toilets, of which 367 were municipally-provided container toilets (70%), and 157 privately-owned pit latrines (30%).
- Of the 367 container toilets, 323 (88%) were housed in standard CoCT-issued concrete structures, whereas 46 (12%) CoCT-serviced containers were housed in self-built structures. Residents did not indicate what had happened to the original panel-cast concrete structures.
- A large percentage of the container toilets were locked (36%) and/or enclosed in private yards (40%).
- 15 of the 18 standpipes were located in public areas providing a communal service, whereas the other three were located in private yards.
- Of the 18 standpipes, one was not working and two others had been tampered with through the addition of illegal household water connections, though it was unclear how many dwellings were thus serviced.

From interviews with residents, the UCT research team found that most were generally unhappy with the sanitation services in Barcelona. Although the majority of container toilets (87%) appeared to be in good condition, residents frequently complained that the 'buckets' were 'undignified', 'smelling' and 'dirty'. This is problematic as CoCT spent nearly R950,000 in 2010 (at R15.75 per container three times a week) to service the detested 'buckets' that residents were unhappy with, excluding the cost of replacing damaged facilities. Residents generally expressed less dissatisfaction with the water supply than with the container toilet service, thereby suggesting that sanitation was a bigger concern than the water supply.

Figure 5-3: A row of communal container toilets (left) and a private pit latrine (right) (Photos by Ashipala and Pan, 2010)**.**

As with the CORC 2010 enumeration survey, the UCT tap and toilet count showed that the available sanitation services in Barcelona were not adequately addressing the needs of residents. Technically, Barcelona (at one toilet for every six households) is underserved according to CoCT's policy (2011) of providing one toilet for every five houses when an adequate amount of space is available. When asked how many households they generally share the facilities with, interviewed residents said it ranged anywhere from two to four other families, thereby suggesting that a large number of residents had no access to sanitation facilities. Given the low coverage of sanitation services and residents' general dissatisfaction with sharing 'buckets', it is not surprising that 157 households in Barcelona have opted to construct their own pit latrines.

Interviews with the residents revealed that most residents explicitly requested waterborne sewerage if additional toilets were to be added by the municipality. In addition, the settlement needs some sort of drainage for standpipes standing in muddy water, greywater and night soil buckets, all of which, as the UCT water and sanitation survey revealed, are concerns in Barcelona. Fortunately, the site's history as a solid waste dumpsite means that it is elevated above the surrounding terrain – an important feature for a gravity service. However, conventional sewerage would be difficult to install in Barcelona because it requires deep excavation into the solid waste (TEP, 2004). These factors thus motivated WSISU officials and the UCT research team to consider Barcelona for an alternative sewerage pilot.

5.3 Settled sewerage pilot project

When WSISU and the UCT research team first consulted BSC representatives in April 2010 regarding the possibility of trailing an alternative sewer scheme in Barcelona, the BSC immediately expressed the residents' desire to have full-flush facilities and thus their interest in partnering in the proposed pilot project – on the understanding that if successful, the CoCT would give serious consideration to extending it. In May 2010, the then Head of WSISU committed the CoCT to the proposed project with up to R2 million towards the construction costs – and then paying for janitorial services on its completion. In addition, he appointed a Project Manager (PM) and Monitoring and Evaluation (M&E) Officer to manage the pilot project. Though not formally outlined between the three parties at the time, the UCT team had meant to restrict their role to: technical design and support to the WSISU PM and M&E Officer as part of the 'technical team'; liaison with the BSC to address their concerns as best as possible; and on-going monitoring to evaluate the applicability of the system in this informal settlement. Both WSISU officials and the UCT researchers expected the BSC members to represent Barcelona residents' opinions, and promote broad support for the project by regularly consulting residents at general meetings and conveying their opinions to the technical team.

The following sections describe: the selection of settled sewerage for Barcelona; the preliminary design of the system; the difficulties encountered in managing the partnership approach used to carry out the pilot – and how they have been addressed up to the time of writing; finalising the technical design; and finally strategising a suitable O&M plan. Concluding remarks are then made at the end of the chapter.

5.3.1 Selecting a settled sewer system

The research team considered conventional, simplified, vacuum and settled sewerage as possible sanitation options for Barcelona. Although the site has the advantage of being elevated up to 7.5 m above its surroundings, differential settling of the underlying solid waste has resulted in the area being very uneven with numerous localised mounds and depressions. The uneven ground levels are problematic for gravity-driven sewerage because of the need for quite deep excavations in some areas if conventional or simplified sewers are used so as to obtain the requisite falls to transport solids without unacceptably high blockage rates. Deep excavations are a concern for three reasons: cost, the uncertainties associated with excavating deep into the solid waste, and the risk of the many shacks in close proximity collapsing as a consequence of the excavations. Access to the pipes for the purposes of unblocking them is also problematic; large numbers of manholes would be required for conventional sewerage – which is not only expensive, but also a blockage risk as it is evident that residents in informal settlements frequently use manholes as refuse bins. Even with simplified sewerage, the relatively large depths that would be required in some areas would require manholes there instead of the junction boxes normally used – thereby negating much of the cost advantage generally offered by system. Both systems would require relatively large diameter pipes (up to 200 mm diameter) to cater for the possible future expansion. Taken together, conventional and simplified sewerage were ruled out for Barcelona. Furthermore, vacuum sewerage was undesirable given CoCT's recent failure with this system in nearby Kosovo and the high cost of importing parts from Germany. Moreover, the fact that Barcelona is officially classified as "*uninhabitable*" land (TEP, 2004) meant that CoCT officials were reluctant to install expensive, permanent infrastructure in the settlement.

Given these constraints, it became evident that settled sewerage was the only really viable option as settling the bulk of the solids in the interceptor tanks allows for the sewers to be of smaller diameter than conventional and simplified sewerage – and laid at flatter gradients, thus reduced excavation depths. This in turn makes it easier to route the sewers along narrow pathways saving on the pipe lengths. Furthermore, there is less disruption to the residents – reducing the risk of time-consuming negotiations and contested relocations to accommodate the sewer installation. Shallower pipes and the absence of gross solids mean that manholes can be replaced with access pipes saving money and reducing the risk of the system being used as a rubbish disposal system. Although the interceptor tanks would have to be de-sludged on a regular basis (approximately monthly), the frequency of emptying required for the relatively few tanks would be far less than that required for the current large number of container toilets (approximately every second day) which should reduce the operational costs should the system be rolled out across the settlement.

In addition to the advantages listed above, the relatively shallow trenches required for the settled sewerage – generally less than two metres – mean that these can be hand dug, thus creating much-desired short-term employment opportunities for Barcelona residents. Yet, such an advantage could easily become contentious, as seen in the Kosovo vacuum sewerage project. Indeed, the Hangberg, Hermanus and Kosovo case studies indicate a number of socio-political threats that could threaten the construction and/or management of the proposed system, and ultimately result in the pilot project failing. Furthermore, there is always the risk of illegal connections to water supply or wastewater sewers which must be prevented if at all possible as they could affect the integrity of the settled system. It is critical that these risks be mitigated.

5.3.2 Designing the settled sewerage

5.3.2.1 Sewer design for a 'temporary' situation

The design of the sewer network had to make provision for possible future expansion of the pilot project. This meant that the sewer network was designed with sufficient capacity to convey the flows that would be likely generated if the entire settlement were to be connected to it in the future. This allowance for future expansion was however riddled with uncertainty for reasons mainly related to the legal status of the settlement. As the settlement is informal, none of the residents have legal tenure over the land they live on. The CoCT Human Settlements Department also have been unable to confirm whether the settlement would ever be formalised. WSISU officials are understandably reluctant to invest in an expensive sewage system that might be abandoned in the future. The research team however came to the conclusion that this state of ‘temporary permanence’ was likely to continue for the foreseeable future, with WSISU officials providing sanitation services as they are legally mandated to do on behalf of the CoCT Municipality. Finally, although WSISU has given verbal assurances on a number of occasions that they will extend the pilot project to the rest of the settlement if it proved a success, at the time of writing there was no written commitment to do so.

5.3.2.2 Facility design

Throughout the technical design process, the UCT research team consulted some 200 residents and the BSC at a general community meeting with regard to the top-structure design, pedestal types and integration with other water services, for example the ablution facilities, laundry areas and ‘night soil’ disposal points (Bourne, 2010). At these meetings, the BSC and residents reiterated their preference for full-flush toilets. Those residents present at the meeting also made it clear that they prioritised individual toilets for each household and ideally wanted fully-serviced houses and not just toilets. Once the limitations of the project were made clear, the BSC chairperson suggested providing public facilities which would allow a larger number of residents to benefit from the pilot project. Those residents present accepted the pilot sewerage project by show of hand. This was however on the condition that, should the pilot system be proved to work, more toilets would be installed for the settlement. The residents in attendance also related that communal showers or wash areas were not a priority at that time and requested that the pilot project first address the issue of providing sewered toilet facilities. The UCT research team was then tasked with developing a public toilet facility. At the same meeting, the residents also delegated the responsibility for finding sites suitable for the pilot project to the BSC (Bourne, 2010).

Currently the concept proposal is for there to be three BSSPP toilet facilities – each comprising 10 toilets situated in their own precast concrete cubicles and placed together on a drained concrete floor slab (Figure 5-4). A standpipe and drain for wash-water will also be provided – as well as a security hut for an on-site janitor to store toilet paper, cleaning materials and maintenance equipment. A roof (similar to a carport roof) will provide a measure of protection from bad weather. Two 1 kℓ rainwater tanks mounted on the concrete cubicles will simultaneously deal with the rainwater runoff from the roof and supplement the water supply to the toilets. Two 1kℓ buffer tanks, also mounted on the concrete cubicles, will provide temporary storage to account for increased flows during peak use times as the water supply to the facilities is quite restricted. At the time of writing, the settlement was supplied entirely by a number of 54 mm pipes branching off the 110 mm and 225 mm mains running next to NY112 and Klipfontein Roads – although a new 110 mm PVC pipeline was recently laid through the settlement to augment the water supply in preparation for the BSSPP project. The facilities will be secured, together with the two interceptor tanks, with concrete palisade fencing with two access gates: one for pedestrian access and the other for maintenance access. Further design details are given in Appendix C.

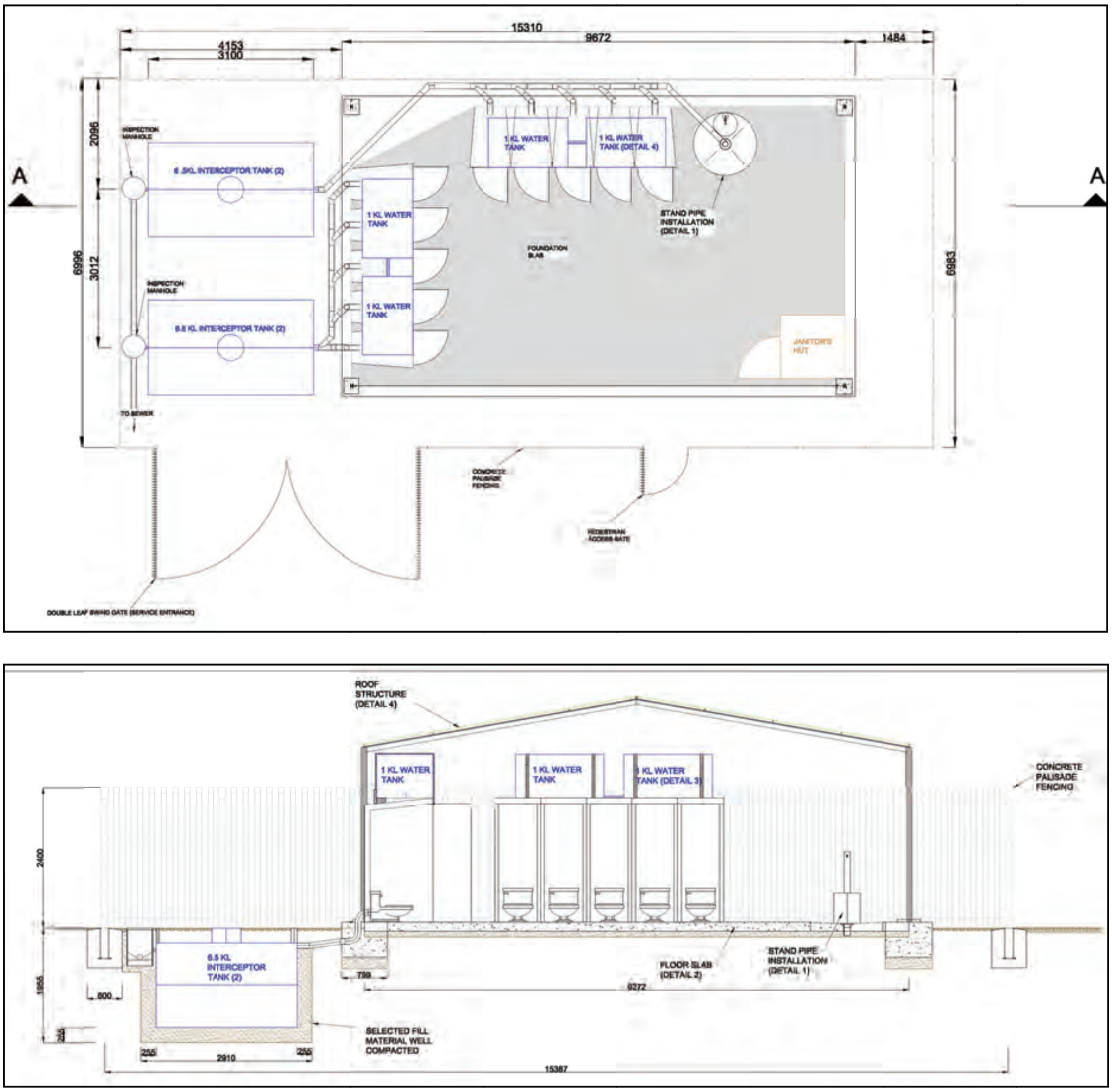

Figure 5-4: Proposed layout for site E: plan view (top) and elevation (bottom).

5.3.2.3 Initial site selection and sewer layout

The selection of sites for the sanitation facilities to be employed for the pilot project was undertaken collaboratively by the research team, the BSC and WSISU officials. As an initial estimate, the team determined that an area of 15 m x 7 m would be ideally required to accommodate a ten-toilet toilet block and the associated two interceptor tanks. This information was presented to the BSC who were requested to assist in identifying sites of the required dimensions. The sites also had to be within the areas that could be serviced by the gravity driven system and were available for use. After one week, the BSC had identified five sites as possible options for the pilot project. During inspection of the proposed locations the UCT team, WSISU officials and the BSC identified a further four sites, thus yielding a total of nine potential sites (Figure 5-5). A UCT researcher then conducted door-to-door consultations with residents living around each potential site outlining, with the help of Xhosa interpreters, the advantages and consequences of having the pilot sites located near their homes or businesses. As a result of this consultation process the number of viable sites was narrowed to four. From these four sites the BSC was then requested to select the three that they felt would be most appropriate for the pilot project (Bourne, 2010). Ultimately, sites A, E, and F were seen by the BSC as being the most equitably distributed around the settlement.

Figure 5-5: Aerial photograph depicting the nine spaces initially identified by the Barcelona street committee and the UCT research group as potential BSSPP sites (after CoCT, 2009a).

The UCT research team then did a preliminary design for a septic tank effluent drainage (STED) system for the identified sites based on a contour map provided by the WSISU (Figure 5-6). According to this initial layout the sewage generated in the northern half of the settlement, was to be gravitated to sewer laid around the northern and western boundaries from where it would flow to a low point at the south-west corner of the settlement. At this point it would merge with the sewage generated in the southern half of the settlement. The combined outflow would then be directed over the culvert across the Lotus River Canal to connect with the existing conventional system at an existing manhole in the formal area of Gugulethu adjacent to Barcelona.

Figure 5-6: Aerial photograph depicting the initial proposal for the BSSPP sewer layout (after CoCT, 2009a).

CoCT officials from the then Housing (now Human Settlements) Department were also informed of the research team's progress. During a coordination meeting, a Housing official informed the research team that the long anticipated Lotus River Canal upgrade would shortly take place. As part of the upgrade, sections of the canal, including the reaches running past Barcelona, would be widened. This would make it difficult to install a sewer alongside the canal as the bank would be too steep, thus Sites E and F could not be gravitated to the main road on the south-western corner. The technical team now had to decide whether to replace the sites on the northern side with new sites on the southern side of the settlement (sloping towards Klipfontein Road) so as to maintain a wholly gravity system or to keep the three sites that had been selected, add a pump station to the design and employ a pressure main to convey the sewage across the settlement. This was discussed with the BSC who said that moving all the sites to the western side would cause conflict with residents in the rest of the settlement, as only part of Barcelona would benefit. This clearly added a degree of complexity and risk to the project in that a pump station would have to be installed and maintained. A sewer system layout was designed in November 2010; however, as will be explained in Section 5.3.4, the sites and sewer layout have changed due to connection issues with the receiving sewer.

5.3.3 Facilitating a partnership approach

The UCT researchers considered that the success of alternative sewerage in an informal settlement setting would likely rely on the adoption of a partnership between the researchers, WSISU officials and the BSC. As discussed in Section 3.5.1, a partnership is generally accepted as a strategic alliance where partners' strengths complement each other to enable them to achieve their mutually recognised objectives (Lee *et al*., 2000; Schaub-Jones, 2010). In Cape Town, a partnership approach has been adopted by a number of municipal departments, residential associations, NGOs, private companies, universities and research groups, in order to share responsibility for improving conditions in the city's informal settlements (Bolnick, 2010; CoCT, 2011).

WSISU officials and UCT researchers initially proposed the settled sewer pilot project to the BSC at the inaugural Sheffield Road-Barcelona Partnership meetings organised by the CoCT Housing Department, the Street Committees of both settlements and the NGOs: Community Organisation Resource Centre (CORC) and Informal Settlements Network (ISN). Aimed at addressing some of the residents' servicing challenges, the Sheffield Road-Barcelona Partnership meetings were primarily facilitated by a CoCT consultant in an effort to provide residents and city officials with a platform where they could communicate directly with one another. The partnership approach adopted for the BSSPP followed the Sheffield Road-Barcelona Partnership pattern. The partners represent three critical perspectives:

- The BSC represents the intended users. It is an elected representative committee that consists of approximately 15 members, one of whom is elected as the Chairperson. The chairperson as of 2012 had held the position for eleven years.
- The WSISU officials are responsible for delivering free basic municipal water and sanitation services, and
- The UCT researchers provide project support, technical advice and documentation. The research group contains, *inter alia*, civil engineers and social anthropologists – with the former being responsible for technical advice and the latter being responsible for social

engagement. It is important to note that, within the scope of the pilot, the UCT team has both a pragmatic interventionist and a research-oriented role, reflecting both an intention to make a success of the project as well as to provide a rich anthropologically nuanced description of the project implementation process.

Over the course of the project to date, several UCT postgraduate researchers have tried to come to an understanding of the social dynamics associated with the pilot project through a process of frequent consultation and ethnographic research. This has helped facilitate progress. What follows are some reflections on the facilitation role played by the researchers in the settlement as well as in the municipality, and the benefits and limitations identified to date.

5.3.3.1 Facilitation in the Barcelona Settlement

In accordance with the partnership's establishment, the university research team engaged directly with the BSC and residents as the project's Social Facilitator throughout the pilot's design and planning stages, and facilitated interaction between the BSC and municipal officials. The researchers met regularly with residents – independent of the municipality – and arranged progress meetings between the pilot's partners. Although residents were afforded little opportunity to contribute directly to the partnership and said they had limited knowledge of the project, many stated during interviews that they were happy to have the BSC represent them. The residents seemed more interested in the job opportunities that were expected to become available than the pilot's planning and implementation. Apart from a small number of community meetings in which the project was mentioned, most information about the project was conveyed to residents via word of mouth, after direct interaction with the researchers or from the BSC after a progress meeting.

By the end of 2012 there had not been any substantial conflicts between the residents and the partners. The partners' transparent approach, as well as the researchers' continued engagement with residents and the settlement's leadership, seemed to be significant in sustaining the BSC's continued involvement in the partnership and acceptance of the unexpected delays. A lack of transparency and trust constitutes a serious threat to projects implemented with a partnership approach, as demonstrated by the BSC's premature withdrawal from another partnership with a NGO owing to inter-personal conflicts.

The BSC also repeatedly expressed support for the pilot in spite of discouragement from housing experts. Municipal officials responsible for housing have repeatedly informed Barcelona residents that the land on which they reside is unsuitable for human habitation and that sewering the entirety of the former landfill is technically impossible. Given Barcelona residents' reluctance to move and the technical constraints of sewering the area, municipal officials proposed allocating each Barcelona household with a portable flush toilet ('porta-potty') and concrete top-structure to place adjacent to their home. The porta-potty is commonly described as a 'camping toilet' and comprises a seat with a small flush tank above a storage tank that collects the waste. Similar to the municipality-provided container toilets, the full storage tanks would need to be collected and replaced with clean tanks regularly by private sector contractors. Porta-potties are used in informal settlements throughout the Cape Town Metro and primarily are allocated to structurally dense settlements where it is difficult to provide communal services and to the elderly or disabled. The BSC significantly refused the porta-potties (which some referred to as 'glorified buckets') as a private alternative sanitation option meant to replace the container toilets on the grounds that they hoped that the public flush-toilet facilities provided through the BSSPP would work.

At this stage of the project it is difficult to assess the contribution and impact of the BSC as they have so far had a limited role in the partnership. There remains a strong possibility of contestation by the BSC and residents during the technical implementation phases of the project (construction and set up of O&M). That is because the project will potentially provide both temporary (construction phase) and permanent (janitorial) employment opportunities. In an area where 51.8% of 18-65 year-olds are unemployed (CORC, 2010), competition for jobs is high and tensions often arise amongst residents with regard to who is employed. The partners also anticipate that some residents will complain about the disruptions during construction. The BSC will likely have to play a significant role in the partnership as the project progresses – particularly with the setting up of acceptable employment processes for residents and negotiating potential impacts of the construction.

5.3.3.2 Facilitation in the City of Cape Town

Several municipal officials, during informal conversations, expressed the opinion that the partners should be equally involved in the management of partnerships. Their opinions were in alignment with the notion that a partnered approach should not put any partner's interests first (Breslin, 2010). The research group's experience to date has, however, raised questions as to whether 'partners' can indeed have equal standing when each has contributed different amounts of time and resources to complete the project, and when each has different objectives. The researchers had initially assumed that the requisite municipal administration would be handled autonomously by the Water and Sanitation Department. Yet a number of extensive project delays, accumulating to some 12 months, were caused by key municipal officials' lack of experience with complex and sometimes unclear municipal supply-chain management policies, something they shared with the researchers. Hoping to avoid further project delays, the researchers then intervened by drafting documents that should ordinarily have been prepared by municipal officials. In the process, what had initially been understood as clearly defined roles thus became confused, resulting in conflict when the WSISU PM complained that researchers had, in a critical project document, given inadequate credit to the municipal and residential partners for their contributions during the design phase.

After further consideration of the next steps of the project, the research group mapped the anticipated relationships between the various role-players expected to be a part of the BSSPP implementation process (Figure 5-7). It became apparent that whilst the project was initiated and originally designed by the UCT research team, ultimately UCT has no formal contractual role; the CoCT remains legally responsible for the BSSPP from beginning to end as they are: (a) legally obliged to provide basic services to Barcelona informal settlement as per the national FBS policy, and (b) will own the infrastructure. UCT meanwhile had no contract with the CoCT – and thus could not be responsible for project management. Thus, in addition to formally defining roles in partnerships, it was also critical to select a CoCT official as the PM.

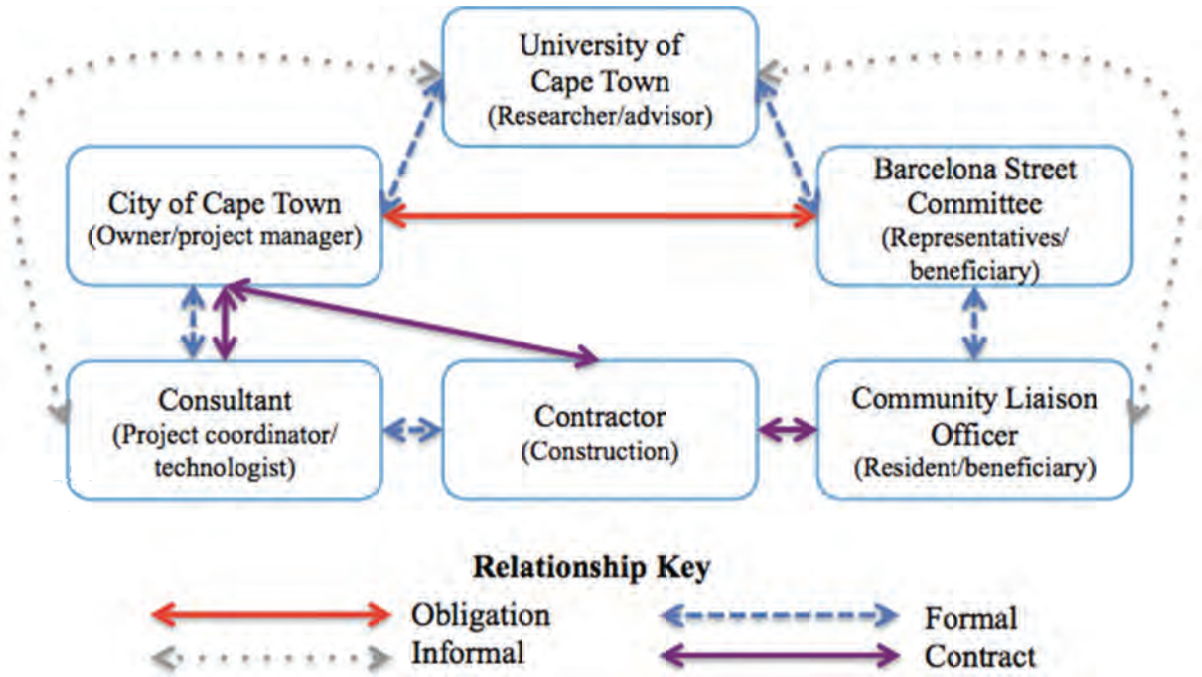

Figure 5-7: Relationships CoCT officials and university researchers expect in the future implementation of the project (as of March 2012).

The consequent tension was subsequently resolved through a non-legally binding Memorandum of Understanding (MoU) between the Water and Sanitation Department and the university research group. It formally defines both parties' expectations, contributions (skills, financial and deliverables), as well as includes a contingency plan in case the pilot project was to fail. The document also clarifies that the role of the research team is to be the party responsible for: engagement with the residents; technical support; and assessing, monitoring and evaluating the system's effectiveness once implemented. The Water and Sanitation officials, representing the municipality as the owner and service provider for Barcelona's sanitation services, are to remain responsible for managing and facilitating the project.

In retrospect, the way in which the researchers drove the project up until the MoU was drafted overextended their role from that of "*supporting partner*" (Eales, 2008) to *de facto* project manager, similar to DAG in the Hangberg in-situ upgrade project. Significantly though, neither the researchers nor the municipal officials perceived the formers' actions as usurpation. From the research group's perspective, the delay had major implications for the study – funding for which lapsed at the end March 2012. In many research projects, researchers have full control over their work programme and budget. In this case, the researchers had to rely on their partners and it took time to recognise that a central concern of the study needed to be to gain a critical understanding of municipal constraints and protocols, a concern which had been lacking at the study's outset. With hindsight, the WSISU PM has also explicitly noted that her appointment to that role came only well after the project's conception and selection of a settled sewer for the pilot, and following it having been proposed by the researchers. For that reason, she readily assumed that the research group should be directing the project as well as the study. In fact, a number of other officials also said they had thought it was a university-led endeavour; an internal report, prepared by consulting engineers and based on interviews with municipal officials referred to the undertaking as the "*UCT [University of Cape Town] Settled Sewer Pilot project… currently being implemented by CoCT [City of Cape Town]*" (BKS, 2011: 28). Moreover, since this was the first such partnership in her department's history, no procedures had been established prior to the pilot's commencement. The PM viewed the MoU's drafting as a critical point in the project in that it clearly defined the two parties' expectations and accordingly encouraged her to accept being 'the boss' and to take on the responsibilities of that role.

5.3.3.3 Project benefits and limitations to-date

The conflict between UCT and WSISU was a regrettable experience that likely contributed to unnecessary delays during the planning of the BSSPP; however, it also was a fortuitous occasion that forced both parties to honestly reflect on how each party's expectations influenced their role and what responsibilities they undertook. In addition, a number of benefits have emanated from the project's collaborative (facilitation-focused) approach. Concerns raised by the researchers regarding low water supply pressure in Barcelona prompted the upgrade of the water reticulation system noted in Section 5.3.2.2. The partners also hope that Barcelona residents will have the tangible benefits of sewerage and limited janitorial services for flush facilities in the settlement. Furthermore, municipal officials have given assurances that, should the pilot prove successful, they will consider rolling out sewerage coverage to the whole settlement. In addition, a number of short- and long-term job opportunities are likely to become available to local residents throughout the project's construction and O&M phases: as unskilled labourers and later as janitors. Finally, the research group's continuing engagement with both Barcelona residents and the Street Committee has helped the researchers to understand how municipal and project constraints delay sanitation delivery, and how the municipality has attempted to address the sanitation needs in Barcelona.

Both the researchers and – perhaps more unexpectedly – Water and Sanitation officials have learned important lessons through involvement in the pilot project, even prior to its formal implementation. Perhaps this should not come as a surprise, given the demographics of both partners – including postgraduate students and young professionals with limited practical experience. Apart from technical skills developed and working friendships established, the difficulties associated with working in a team comprising diverse members from different backgrounds have required constant negotiation and careful adaptation of the partners' expectations, roles and responsibilities. In the process, the researchers have come to a better understanding of the overwhelming challenges municipal officials face when attempting to provide basic services in some 350 settlements which are all, in some respects, unique. To provide such services within a relatively inflexible municipal framework where procedures are complex and not always clearly defined requires that project planners be both patient and flexible.

5.3.4 Finalising the technical designs

Having recognised their technical capacity constraints, Water and Sanitation officials appointed an engineering consultant to ensure the pilot project meets national engineering standards and municipal procurement policies in November/December 2011. The appointed consultant is required to finalise the project designs, draw up tender documents and supervise construction. Appointing the consultant has already proved to be of major benefit to the project because the consultant's review of the preliminary designs revealed that the planned sewer connection was no longer acceptable. The proposed sewer connection used in the UCT designs was to a mid-block sewer that went through a series of backyards on Klipfontein Road (Figure 5-). An assessment of this sewer by the W&SD Hillstar District officials in 2012 found they had up to eight blockages a month (BSSPP, 2011). Moreover, since it was constructed, backyard dwellers have erected shacks over it thereby making manholes difficult to access. The Hillstar team thus opposed connecting to any of the nearby mid-block sewers. Negotiations between the consultant and W&SD have resulted in the selection of a manhole situated in the NY 111 road reserve as the connection point for the pilot project. Blockages on this line will result in sewage overflow onto the road rather than into shacks. If the settled sewer scheme is expanded, a new sewer connection will have to be made either under the N2 highway to the Airport Industrial Sewer or two kilometres west on Klipfontein Road to the Nyanga Sewer (BSSPP, 2012).

This particular incident illustrates the difficulties of implementing a sewer project where data (commonly patchy for informal areas) and adequate receiving bulk infrastructure are necessary but not readily available. The events leading up to why the mid-block sewer was initially selected and later changed also highlights the need for better servicing agreements between CoCT departments. It was unclear to the research team why critical information such as the blockage rates were not conveyed earlier to WSISU officials when the Hillstar District team was initially involved in late 2010. The late change of the sewer connection unfortunately has contributed to an additional one year construction delay, which may be longer as one of the sites selected for the pilot has to be renegotiated with Barcelona residents as sewage from Site A cannot be gravitated to the NY 111 sewer. In March 2012, nearly two years after the project was first initiated in April 2010, the project team met with the BSC to inform them of the problem with the connection. The present BSC members, disappointed that Site A had to change and construction was further delayed, helped nevertheless to identify three potential sites to replace Site A.

Figure 5-8: The consultant's sketch of the BSSPP's possible sewer connections and routes (BSSPP, 2011). **Sections D and E are existing mid-block sewers (one of which was the initial connection highlighted in yellow). The consultant speculated that the pilot could gravitate to the NY 111 sewer (Areas A and B) along a route marked C.**

Though it is still too early to comment on how Barcelona residents will receive the change, the research team hopes that the technical team's honesty with the BSC members will help herald continued support for the pilot settled sewer. CoCT-appointed land surveyors conducted a topographical survey of the potential pilot facility sites and the associated routes to the NY 111 manhole in October 2012 and it is anticipated that CoCT officials will advertise for a construction contractor in early 2013.

5.3.5 The O&M strategy

UCT researchers anticipate they will assist CoCT officials and BSC members in developing an O&M strategy for the settled sewer system after the construction tender is advertised. The proposed O&M arrangements (outlined in Appendix C) will be funded by WSISU, who intend to employ residents as janitors. The details of the final management arrangements still need to be agreed upon by the various parties involved. They need to address both the issues of the management of sanitation facilities and the technical maintenance of the sewerage infrastructure. It is envisioned by CoCT's WSISU that the PM will hand over the project management responsibilities to the M&E Officer, who will likely assess the system's technical performance and liaise with the janitors and BSC to discuss concerns and necessary remediation in the future. The proposed O&M strategy for the BSSPP would be premised on a responsive relationship between the janitors, BSC and CoCT officials.

In order to ensure optimal technical performance it is imperative that the appropriate maintenance activities are regularly carried out for the various system components. Standard O&M tasks include: monitoring of the sludge levels in interceptor tanks and de-sludging if required; checking for – and clearing – blockages in sewer lines; cleaning the facilities and repairing any broken fixtures in a timely manner.

It is critical that the BSSPP facilities have a full-time janitorial service during operating hours because the toilets will be open to the general public and are thus susceptible to damage or inappropriate usage if they are not controlled. The O&M tasks could potentially be shared between Barcelona janitors and the municipality with the latter party responsible for tasks that require specialised skills and/or equipment. It is proposed that the janitors will clean the facilities, repair minor maintenance issues and promote appropriate use of the facilities by familiarising residents with the settled sewerage technology when necessary. It is also proposed that the janitors also collect data on use patterns (for instances the number and gender of users per day, and the approximate distance they walk to the facilities) for each sanitation block, which will allow WSISU and the UCT research team to analyse who uses the system, and whether it can be extended to address the sanitation needs of all Barcelona residents. The janitors and BSC must jointly check for unauthorised sewage connections. See Appendix C for an initial proposal for O&M tasks. This may require adaption with time as each party comes to understand what is required of them.

5.4 Conclusions

This chapter presented the development of the BSSPP project from inception to the time of writing. In particular, it describes the attempt to set up a partnership approach that include all the relevant role-players – in particular the users – and would thus avoid repeating the mistakes made in other informal settlement upgrades in the past. However, the UCT researchers and WSISU officials have agreed in hindsight that they naively committed to this without fully understanding how it should be implemented. These two partners now recognise that establishing roles and responsibilities up front based on mutual expectations is critical when implementing such an approach as the failure to do so potentially had serious implications for the success of this project. Even with the MoU that resulted from this recognition, there is still risk of a breakdown in the partnership between the municipality and the BSC. The research team observed the negative consequences of such breakdowns in a number of Cape Town partnerships.

Another realisation that has emerged is the fact that, in the context of service delivery in informal settlements, the partners are inherently unequal. This can lead to severe tensions and potentially a breakdown in communication leading to failure. It is thus important that the partnership be facilitated by someone with experience and authority. Experience to date has also underlined the importance of: taking into account partners' procedures and constraints; the need to help build capacity in partners from time to time; and continuously building relationships between the various stakeholders.

Unfortunately, owing to the various delays, construction has not started for the Barcelona Settled Sewer Pilot Project as of January 2013, 32 months after the partnership described above was first established. Consequently, no final conclusions can be offered as to whether settled sewerage can be successfully introduced into such a setting, or indeed whether the 'partnership approach' adopted by the project partners is an appropriate vehicle for the delivery of sanitation services in Barcelona informal settlement. Undoubtedly new challenges will arise through the construction phase and into the O&M phase of the completed project. Hopefully the project will be successful, and the researchers will come to a better understanding how to build and to sustain mutually beneficial partnerships that 'deliver the goods'.

Finally, application of an anthropological approach has enabled an understanding of some key elements that make for a successful partnership. It is clear that the delivery of sanitation services in urban informal areas requires a multi-disciplinary approach. However, it is becoming evident that it is the personal relationships between the members of the implementing team – coupled with sound leadership – rather than the technology that largely determines whether or not a project succeeds. The work has also unearthed evidence to support the growing belief that service providers need to manage public facilities in informal settlements. Ultimately the intention is provide guidelines that can guide the formation of effective partnerships for sanitation delivery in South African informal settlements.

6. Conclusions and recommendations

6.1 Introduction

This report underscores how difficult servicing informal settlements are in light of the technical, social and institutional challenges. A significant amount of literature, 'best practice' principles and discourse was reviewed on alternative sewerage schemes and participatory approaches as a means to possibly improve urban sanitation conditions in South Africa's high-density informal settlements. There are several alternatives to conventional sewerage that have great potential in South African informal settlements because they can be more cost-effective and offer greater flexibility in terms of planning and design. Simplified, settled and vacuum systems have been technically proven to work in a number of appropriate settings; however, the research to date has reached the conclusion that: (a) the social processes that underlie the planning, provision and management of sewerage systems are just as significant as technology choice; and (b) municipalities need to be fully accountable for the O&M of the toilets they provide as part of their Free Basic Services (FBS) obligations. The implementation of any kind of sanitation facility in an informal settlement requires that it be accompanied by a fully and carefully developed project management and O&M servicing plan that accounts in full for the social context in which the facility has been introduced. In many instances, the local authority may have to introduce janitorial services to fulfil their FBS obligations. Such a sanitation strategy will ideally be accompanied with provision of solid waste, greywater and stormwater disposal services. What follows are the major TIPS (technology, institutions, people and services) learnt from the research study on the application of alternative sewerage systems by South African municipalities.

6.2 Technology: Implementing alternative sewerage

The most common technical challenge with applying alternative sewerage technology in South Africa has been the lack of experience and familiarity of designing, constructing or operating such infrastructure in densely settled informal areas. Skilled professionals are required to plan, construct and manage alternative sewerage systems for the purpose of minimising the risk of poor design, construction or operation and maintenance (O&M). No matter what alternative system is installed, a teething period should be expected with unfamiliar systems where there will likely be initial design, construction and management problems. Problems, when encountered, should be immediately addressed and remedied as far as is possible by training responsible maintenance personnel. Furthermore, two potential issues that should be negotiated in advance are the prevention of unauthorised private connections to communal drainage services and building over shallowly-laid sewers as both of these risks can affect their integrity.

Eslick & Harrison (2004) noted that national legislation and the National Building Regulations (NBR) often conflict with innovative methods for developing low-income areas. For example, in eThekwini's simplified sewer pilot project, the premise of 'shared' property conflicted with South African legal property acts because servitudes cannot be given to non-legal entities; they can only be attached to individual land titles. Furthermore, the NBR does not allow for non-licensed professionals to install or manage drainage systems, thus defeating the 'sweat equity' principle in the condominial approach. Eslick & Harrison (2004) consequently suggested the need to change inflexible policies and building regulations based on historical ideas of property and conventional technology to allow for the introduction of alternative technologies and methods. This is particularly critical when using participatory approaches and instituting non-conventional infrastructure for informal settlements.

Lastly, involved parties should distinguish between technical problems caused by design or construction issues and systems malfunctioning due to poor management. Any sewerage technology – regardless of whether it is installed in a formal or informal area – will fail if no one manages the components of the system (*i.e.* toilets, pipes, pumps, *etc*.), and ensures that the technology is used according to design.

6.3 Institutions: Establishing responsibility for municipal toilets

South African municipal officials have reported the failure of shared sanitation facilities despite residential leaders' 'promises' to manage them (Mjoli *et al.*, 2009; Taing *et al.*, 2011). Generally in practice, shared toilets are mismanaged because neither the local authorities nor users accept responsibility for them. From the users' perspectives, as noted by Beauclair (2010) and Taing *et al.* (2011), 'community-managed' toilets often fall into disrepair because the users do not want to 'take ownership' of shared toilets. Instead, residents generally expect that government-funded full-flush sanitation toilets should be accompanied by a government-funded janitorial and operation and maintenance (O&M) service. In other words, toilets in informal settlements should operate in a similar manner to those that are provided at public facilities such as parks. Informal settlement residents expect to be provided with the same sanitation technology and service as neighbouring formal areas; service providers should not expect them to readily accept different service levels based on their circumstances.

The shift to janitorial services should be considered as part of the FBS and Water Services Authority (WSA) obligations of municipalities. According to the Water Services Act, WSAs are ultimately responsible and accountable "*for ensuring that end-users have **access** to water and sanitation services*" (DWAF, undated: 8; text bolded for emphasis). Managers of municipalities, as policy and operation leaders in WSAs, should therefore delegate tasks to appropriate service providers (*i.e.* a municipal department or "*any person who provides water services to [users]*"), regulate their progress and arbitrate any conflicts.

6.4 People: Coordinating contributions

Many WSAs are fragmented by severe decentralisation that has resulted in uncoordinated delivery of services from municipal departments, as well as the occasional ad-hoc duplication of roles and tasks. This subsequently makes it difficult for officials to establish clear lines of accountability in projects and coordinate services across rigid departmental management and budget silos. Municipal sanitation delivery is further complicated by the WSAs' capacity and experience constraints, leading to significant project roles such as engaging public participation, designing sewer systems and building toilets being outsourced informally to civil society organisations or contracted to private firms. Municipal outsourcing of public engagement to civil society organisations – who are meant to represent the interests of municipal FBS services beneficiaries – has also been popular as of late in South Africa due to the widely supported belief that all South Africans are collectively responsible for ensuring that those who lack access to basic services get them (Eales, 2008; Schaub-Jones, 2010).

Participatory approaches have had merits in demonstrably building consensus between service providers, users and civil society organisation representatives, as well as obtaining users' input into and consent of technical designs. The popular theory that residents' sentiments of long-term ownership and responsibility will develop, however, is flawed in that such sentiments are not guaranteed with municipally funded services, even if the beneficiaries are engaged in a participatory process. For example, the municipalities of eThekwini (in the Emmaus and Briardale simplified sewer pilots) and City of Cape Town (in the Hangberg, Kosovo and Barcelona) found they were held accountable for delivering services by residents, social movement advocates and university researchers regardless of whether projects were planned in collaboration with users or not.

If organisations choose a 'partnership' approach as their main operating model then, as experience from the case studies discussed in this report has shown, they should define each party's expectations and roles at the very beginning of their projects. Moreover, each partner must be flexible because, as outlined in the report, the partners may need to renegotiate and redefine the terms of their partnerships when partners' limitations and constraints turn out to pose significant obstacles. In instances where municipal services are provided as part of their FBS obligations, local authorities should be the 'managing partners' and coordinate collaborations between stakeholders.

6.5 Services: Transitioning from 'community-managed' facilities to municipal services

DWAF (2003), in the Strategic Framework for Water Services, distinguishes between sanitation 'facilities' and 'services' as follows: a sanitation facility is infrastructure that "*enables safe and appropriate treatment and/or removal*" of waste, whilst a sanitation service includes the "*provision of a basic sanitation facility … [that] includ[es] the safe removal of human waste and wastewater*". What that means is that a sanitation service is different from a sanitation facility in that a service requires those who have provided it to ensure that all waste that enters it will be removed safely, whereas a facility simply ensures the possibility for that removal to occur. Municipal officials tend to provide shared sanitation facilities instead of services because they hope that the users will manage the shared toilets collectively as a 'community'. In reality, however, informal settlements are occupied many different people who cannot reasonably be expected to organise themselves into coherent groups. The deteriorating state of 'community-managed' shared toilets thus represents, in part at least, one consequence of imagining informal settlement residents as 'communities' with shared purposes. Given the failure of communal toilets in informal settlements, there is an undoubted need for WSAs to transition from providing shared facilities that are maintained collectively by users, to providing public toilets that are serviced by the municipality. In other words, WSAs – when fulfilling their FBS obligations – should preferentially deliver sanitation services in which they will be responsible for ensuring that toilets function as designed from the facilities' set-up phase to its eventual decommissioning.

Interviews conducted in 2010 to early 2011 indicated that eThekwini, Overstrand and City of Cape Town (CoCT) officials generally considered janitorial services for toilets in informal settlements as necessary when fulfilling the municipalities' FBS obligation. During that period, eThekwini and Overstrand officials supported a city-wide caretaker service for shared toilets in Durban's and Hermanus' informal settlements. eThekwini and Overstrand officials noted that their janitorial services were cost-effective because their departments have less rehabilitation costs for municipally provided toilets located in informal settlements. In addition, they said that most users reported they were satisfied with the local authority's cleaning and maintenance of the facilities. Coincidentally, whilst this research was been undertaken, CoCT officials arranged for a janitorial service that was initially limited to toilet blocks in settlements in Khayelitsha and Pooke se Bos but then extended further in late 2011/early 2012 (Cape Times 2012a, b) employing local residents as janitors to clean the toilets. Despite criticism from media and activist groups about operational problems, the interviewed CoCT officials generally supported this approach.

While not the focus of this report, it bears mentioning that many of the problems linked with sewerage can also be tied to the shortcomings of stormwater infrastructure and solid waste management. Even when formal stormwater drainage is provided, high volumes of litter often fall into catchpits and block drains. The location and design of solid waste skips and collection systems can also have an impact on the functionality of sewerage. The research team did not conduct an in-depth study on solid waste practices, but it was noted that collection points tended to be located on the edge of the studied settlements. Given that solid waste community workers often only collect rubbish once a week, it is not a surprise that toilets are also used as rubbish bins. Service providers responsible for sanitation provision should thus consider how lack of *any* basic service in informal settlements also impacts the operation of associated systems when designing and managing sewerage systems. This broader understanding of waste management infers the need to holistically manage 'urban sanitation' systems such as that prescribed by Brazil's 2011 national sanitation law (PLANSAB, 2011) – rather than solid waste, drainage and sanitation separately. Due to the unclear lines of responsibility and the fragmented state of service delivery, WSAs must start: (a) coordinating and regulating all their personnel involved in service delivery, (b) establishing procedures and processes to upgrade informal settlements and (c) managing public infrastructure provided as part of their FBS policy obligations.

6.6 Supplementary poster guide

The researchers have conceptualised a process to guide WSAs when planning, implementing and managing sewered sanitation services for informal settlements. Table 6-1 outlines the different roles and responsibilities of the municipality and other stakeholders in the five project phases as shown in the supplementary poster guide "*TIPS for sewering informal settlements*": planning and service design; implementation; commissioning; operation, maintenance and adaptive management; and decommissioning. WSAs (or service providers acting on their behalf) may outsource certain tasks, but the WSA is still accountable for the tasks that are undertaken on their behalf, as it is their responsibility to ensure satisfactory services are provided to users. Critical project roles are highlighted to help WSAs coordinate the various people involved in any given project. The tasks are loosely assigned to allow project team members to negotiate their roles and responsibilities based on their circumstances. A list of risks is included with each step to enable WSAs to anticipate and mitigate potential problems.

The poster guide focuses on the project concerns of higher-level management coordinating services, but the guide would also be helpful to municipal officials (service providers) and informal settlement residents (users) by assisting them to identify which other departments and groups should be involved in sanitation design and management. Negotiating directly with residents also creates an opportunity for implementing agencies to highlight the budgetary and capacity constraints that slow service delivery.

The roles and responsibilities presented not meant to be prescriptive. Whether or not such a process is adopted for sewering informal settlements, it is significant that stakeholders understand that their actions and interaction with each other affect the state of the project. Adopting a holistic plan from beginning to end that encompasses the range of people involved in sanitation planning is critical to make the project a success.

6.7 Conclusions & further research

It is evident from the numerous examples of dilapidated infrastructure in informal settlements across South Africa that the management strategies adopted for FBS sanitation infrastructure need to change. The report shows that residents and users from informal settlements are driven by their expectations that toilets provided by the municipality should be fully subsidised and serviced the municipality. In other words, residents and users expect free basic services and not just the provision of facilities that they are themselves expected to manage and maintain collectively. To realise these expectations requires all public toilet facilities to have municipally-funded janitorial services. In December 2011, the WRC approved funding for a follow-on two-year study on the social constraints to sanitation provision and management that were encountered in this study (Project K5/2120). One goal of the follow-up research study is to interrogate the introduction and/or provision of janitorial services in public full-flush toilet facilities in informal settlements in and around greater Cape Town.

Table 6-1: Roles and responsibilities in a sewerage project.

Role	Responsibilities
Phase 1: Planning and Servicing Design	
Owner	The conduit for funds and legal titleholder who appoints the Project Manager (PM) and monitors his/her performance; gauges and responds to Users' satisfaction and associated O&M requirements.
Users	A community-based group or a number of informal settlement residents who assist in the service design of the service and report satisfaction to PM and thence to Owner.
Project Manager	An internal municipal appointment who oversees the sanitation service on the Owner's behalf and coordinates involved parties.
Designer	An internal municipal or external appointment who prepares the technical specifications
Social Facilitator	An internal municipal or external appointment who consults and engages the Users and mediates between the PM, Designer and Users.
Project Support	The Technicians, Administrators, Researchers, Information Specialists (*e.g.* GIS Analyst), *etc*. employed as internal municipal or external appointments.
Phase 2: Implementation	
See 'Planning' phase for responsibilities**: Owner, Users, PM**, **Designer**, **Social Facilitator** and **Project Support**.	
Construction Supervisor	The Designer's representative who is responsible for ensuring the Builder avoids shortcuts.
Builder	An internal or external appointment who should construct the facilities according to the specifications and agreed deviations.
Settlement Representative	Informal settlement resident contracted by Builder who mediates between Builder and Users on a day-to-day basis.
Labourers	Skilled, semi-skilled or unskilled construction workers. Informal settlement residents ideally will be appointed.
Phase 3: Commissioning	
See 'Planning' phase for responsibilities**: Owner, Users, Project Support, Builder, Settlement Representative and Labourers.**	
Project Manager	Needs to set-up an O&M strategy, including appointing and training Operators to manage the system.
Construction Supervisor	Signs-off the construction snag list.
Operators	Have training in the operation and maintenance of the sewer system and sanitation service. Includes janitors, desludgers, plumbers, *etc*.
Phase 4: Operation, Maintenance and Adaptive Management	
See 'Planning' phase for responsibilities**: Owner, Users,** and **Project Support**.	
Project Manager	Should supervise the service and troubleshoot when necessary.
Operators	Operate and maintain the sewer system and sanitation service.
Phase 5: Decommissioning	
Owner & Users	The Owner (in consultation with Users) decides whether the facilities should be decommissioned based on their needs, the facilities' state, and whether the sanitation service should be replaced.

This report also concludes that municipalities are accountable for finding an interim method for sanitation provision in negotiation with informal settlement residents. In order to achieve this, it is imperative that WSAs develop mechanisms in which they can coordinate how their service providers (*i.e.* municipal departments, servicing contractors, *etc*.) and partners will interact, as well as what each party's roles and responsibilities will be. WSAs, service providers and users can also use the supplementary poster guide in order to discuss each party's expected roles and responsibilities. It is hoped that collaboration and co-operation between users and the implementing agency can serve to develop systems that are suited for a specific context and that can be sustained with the resources available. Through these processes, interventions to improve sanitation in informal settlements can perhaps tap into existing social structures to support project initiatives or alternately identify management gaps which the implementing agency needs to address. In particular, the municipalities' management gaps with regard to design, construction, O&M and training need to be addressed to ensure that infrastructure provided as part of the FBS policy is planned according to residential needs and implemented according to the WSAs' capabilities. Further research needs to be conducted in order to ascertain what realistic objectives can be achieved when applying participatory approaches, as well as what management gaps can be addressed when using a partnership approach.

Lastly, this report also aims, in part, to contribute to an understanding of how to address the complexity of delivering and maintaining sanitation services in urban informal areas through multi-disciplinary approaches and multi-stakeholder partnerships. Future research studies related to the design, application and management of infrastructure need to document what methods are used to assign and negotiate the roles and responsibilities of involved parties, particularly ways of overcoming economic and socio-political problems. In light of the complexity of managing public full-flush toilets in informal settlements, the authors intend to build upon the present report's findings by developing a guide for such facilities as part of the research outcomes of the K5/2120 study. Ultimately the research group's intention is to create simple tools and processes (such as the supplementary poster guide), which officials can use to facilitate effective approaches for sanitation delivery in South African informal settlements.

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Appendix A: Alternative sewerage specifications and O&M requirements

A1. Simplified sewerage

A1.1 Design principles

A number of different design specifications have been developed to reduce the costs associated with gravity sewerage installations around the world. These specifications are primarily based on local experience and include those adopted for “flat-grade sewerage” employed in Nebraska, “modified conventional gravity systems” in Australia and simplified sewerage in Brazil and other South American countries (Mara *et al.*, 2001). A common theme in all these instances is the relaxation/modification of conventional gravity sewerage standards. CAERN’s (the Water and Sewerage Company of the north-eastern Brazilian state of Rio Grande do Norte) simplified sewerage technical design criteria have been the most extensively used (Mara *et al.*, 2001). The total cost of laying sewers is reduced by limiting sewer lengths through the successive linking up of each household's point of discharge. Sewers are laid below backyards, front-yards and/or sidewalks. Sewers laid at these locations generally have a reduced risk of exposure to heavy traffic loads, thus shallow pipe cover depths may be employed, which reduces excavation costs. This also eliminates the need for deep manholes, which are replaced by cheap junction boxes (Mara *et al.*, 2001). The minimum sewer gradients are determined with the critical shear stress approach, which is considered to have a sounder theoretical basis than the minimum velocity approach generally adopted in conventional sewerage design, and which generally results in a less conservative design. This also reduces excavation costs (Mara *et al.*, 2001).

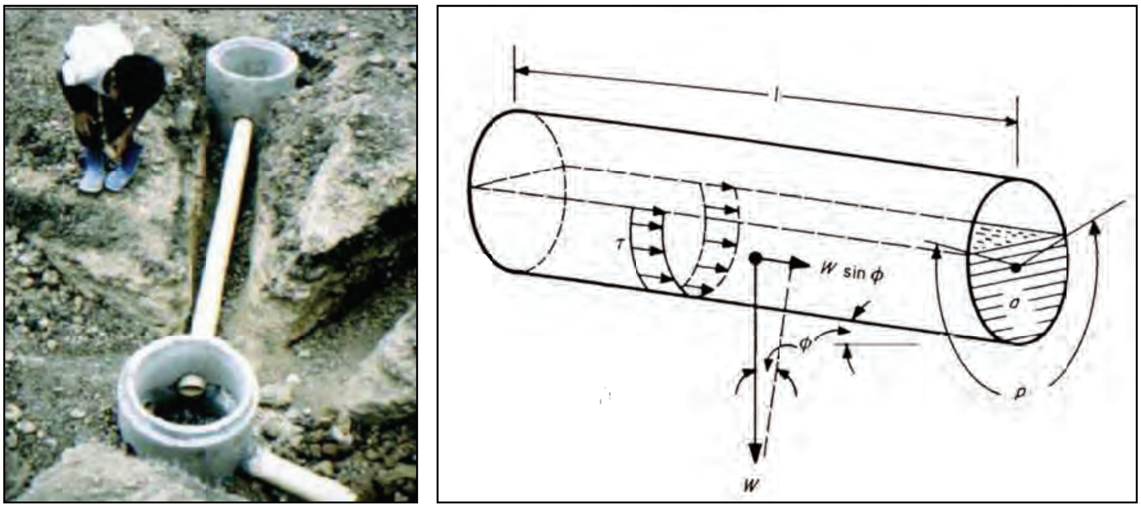

Figure A-1: Junction box at changes in direction (left) and a simplified schematic representation of the bed shear stress concept (right) (Mara, *et al.*, 2001)**.**

Table A-1: Simplified sewerage design criteria and specifications.

Criteria	Specifications
Sewer layout	Sewers successively linking up each household's point of discharge are laid below backyards, front-yards and / or sidewalks in order to minimize the total sewer lengths. This also reduces the risk of exposure to large traffic loads thus warranting the use of shallower pipe cover depths which in turn eliminates the need for deep manholes (Watson, 1995; Mara *et al.*, 2001).
Maintenance structures	Inspection boxes that facilitate cleaning and maintenance are installed along the household sewer immediately upstream of the point at which it intersects with the service line. Shallow junction boxes may be installed at changes in direction. Where required, reduced diameter "simplified manholes" may be installed (Bakalian *et al.*, 1994; Mara *et al.*, 2001).
Design flows	Context specific peak design wastewater flow rates (***q*** measured in l/s) are based on the expected or average daily water consumption (***w*** measured in l/capita.day), multiplied by the population figure (***P***), peak factor ($\boldsymbol{k_1}$) and wastewater return rate ($\boldsymbol{k_2}$). The designer specifies expected values for the peak factor) and wastewater return rate. A minimum of 1.5l/s is recommended for the design peak flow rate. In low-income areas it is expected that the bulk of the water used will eventually end up in the sewer system and thus wastewater return rates ($\boldsymbol{k_2}$) of up to 0.9 may be used. The formula for design flows is: $$q = \frac{k_1 k_2 P w}{86400}$$
Minimum gradients/ sewer self-cleansing	Minimum sewer gradients ($\boldsymbol{I_{min}}$) are determined based on the attainment of a minimum tractive force of 1 N/m^2 for a recommended minimum flow depth (d/D) of 0.2 (Mara, *et al.*, 2000). The design peak flow rate (***q***) is measured in l/s. The formula for calculating the minimum sewer gradients is: $$I_{min} = 5.64 \times 10^{-3} q^{-6/13}$$
Sewer sizing	The required sewer diameter (***D***) is determined using the Gauckler-Manning equation, with ***n*** (roughness coefficient) generally taken as 0.013 for smooth pipe materials. $\boldsymbol{k_a}$ and $\boldsymbol{k_r}$ are coefficients relating to the cross-sectional area and the hydraulic radius which may be taken as 0.6736 and 0.3042 respectively for a flow depth to pipe diameter ratio of 0.8 to allow for stormwater/groundwater infiltration. A minimum diameter of 100 mm is recommended (Bakalian *et al.*, 1994; Pegram & Palmer, 1999). ***I*** is the sewer gradient and ***q*** is the design peak flow rate (l/s). A sewer diameter can be determined with the following formula: $$D = n^{\frac{3}{8}} k_a^{-\frac{3}{8}} k_r^{-\frac{1}{4}} (q/I^{\frac{1}{2}})^{3/8}$$
Minimum sewer cover depth	Backyards and front-yards: 0.45 m
	Sidewalks: 0.65 m
	Streets: 0.95 m

A1.2 Operation and maintenance requirements

Simplified sewerage relies on gravity for sewage transport, hence sufficiently steep gradients and a reliable supply of water are required. In instances where shallow gradients are necessary due to the topography of the area being serviced, simplified sewerage requires a particularly high level of connection into the sewer system in order to provide the flows required for sewer flushing. Mara *et al.* (2001) recommend that simplified sewerage only be considered where a reliable on-site water supply capable of providing at least 60 litres per person per day is available.

The maintenance requirements for simplified sewerage systems are similar to those of conventional gravity systems. Preventative maintenance tasks include periodic sewer flushing, repairs, and supervision of connections and disconnections. In order for the maintenance program to be effective it is imperative that the types of problems frequently occurring are recorded and resolved and trouble areas routinely inspected. Blockages should be removed without delay whilst the system should be occasionally flushed to clear of any build-up of solids that may have occurred (Bakalian *et al.*, 1994).

Responsibilities for sewer maintenance in simplified sewerage are generally related to the sewer network layout. In backyard sewer systems, residents may be responsible for that portion of the sewer network that runs from their dwelling to the next. In other layouts, the users could be responsible for maintaining the sewer lines that pass though their land, including inspection boxes. In these arrangements the service agency (or some other appointed entity such as a neighbourhood maintenance team) would be responsible for the operation and maintenance of all lines in the road reserve, including sidewalk sewers (Mara, 2006).

A2. Settled sewerage

A2.1 Design principles

As with simplified sewerage the development of settled sewerage throughout the years in different places has resulted in various specifications being developed. The earliest systems were installed in 1960 in Chipanda (Zambia) and made use of aqua-privy tanks which were drained by sewers (with a 100 mm minimum diameter) that were designed to flow partially full attaining a minimum daily peak self-cleansing velocity of 0.3 m/s. Similar design specifications were adopted in 1962 in Pinnaroo (Australia) with the exception that a self-cleansing velocity of 0.46 m/s was used for sewers flowing half full. These lower self-cleansing velocities (compared to 0.6 - 0.7 m/s for conventional gravity systems) were considered acceptable due to the assumption that most settleable solids would remain in the interceptor tank (Otis & Mara, 1985). The US Environmental Protection Agency (EPA, 1991) reports that studies have shown that any solids passing through the interceptor tanks and any slime growth which develops within the sewers are easily carried away by flow velocities as low as 0.15 m/s. Some agencies do however still recommend a minimum flow velocity of 0.3-0.45 m/s during the daily peak flow periods as a further factor of safety (EPA, 1991).

In the 1970s, agencies in the United States adopted an inflective gradient approach, which allows for sewers to follow natural ground slopes with sections of the sewer depressed below the hydraulic grade line. This results in flows in a settled sewer alternating between open channel flow and pressure flow. For this design to work the hydraulic grade line must not rise above the level of the outlet invert of any interceptor tank along the sewer which would result in wastewater flowing from the sewer into the interceptor tank (EPA, 1991; Otis & Mara, 1985). According to Laubscher (2010), research in South African conducted from 1988-1992 indicated that Australia was the world leader with STED systems; hence Australian design standards were adopted and applied to the design and installation on close to 5,000 properties around South Africa.

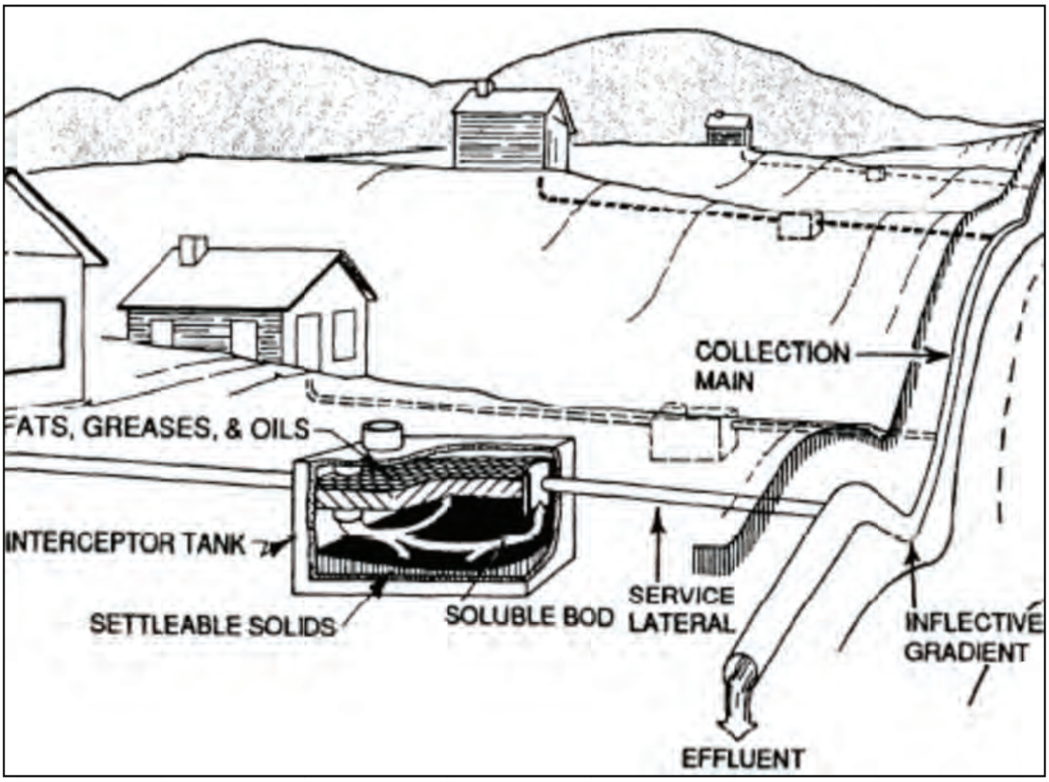

Figure A-2: A settled sewer schematic (EPA, 1991)**.**

The design criteria adopted for these systems included limiting interceptor tanks sizes to a minimum of 2 kℓ for what Laubscher (2010) describes as a ‘normal’ household (a problem since there is no such unit anywhere, least of all in South Africa), minimum sewer outside diameters of 110 mm, installation of cleaning eyes at a maximum distance of 100 m, limiting sewer gradients to a minimum of 1:250, installation of 50 mm diameter outlet tees and the installation of manholes where accumulation sewers meet. Using such criteria, Laubscher (2010) argued, the capital costs for the installation of such systems could be as much as 60-70 percent less than installing conventional gravity sewerage. However, whereas in Australia and the United States interceptor tanks are considered part of the treatment system and are serviced and maintained by the respective local authorities, South African local authorities have reportedly resisted taking responsibility for maintaining such septic tanks, primarily because most of the tanks concerned are situated on private properties – this is a consequence of settled sewerage having been introduced primarily in areas of previously low density (often holiday home, and so infrequently used) detached homestead sites. Moreover, Laubscher (2010) raised concerns about the effect of reducing the organic content from the wastewater on the nutrient removal at the WWTW, although at Sedgefield, one of the localities where settled sewerage has been retrofitted to service existing holiday-home septic tanks, full nutrient removal has reportedly been obtained when treating STED effluent.

The design considerations for STEP systems are similar to those for pressure mains used in conventional sewerage. Typical design considerations include pump selection and control considerations, venting at high points and determining locations for check valves, isolating valves and odour control measures.

Table A-2: Settled sewer design criteria and specifications.

Criteria	Specifications
System layout	On-site sewer layouts are similar to those for conventional gravity sewerage with the exception that household wastewater passes through an on-site interceptor tank before entering the main reticulation. Due to an absence of settleable solids settled sewers may have inflective gradients and may curve to avoid natural or manmade obstacles (Otis & Mara, 1985).
Maintenance access structures	Cleanouts for sewer flushing should be provided at all upstream connection, sewer junctions, major changes in direction, high points and at intervals of 150 m to 200 m on long flat sewer section. Manholes may also be provided at major junctions (Otis & Mara, 1985).
Design flows	Design flows are estimated in much the same way as for conventional systems with the exception that peak flows may be markedly attenuated as they pass through the interceptor tank. Otis & Mara (1985) report that peak factors of between 1.2 and 1.3 have been observed for a systems serving 200 people in Wisconsin, but caution that until more field data is obtained a conservative peak factor of 2.0 should be adopted for design.
Minimum gradients/sewer self-cleansing	The maintenance of minimum gradients to ensure the attainment of a minimum self-cleansing velocity is not required. An overall fall must however exist across the system and the hydraulic grade line must not rise above the outlet invert of any interceptor tank (Otis & Mara, 1985; EPA, 1991).
Sewer Sizing	Sewers may be sized using Manning’s equation. Minimum pipe diameters of 50 and 100 mm have been used successfully in experimental systems in the United States, a minimum diameter of 100 mm is however recommended for developing countries (Otis & Mara, 1985).
Minimum sewer cover depth	Otis & Mara (1985) recommend a minimum cover depth of 0.5 m. The EPA (1991) suggests minimum cover depths of 600 mm and 750 mm if no vehicular traffic loadings are anticipated. The pipe cover depth will also depend on the piping material used and as such it is recommended that pipe manufacturers be contacted to determine the absolute minimum pipe cover depth.

A2.2 Operation and maintenance

The on-site interceptor tank requires appropriate use and maintenance if it is to function properly. In order to ensure that anaerobic processes in the tank occur as intended, users must ensure that only biodegradable items enter the interceptor tank. The disposal of large amounts of inert items can significantly increase desludging frequency and result in blockages of the tank inlet and outlet. The main maintenance procedure required for the adequate performance of the interceptor tank is the monitoring of sludge levels and the subsequent desludging of the tank. Otis & Mara (1985) recommend that the service agency take responsibility for monitoring and maintaining all components of the settled sewerage system including interceptor tanks. For this arrangement the agency must schedule inspections of the interceptor tanks at some predetermined interval. This also applies to the pumps and electronic equipment employed in STEP systems. Another option is for the monitoring of the sludge levels to be undertaken by the users themselves, who then notify the service agency when tank desludging is required. Du Pisani (1998) however warns that interceptor tank monitoring cannot solely be left to the user as experience has shown that this is often not performed in a timely manner. If an interceptor tank is left unchecked eventually solids will pass through the tank and block the pipes. Interceptor tank monitoring must also include checks for water-tightness in order to prevent pollution of surrounding water bodies.

Routine flushing of the sewer network is required to facilitate the removal of any build-up of solids. The practice involves the introduction of a large volume of water at the sewer cleanout which flushes out most solid build-ups. Flushing is carried out starting at the most upstream end of the sewer network and the maintenance crew progressively moves through to the lowest point (Du Pisani, 1998).

A3. Vacuum sewerage

A3.1 Design principles

Vacuum sewer systems consist of three major components, namely: the service (consisting of a sump, interface valve and sensor unit); the collection mains; and a centrally located vacuum station (which houses the vacuum pumps, vacuum vessels and discharge pumps) (EPA, 1991). In the orientation generally adopted for residential developments, wastewater from one or more properties initially flows by gravity to the service where it temporarily accumulates in the small sump. Once a predetermined volume of sewage has accumulated in the sump, the pneumatically driven sensor unit triggers the opening of the vacuum valve, which is normally closed thus maintaining a seal between the sump which is open to the atmosphere and the collection main which is under negative pressure. Once the vacuum valve is open the wastewater is suctioned into the collection main. The interface valve remains open for an amount of time necessary for all the wastewater to be evacuated (usually between 3 to 4 seconds), as well as for an additional 2 to 3 seconds to allow atmospheric air, from an intake located on the property pluming, to enter the system after which it once again returns to the closed position (EPA, 1991).

Wastewater then travels through the collection mains that are typically solvent welded or gasketed SDR21 PVC pipe (SDR or the standard dimension ratio denotes the ratio between the outside diameter and the wall thickness) with diameters ranging from 75 mm to 200 mm, in transport-deposition cycles (EPA, 1991). For this purpose the collection mains are laid in a saw tooth profile. This profile results in pockets of sewage forming upstream of the saw tooth leaving a small section of the sewer above the sewage open, thus allowing air to pass throughout the network so as to maintain the required vacuum condition. The momentum of the air-sewage mixture entering the sewer system at individual valve chambers causes previously deposited pockets to be carried along the sewer at velocities of 4.6 to 5.5 m/s until frictional forces causes it to once again be deposited at another location along the line. This cycle is repeated as each interface valve opens with each subsequent energy input forcing the sewage to be transported further along the line until it eventually reaches the vacuum station (PDHEngineer, undated). Division valves are located at various locations (generally at all branch/main intersections, at bridge crossings, at anticipated problem areas and at periodic intervals on long routes) along the collection mains for isolation purposes during troubleshooting (EPA, 1991).

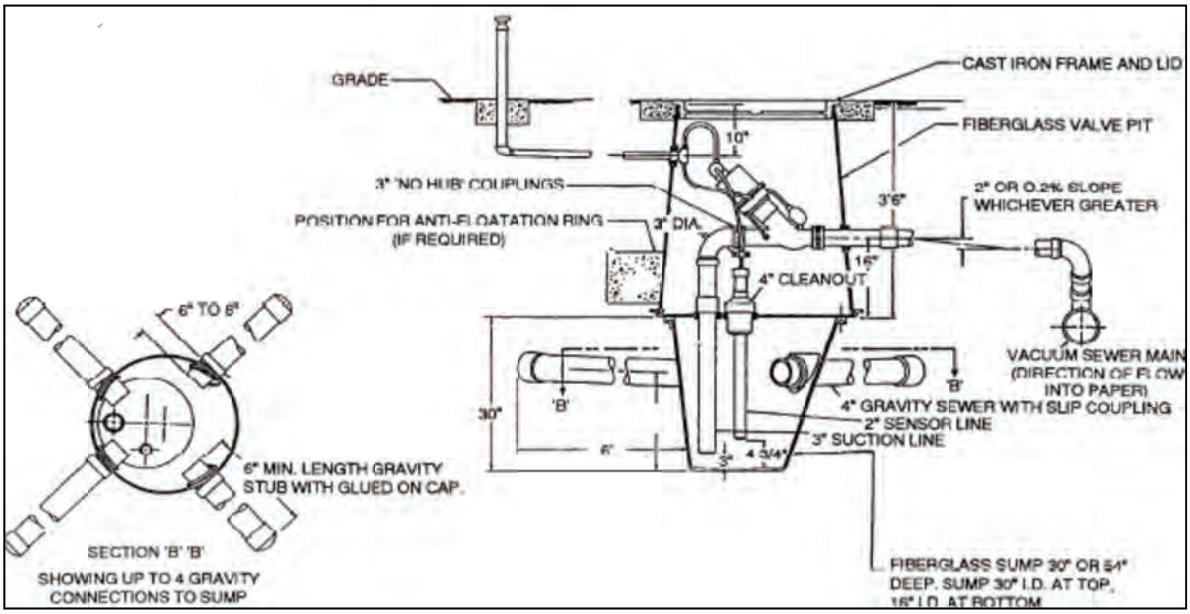

Figure A-3: Example of service installation (EPA, 1991).

When the wastewater arrives at the vacuum station it accumulates in the vacuum vessels. The vacuum pumps generate the suction pressure required for wastewater transport. The vacuum pumps and the vacuum mains are connected to the top of the tank which is kept free of sewage in order to allow for the negative pressure generated by the pumps to be transferred through the tanks, along the mains and eventually to the interface valves. The vacuum pumps operate in short cycles lasting 3 to 5 minutes in order to establish the required negative pressure, which is typically -0.7 bar. Once this level is achieved the pumps turn off and only turn on again once the vacuum levels drops due to the inflow of atmospheric air at the interface valves to a level of about -0.5 bar. The vacuum pumps then operate again until the level of -0.7 bar is re-established. Once a predetermined amount of sewage has accumulated in the collection tank the sewage pumps switch on and pump the sewage out of the collection tank through a force main to the ultimate point of disposal. In the case of both the vacuum pumps and the discharge pumps, several duty-alternating pumps are generally used with each pump capable of providing 100 percent of the required capacity. A control and monitoring system with data logger will generally be installed at the vacuum station. This system will monitor and record information such as pressure level trends, vacuum pump operating hours, sewage accumulation level and discharge pump operating hours (EPA, 1991).

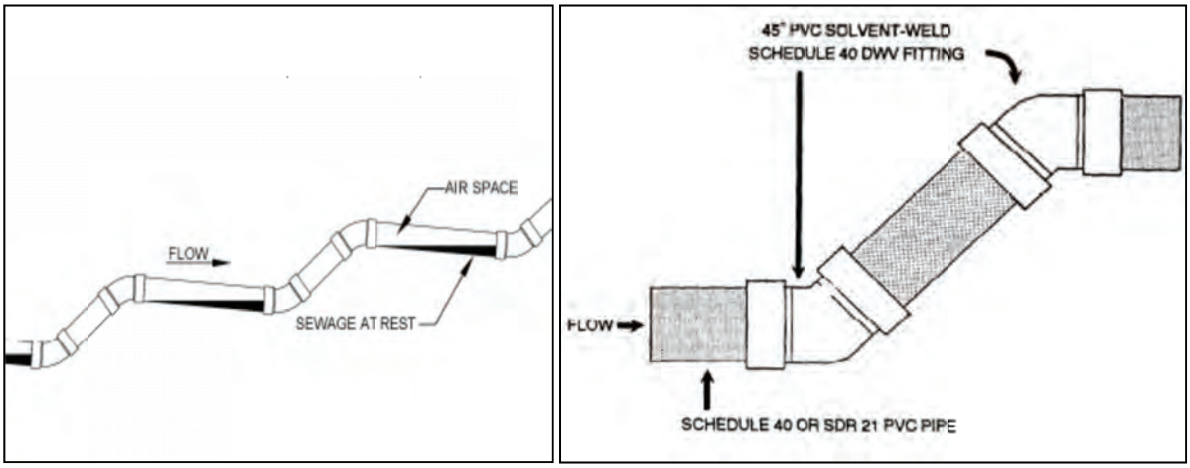

Figure A-4: Sawtooth profile adopted for vacuum sewerage collection mains (left) and detail of typical lift connection (EPA, 1991).

The design specifications for vacuum sewer systems have been developed through the years based on experience gained from studying operating systems and will generally differ for each manufacturer (PDHEngineer, undated). As such, it is recommended that specific manufacturers be approached for detailed information relevant to their system before undertaking the design.

A3.2. Operation and maintenance

Vacuum sewer systems employ various components that operators may not initially be familiar with. It is thus imperative that training is provided for the personnel tasked with maintaining the system prior to the adoption of their duties. The maintenance of vacuum stations typically entails performance monitoring and general upkeep. This generally includes daily inspection of check valves, plug valves, vacuum pumps, discharge pumps, generator, and the control system, keeping of operation and maintenance records and preventative maintenance such as oil changes and servicing of pumps. The control system will generally have a communication device that will inform the operator in case of an emergency (PDHEngineer, undated).

The condition of the vacuum collection mains may be monitored from the vacuum station control systems. A broken pipe will allow the ingress of air which will be detected as pressure is lost throughout the system. The only routine maintenance required for the sewer collection mains is the yearly “exercising” of the division valves in order to keep them in good working condition. A yearly inspection of the interface valves and sensor units is also recommended. During this inspection interface valves should be manually cycled and sensor unit cycle time recorded and compared to the original setting. As interface valves and sensor units are mechanical parts that will experience wear and tear, they will periodically have to be replaced (PDHEngineer, undated).

International experience has shown that maintenance personnel who are hired before or during the period when a vacuum sewer system is constructed are the most effective in maintaining it. They become familiar with the system, including the location of all vacuum sewer lines, isolating valves, valve chambers and other components (PDHEngineer, undated).

Appendix B: Kosovo vacuum system technical specifications and CoCT's O&M procedures

B1. Technical description

The 42 communal sanitation blocks, each comprising between six and ten toilets, are drained by a 110 mm diameter gravity sewer conveying wastewater to an adjacent 40 litre collection chamber with a 63 mm diameter interface valve connecting it to vacuum sewer mains which ranged from 90 mm to 250 mm in diameter (CoCT, 2010c). The vacuum sewer network terminates at one centrally located vacuum pump station (Figure B-1; depicted as a red square in Figure B-2) where sewage accumulates in a 250 m^3 vacuum vessel. A second 250 m^3 vacuum vessel was installed to be brought online should the first tank need to be taken off-line for maintenance. Three rotary vane type duty alternating vacuum pumps generate the negative pressures required by the system. The vacuum pumping system is designed to effect a pressure of -0.8 bar throughout the system. This pressure steadily reduces as each interface valve opens to allow sewage to enter the vacuum mains. The pumps switch on once the pressure drops to -0.6 bar and run until the pressure of -0.8 bar is re-established. Sewage entering the vacuum vessel accumulates until approximately 40 m^3 has been collected at which point the sewage discharge pumps switch on and evacuate the sewage. The two, duty alternating, discharge pumps deliver the sewage via a 160 mm diameter rising main (depicted as the red line on Figure B-2) to a gravity main (depicted as green line on Figure B-2) which eventually conveys the wastewater to the wastewater treatment plant. An electronic control and monitoring system coordinates and monitors all pumps performance, pressure levels and vacuum vessels levels.

Figure B-1: Vacuum vessels and discharge pump (left) and a vacuum pump (right)
(Photos by Ashipala, 2011)**.**

Figure B-2: Layout of Kosovo vacuum sewer system (after CoCT, 2010c). **The vacuum station is depicted as the red square in the middle of the map.**

B2. Operation and maintenance

Until its effective decommissioning, maintenance of the vacuum system was undertaken by two maintenance teams from different units within the City of Cape Town's Water and Sanitation Department. Maintenance of the mechanical equipment at the pump station was undertaken by personnel from the Raapenberg pump stations unit (RPS), whilst the vacuum sewers and the collection chambers were maintained by a team of artisans from the Informal Settlements Unit (WSISU). Communication between the two teams seemed to be effective in getting requests for maintenance work to be undertaken in a timely fashion. However, there seemed to be no formal system for planning, coordinating and documenting the maintenance work carried out. The WSISU personnel informally kept a log of chambers that were operational and the pump station personnel kept a record of when pumps were removed for maintenance, but future maintenance task were not being planned nor was performance assessment undertaken collectively (Cornelius, 2010).

The research team found that although the personnel currently responsible for maintaining the vacuum system had not received any formal training for the system, the experience that they had garnered thus far had resulted in them becoming reasonably competent in carrying out the emergency maintenance tasks. The operators had been provided with information on the system (design drawings and maintenance manuals) which they perused and as a result had obtained a particularly good understanding of how the system works. The maintenance activities that were being regularly undertaken were however seemingly limited to reactive maintenance tasks. It was also discovered that the equipment required for inspecting the system for air leaks had not been procured hence limiting the maintenance team's ability to effectively troubleshoot the system. The lack of test balls (inflatable rubber balls inserted into the vacuum sewer in order to isolate sections of the sewer) and pressure gauges meant that if sewer failures were to occur there would be no way of determining in which section/s along the vacuum sewer line they had occurred. Air leak tests undertaken, however, did not reveal any leaks in the pump station or for the single vacuum sewer line operational at the time. In addition, at the time of writing the 12 spare sets of interface valves and sensor units that had been procured shortly after the system's installation were insufficient to repair all the dysfunctional chambers.

An informal survey of the toilet blocks revealed that numerous cisterns had become damaged resulting in the water leaking from these continuously entering the collection chambers. Scrutiny of the vacuum vessel level and pressure curves revealed that this resulted in the cyclic conveyance of clean potable water through the vacuum sewer system. As a consequence of the damaged cisterns the vacuum pumps were collectively operating for approximately 12 hours over each 24 hour period and the discharge pumps were evacuating the vacuum vessel approximately once every 60 minutes.

Appendix C: Barcelona Settled Sewerage Pilot design information and proposed O&M schedule

C1. Sewer design wastewater flow calculations

In estimating wastewater flows for the sewer network it was assumed that the settlement's population would remain relatively unchanged for the foreseeable future. Whereas the sizing of the interceptor tanks was based on flows expected to be generated by the limited number of Barcelona residents that will make use of the pilot sanitation facilities, the settled sewers network was sized to the flows that would be generated if the whole settlement were to connect to the settled sewer network. The average daily per capita wastewater flow was taken as 70 ℓ/c.d as recommended for low income areas in the Red Book (CSIR, 2005). This estimate of the daily per capita wastewater flows was considered acceptable on the assumption that this is the flow that would typically be generated from a low-income household with full on-site water supply which is the highest likely level of service. It is imperative that the sewers have sufficient capacity to convey such flows should the need arise in future. The gross population density (population per unit area) was then used to determine the average daily flow generated from an area of a given size within the settlement (kℓ/m^2.day).

There is very little data available on the magnitude of peak flows in settled sewerage. Otis & Mara (1985) report that in a system serving 200 people at Westboro (Wisconsin) peak factors of 1.2 to 1.3 were observed. Otis & Mara (1985) however recommend that a peak factor of 2 be used until more data is available, so this was used instead. This is slightly less than for conventional sewerage (which is generally taken as 3) as it takes into account the attenuation of flows passing interceptor tanks. An allowance of 15% (as generally adopted for conventional gravity sewerage) was made for stormwater ingress and groundwater infiltration.

C2. Sewer self-cleansing criteria

Settled sewers are only meant to carry settled effluent with a small concentration of suspended solids. This allows the use of shallow gradients and even inflective gradients without concern for sewer blockages occurring as long as no unsettled sewerage enters the sewer system. According to Laubscher (2010) settled sewer systems that have been built across South Africa with a minimum slope of 1:250 for 110 mm outside diameter sewers have been operating effectively for several years. In a study on sewer self-cleansing based on the theories of incipient motion, Ayele (2009) determined that sediment bed scouring may be obtained in sanitary sewers with a design bed particle size of 1.5 mm by employing minimum slopes of 1:250 and 1:370 for sewer diameters 100 mm and 150 mm respectively. The BSSPP settled sewers were designed with a slightly more conservative minimum slope of 1:200 for

110 mm outside diameter sewers and 1:300 for 160 mm outside diameters. Comparing this to the self-cleansing velocity approach yields full-bore self-cleansing velocities of 0.5 m/s at peak flow which is a slightly more conservative value than the range of 0.3 - 0.45 m/s recommended by Otis & Mara (1985). The gradients also yield an average full-bore bed shear stress of 1.35 N/m^2 and 1.31 N/m^2 for 100 mm and 160 mm outside diameter sewers respectively, which is within the range of 1-2 N/m^2 recommended by Yao (1974, as cited by Mara *et al.*, 2001) for sanitary sewers. Mara *et al.* (2001) report that a minimum full-bore bed shear stress of 1 N/m^2 at peak flow has been used successfully for simplified sewerage systems in which toilet paper was not disposed of in the toilet bowl and the ingress of stormwater was minimal. These conditions are similar to those expected to prevail in the settled sewers employed for the BSSPP seeing that the bulk of the solids have been removed prior to the flow entering the sewers.

Maintaining positive gradients throughout the sewer system is considered necessary in light of the unpredictable nature of the area in which the system is to be installed. A particular concern is illegal connections and poorly constructed interceptor tanks that might result in solids entering the system. The use of negative gradients throughout gives the system a degree of self-cleansing ability for the flushing of solids entering the system and for scouring sewer slime build-up. The use of positive gradients (falls) throughout the network also protects users who may in future have to connect at local low points, from wastewater back-flows.

C3. Sewer materials selection

The nature of the partially degraded wastewater that is to be conveyed by the sewer system necessitated the use of materials that are resistant to sulphide attack. In particular High Density Polyethylene (HDPE) and unplasticised Poly-Vinyl Chloride (uPVC) pipes were considered. uPVC pipes are commonly used for household plumbing and collection mains in South Africa and cost approximately half the price of HDPE pipes. The fittings for uPVC sewer pipes are also more widely available and local contractors are familiar with the installation practices. HDPE pipes however have several key advantages that led to their selection for the pilot project. HDPE pipes have a higher impact strength than other plastic pipe materials which makes them more resistant to damage. This is particularly important as the research team is seeking to limit the excavation depths in the solid waste material underlying the settlement by reducing pipe cover depths to a minimum of 0.5 m. HDPE pipes are also more flexible than uPVC (depending on the pipe class HDPE pipes can be bent to a minimum bending radius of 20-30 times the pipe outside diameter) which is a particularly useful property as the HDPE pipes will have a greater resistance to damage caused by possible deflections arising from the differential settlement of the underlying solid waste matter. HDPE pipes are also resistant to a wide range of chemical agents, making it useful for installation in an area underlain by solid waste, the makeup of which is largely unknown.

HDPE piping is locally available in coils which can be laid and cut to the required length on site. The use of mechanical compression couplings provides a jointing system which can easily be assembled on site. These features will simplify the installation allowing the use of more unskilled local labour and eliminating the need for bulky and expensive on-site pipe joint welding equipment.

C4. Minimum sewer diameter specifications

The minimum outside diameter of the collection sewers employed in the Barcelona settled sewer system has been limited to 110 mm. This will allow the network to cater for future flows as well as make it easier to remove blockages should they occur. The interceptor tanks employed for the pilot project have a 50 mm tank outlet diameter which will discharge into an access point before entering the collection sewers. It is imperative that tanks installed in future are provided with outlets of smaller diameter than the minimum employed for the collection sewers. This is to ensure that should any solid pass through the tank its size will always be less than that of the collection mains, thus reducing the risk of blockages.

C5. Maintenance access structure requirements

Cleanouts for removing blockages and periodic sewer flushing are to be provided at all major changes in direction and at a maximum interval of 100 m along straight lengths. Larger access points are to be installed at all locations where the risk of sewer blockages is deemed to be high. These include at all sewer junctions, changes in sewer size, where pressure mains discharge into a gravity main and at interfaces of settled sewers with conventional gravity sewers.

C6. Interceptor tank materials selection and sizing

In light of the uncertainty in the settlement of the solid waste material above which they are to be installed, the ability of polyethylene tanks to more readily deform whilst still remaining watertight was an advantage over concrete and clay brick tanks for the pilot project. Polyethylene tanks are known for their watertight integrity, resistance to corrosion and the fact that they are lightweight, which makes them easier to transport, handle and install. The tanks do however require anchorage to ensure that they do not float out of the ground due to elevated groundwater tables. Backfilling during installation also has to be carried out carefully to ensure that tanks are not damaged. The required interceptor tank size was estimated as follows:

- It was assumed that low flush cisterns delivering six litres per flush will be utilised.
- It was then assumed that the average time that a user would spend in the toilet is five minutes. This would result in 12 toilet flushes per hour if the toilets were to be in continuous use for that hour.

- In discussions with the Barcelona Street Committee, the project team decided that the sanitation facilities would only operate for a limited number of hours per day when a caretaker opened the facilities. This decision was made based on concerns over the safety of residents walking to the toilets at night. It is assumed that the sanitation facilities will be open for 16 hours per day and operate from 05h00 to 21h00.
- The usage will fluctuate throughout the course of the day. If the worst-case scenario is assumed where the toilets are in continuous use during the 16-hour period (156 flushes per toilet per day) this would result in a flow of 702 ℓ per toilet each day.
- Each interceptor tank was designed to serve five toilets, which would result in a total flow of 3.510 kℓ emanating from the toilets per day. If a factor of safety of 1.5 is used to factor in the wastewater generated as a result of handwashing and spillages from water collection at the standpipe, a flow rate of 5.265 kℓ per day is obtained.
- A minimum mean hydraulic retention time of one day is generally recommended for intercept tank design in order to ensure sedimentation processes within the tank occur effectively. Thus interceptor tanks of at least 5.265 kℓ would be required for each set of five toilets. The next larger size of the polyethylene tanks to be used for the pilot project is 6.5 kℓ. The larger tank size was thus selected for use in the pilot project.

The widely accepted empirical relationship proposed by Weibel *et al.* (1955) yields an estimated sludge and scum accumulation rate of 0.5 ℓ/c.d. It was assumed that each user will generally only defecate once a day, although they may go to the toilet to urinate several times a day. It was thus assumed that the above mentioned sludge and accumulation rate can be associated with one out of three toilet flushing events, giving a sludge and scum accumulation of 0.167 ℓ per flush. If this value is applied together with the assumption of a maximum of 156 possible flushes per toilet per day, as specified earlier, a sludge and scum accumulation rate of 26 ℓ per day per toilet employed in the communal sanitation facilities is obtained. Interceptor tanks must be de-sludged periodically to ensure proper system performance and reduce the risk of hydraulic failures. This should be carried out before the accumulated sludge and scum encroaches on the tank outlet. The actual de-sludging frequency will depend on the composition of the material that enters the tank which will affect the efficiency of the anaerobic digestion processes within the tank. In order to obtain an initial estimate of de-sludging frequency it was assumed that tank de-sludging will have to be carried out once the total sludge and scum accumulation exceeds 60% of the total tank volume. If the bulk accumulation of solids (i.e. without taking into account the reduction of sludge volumes due to anaerobic digestion within the tank) is based on the use of 6.5 kℓ interceptor tanks for each set of five toilets and a sludge and scum accumulation rate of 26 ℓ per toilet per day, it is estimated that the de-sludging frequency for the interceptor tanks will be approximately once a month. This is an improvement on the current arrangement where container toilets are desludged three times a week.

Table C-1: Sanitation facility criteria & proposed BSSPP top-structure design features.

Criteria	Specifications	Feature
1. Drainage	Drainage in the form of a raised concrete floor slab shall be provided around sanitation facilities in order to prevent ponding and the formation of muddy pools. Roof drainage should also be accounted for to ensure that it does not pose a risk to surrounding properties.	A raised concrete floor slab, draining to a gully at a grade of 1:50 is to be provided for the sanitation facilities. The rainwater harvesting system collects the roof drainage with an overflow directed away from adjacent properties.
2. Shelter	A roof to shelter users entering, exiting and waiting at the sanitation facilities from the elements shall be provided where feasible.	A roof supported by a structural steel frame will cover the areas surrounding the toilet cubicles and the tapstand.
3. Greywater disposal	Provision shall be made for the safe disposal of greywater.	A gully with a p-trap water seal is to be provided for greywater disposal at the base of the tapstand.
4. Safety and Security	The layout and location of sanitation facilities shall be selected in such a way that promotes visibility. Lighting should be provided at the sanitation facilities if they are provided in poorly lit areas.	The sanitation facilities will be provided with lighting. The L-shaped layout of the facilities eliminates dark corners and also allows visibility of the central courtyard area from the street. The facilities are fenced off with palisade fencing, which allows for visibility whilst limiting access at times during which the sanitation facilities are not open to the public.
5. Water supply	Where water supply is limited, a buffer supply shall be included in the design so as to limit the peak loads on the water reticulation. Standpipes heights shall be selected based on the guidelines provided in (Haarhoff & Rietveld, 2009) coupled with observations of local practices, a raised platform for placing collection containers shall be provided if required.	The sanitation facilities will be provided with buffer tanks to augment the water supply to the toilets during peak usage times. Half of the tank's capacity will be used to collect rainwater from the roof. The tapstands' design provides a raised platform for placing buckets and is at the optimum height as recommended by (Haarhoff & Rietveld, 2009).
6. Aesthetics	The provision of aesthetically appealing sanitation facilities shall be encouraged where it is economically feasible. Local artists and children should be invited to take part in decorating the sanitation facilities.	The exterior and interior walls of the toilet cubicles and the concrete palisade fencing can be painted, but it has not been determined who will cover this cost. Local artists will be invited to create mosaics to decorate the exterior walls of the toilet cubicles.
7. Night-soil disposal	Facilities for the safe disposal of night soil shall be incorporated into the design of sanitation facilities to allow residents living in close proximity to safely disposed the contents of their bucket, where required.	Night-soil disposal has not been catered for in this design as per the request of the Barcelona Street committee.

Table C-2: Proposed BSSPP O&M task matrix.

Task	Description	Frequency	Reporting, Monitoring and Performance Management	Responsible	Support Requirements from Local Authority
Operators' tasks					
Janitorial Services	Open/close sanitation facilities, clean toilets and surrounding area, provide toilet paper	Daily	Performance based contract evaluated by BSC	Locally sourced labour; Supervised by Barcelona Street Committee on a daily basis and evaluated by the M&E Officer	Funding and training; establishment & maintenance of communication channels.
Monitoring of interceptor tank levels	Record and report the sludge level in the interceptor tanks and notify M&E Officer of need to desludge tank when required	Weekly	Weekly sludge level report to be submitted to M&E Officer		
Monitoring of sewer lines	Check that no illegal connections are made; notify M&E Officer of illegal connections, blockages, sewer infrastructure damage, etc.	Weekly	Weekly sewer condition report to be submitted to M&E officer; immediate reporting of sewer maintenance requirements to Task Team and ME officer.		
Monitoring of sanitation facilities	Monitor the condition of toilet units, washbasins, taps, septic tanks, fencing and surrounding areas.	Monthly	Monthly facilities condition report to be submitted to Task Team and M&E officer; Immediate reporting of maintenance requirements to Task Team and M&E officer		
Monitoring and maintenance of janitorial services, interceptor tank, sewerline and sanitation facilities.	Monitor sanitation facilities and check that they are open, clean and fully operational during operating hours.	Monthly	Monthly performance report to be submitted to Task Team & M&E officer; Report Ad hoc and emergency maintenance task to M&E Officer	Supervised by the Barcelona Street Committee and monitored by the M&E Officer	
Municipal officials' tasks					
Desludging of interceptor tank	Desludge interceptor tank and transport to treatment plant	By request	Keep records of desludging frequency	CoCT M&E Officer	Funding
Maintenance and repairs to Sanitation facilities and sewer lines	Maintenance of sanitation facilities including repairs to toilets, taps, basins, fences and interceptor tanks; maintenance of sewers including blockage removal, sewer flushing and repairs.	By request	Record and document maintenance tasks and frequency	CoCT M&E Officer	Funding and O&M personnel

Appendix D: Study products

Supplementary poster guide:

J. Hilligan, L. Taing, N.P. Armitage & A. Spiegel (2012), **TIPS for sewering informal settlements**, Water Research Commission: Pretoria, South Africa.

Journal publications:

N. Ashipala & N. P. Armitage (2011), **Impediments to the adoption of alternative sewerage in South African urban informal settlements,** Water Science & Technology, Vol. 64, No. 9, pp 1781-1789.

J. Hilligan, A. Spiegel & N. P. Armitage (2012), **Taps and toilets count: People matter**, The Water Wheel, Water Institute of South Africa, July/August 2012, pp 28-31.

L. Taing, S. Pan, J. Hilligan, A. Spiegel & N. P. Armitage (Forthcoming), **Challenges facing sanitation-provision partnerships for informal settlements: A South African case study**, Journal of Water, Sanitation and Hygiene for Development, International Water Association, Accepted for publishing in September 2012.

Conference papers, presentations and posters:

N. P. Armitage, R. Beauclair, N. Ashipala & A. Spiegel (2010), **Draining the shantytowns; Lessons from Kosovo informal settlement (Paper/presentation)**, Novatech 2010, Lyon, France, 27 June - 1 July, 2010.

N. Ashipala & N. P. Armitage (2010), **Impediments to the adoption of alternative sewerage in South African urban informal settlement (Paper/presentation)**, International Water Association, Sewer Processes, Gold Coast, Australia, 11-15 November, 2011.

L. Taing , A. Spiegel & N. P. Armitage (2011), **Cape Town's problematic vacuum sewer: A reflection on the social, technical and institutional blockages that constrain municipal management (Paper/poster)**, 12th International Conference of Urban Drainage, International Water Association, Porto Alegre, Brazil, 10-15 September 2011.

J. Hilligan, L. Gangatele, S. Pan & L. Molefi (2011), **Barcelona Settled Sewerage Pilot Project: A partnership approach to sanitation design and planning (Poster)**, 2nd Southern African Young Water Professionals Conference, International Water Association, Pretoria, South Africa, 3-5 July 2011.

L. Taing, L. Cornelius, A. Spiegel and N. P. Armitage (2011), **Cape Town's problematic vacuum sewer: Recommendations to address an informal settlement's complex sanitation challenge (Paper/presentation)**, 2nd Southern African Young Water

Professionals Conference, International Water Association, Pretoria, South Africa, 3-5 July 2011.

L. Taing, A. Spiegel and N. P. Armitage (2011), **Cape Town's problematic vacuum sewer (Presentation),** ASnA Annual Conference, Anthropology South Africa, Stellenbosch, South Africa, 3-6 September 2011.

L. Taing, S. Pan, J. Hilligan, A. Spiegel & N. P. Armitage (2011), **Rethinking relationships in sanitation operator partnerships: Barcelona Settled Sewerage Pilot Project case study (Paper/presentation)**, 2nd IWA Development Congress and Exhibition, International Water Association, Kuala Lumpur, Malaysia, 21-24 November 2011.

L. Taing (2011), **Meeting the future water and sanitation challenges in developing country contexts: Thoughts, vision & recommendations (Presentation)**, 2nd IWA Development Congress and Exhibition, International Water Association, Kuala Lumpur, Malaysia, 21-24 November 2011.

J. Hilligan, A. Spiegel & N. P. Armitage (2012), **Taps and toilets count: People matter (Paper/presentation)**, WISA 2012 Conference, Water Institute of South Africa, Cape Town, South Africa, 6-10 May 2012.

S. Pan & N. P. Armitage (2012), **An application of soft systems methodology to water and sanitation projects in Barcelona Informal Settlement (Paper/presentation)**, WISA 2012 Conference, Water Institute of South Africa, Cape Town, South Africa, 6-10 May 2012.

Student dissertations:

S. Reznik (2008), **An Analysis of Alternative Sewerage Systems and their Applicability for the Upgrading of Informal Settlments in South Africa**, Unpublished BScEng dissertation, Department of Civil Engineering, University of Cape Town, Cape Town.

B. Ayele (2009), **Minimum Gradients for Sewer Self-Cleansing Based on Theories for Incipient Motion**, Unpublished BScEng dissertation, Department of Civil Engineering, University of Cape Town, Cape Town.

K. Masindi (2009), **An Economic Analysis of Alternative Sewerage**, Unpublished BSc Thesis, Department of Civil Engineering, University of Cape Town, Cape Town.

R. Beauclair (2010), **Development and Disappointment: An ethnographic study of Kosovo informal settlement's water and sanitation system upgrade**, Unpublished MA dissertation, Department of Social Anthropology, University of Cape Town, Cape Town.

A. Ally (2010), **Wet versus dry sanitation in South Africa**, Unpublished BScEng dissertation, Department of Civil Engineering, University of Cape Town, Cape Town.

N. Ashipala (2011), **The implementation of alternative sewerage in the informal settlements of South Africa**, Unpublished MScEng dissertation, Department of Civil Engineering, University of Cape Town, Cape Town.

S. Pan (2011), **Improving water and sanitation services in informal settlements in Cape Town: Finding the balance between "hard" and "soft" approaches**, Unpublished MScEng dissertation, Department of Civil Engineering, University of Cape Town, Cape Town.

J. Hilligan (Forthcoming), MA dissertation, Department of Social Anthropology, University of Cape Town, Cape Town.

TIPS for sewering informal settlements

Considering roles, risks and responsibilities

WRC Project K5/1827

J. Hilligan, L. Taing, N.P. Armitage and A. Spiegel

WATER RESEARCH COMMISSION

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ETHEKWINI MUNICIPALITY

This poster provides TIPS for Water Service Authorities (WSAs) to consider when planning, implementing and managing sanitation services for informal settlements. Critical project roles are highlighted to help WSAs coordinate the various people involved in any given project. The tasks are loosely assigned to allow project team members to negotiate their roles and responsibilities based on their circumstances. A list of risks is included with each step to enable WSAs to anticipate and mitigate potential problems.

The poster supplements the WRC report *TIPS for sewering informal settlements: Technology, Institutions, People and Services*. It represents the conclusions of that report: (a) the social processes that underlie the planning, provision and management of sewage systems are just as significant technology choice, and (b) WSAs need to be fully accountable for the operation and maintenance (O&M) of the toilets they provide as part of their Free Basic Services obligations.

KEY ROLE: **Owner** (Conduit for funds and legal titleholder): Appoints Project Manager (PM) and monitors his/her performance; gauges and responds to Users' satisfaction and associated O&M requirements; and decides when services will end.

Users (Informal settlement residents and targeted beneficiaries): Assist in service design process and report satisfaction to PM and thence to Owner.

Construction Supervisor (Designer's representative): Ensures Builder avoids shortcuts; assesses whether facilities are built according to specifications; and signs-off construction snag list.

Project Manager (Internal municipal appointee): Oversees sanitation service on Owner's behalf; coordinates involved parties; sets-up and manages O&M plan; appoints and trains Operators; and adapts management procedures when necessary.

Builder (Internal municipal or external appointee): Constructs facilities according to specifications and agreed deviations.

Designer (Internal municipal or external appointee): Prepares technical/engineering specifications.

Settlement Representative (Informal settlement resident contracted by Builder): Mediates between Builder and Users on a day-to-day basis.

Social Facilitator (Internal municipal or external appointee): Consults and engages Users and mediates between PM, Designer and Users.

Labourers (Internal municipal appointees or contracted by Builder): Skilled, semi-skilled or unskilled construction workers. Informal settlement residents ideally will be appointed.

Project Support (Internal municipal or external appointees): Technicians, Administrators, Researchers, Information Specialists (*e.g.* GIS Analyst), *etc.*

Operators (Internal municipal or external appointees): Operate and maintain sanitation system/service. Includes janitors, desludgers, plumbers *etc.*

	TASKS	RISKS	RESPONSIBILITIES
	PLANNING AND SERVICE DESIGN		
1	**Facilitating user consultation for joint design and planning**	1.1 Difficulty finding suitable representatives that should be consulted, especially when turnover in settlements and municipal offices results in different people being consulted throughout sanitation service lifespan 1.2 Demands are difficult to meet 1.3 Agreements between Users, PM and Owner become problematic when promises cannot be kept 1.4 Political interference	1.1.1 Identify all relevant parties that should be consulted and continuously facilitate consultation through planning phase to eventual decommissioning 1.1.2 Guide Users through participatory planning process if necessary 1.2.1 Discuss pertinent issues collectively and mediate opposing perspectives 1.3.1 Discuss reasons for which old arrangements need to be changed and negotiate new agreements 1.4.1 Assess how such interference affects service, and subsequently plan/negotiate with relevant parties to continue or discontinue project
2	**Technical and service design**	2.1 O&M requirements and costs are overlooked and therefore unbudgeted 2.2 Prolonged design phase due to conflicts, project coordination and municipal capacity constraints 2.3 Residents' refusal to move to accommodate design/construction or settlement's layout changes between design finalisation and implementation 2.4 No convenient sewer connection point 2.5 Insufficient capacity in surrounding sewer network and wastewater treatment facility 2.6 Poorly written tender documents	2.1.1 Design O&M plan according to Users' and Owner's current and future requirements 2.1.2 Establish capital/O&M costs based on expected lifespan 2.2.1 Mediate conflicts immediately and negotiate arrangements agreed upon by conflicting parties 2.2.2 Identify capacity gaps and commence training or management adjustments to accomodate these gaps 2.3.1 Facilitate negotiation with Users; if a compromise cannot be achieved then consider changing design or discontinuing project 2.4.1 Obtain necessary data to inform design (e.g. existing As-Builts, topographical survey, sewer blockage rates, etc. 2.4.2 Obtain permits (e.g. way-leaves, servitudes, etc.) or inter-departmental servicing agreements 2.5.1 Ensure that requisite bulk infrastructure is upgraded ahead of proposed sewer connection 2.6.1 Prepare clear and precise construction tender documentation
	IMPLEMENTATION		
3	**Local labour selection**	3.1 Unclear or inflexible labour selection procedure 3.2 Users unhappy with selection of Settlement Representatives and Labourers 3.3 Temporarily employed local residents expect or seek permanent positions	3.2.1 Discuss employment opportunities and set-up a fair labour selection process with Users, Ward Councillors and necessary Municipal departments 3.2.2 Advertise available positions and labour selection procedure as widely as possible (e.g. via posters, word-of-mouth, etc.) and appoint most appropriate Settlement Representatives and Labourers 3.3.1 Decide whether to offer temporary or permanent contracts at the beginning of the employment process, and ensure all appointees understand whether their contracts are renewable or extendable
4	**Construction**	4.1 Poor construction and/or too long construction time frames due to lack of technical expertise, use of labour-intensive methods and poor planning 4.2 Proposed infrastructure might cross private property or impact on existings services 4.3 Unforeseen project delays, particularly due to selection of Settlement Representatives and Labourers 4.4 Open construction site poses physical danger and invites tampering 4.5 Corruption	4.1.1 Consider Builder's experience/capability to facilitate labour-intensive construction in an informal settlement 4.1.2 Consider length of time required for building, factoring in seasonal impacts and labour-intensive methods 4.2.1 Obtain construction way-leaves 4.2.2 Re-route design if necessary 4.3.1 Mediate conflicts immediately and negotiate arrangements agreed upon by conflicting parties 4.4.1 Ensure health and safety precautions are followed 4.5.1 Ensure adequate supervision to minimise risk of any bribery or corruption
5	**Construction supervision**	5.1 Poor supervision due to lack of technical expertise and/or limited on-site monitoring results in poor construction 5.2 Corruption	5.1.1 Consider Construction Supervisor's experience/capability to complete project as required 5.1.2 Determine and advertise the appropriate construction supervision level and extent of monitoring needed 5.2.1 Ensure Construction Supervisor follows agreed procurement procedures
	COMMISSIONING		
6	**Service set-up**	6.1 O&M tasks are overlooked or not done 6.2 Spare parts are not immediately available	6.1.1 Review/adapt O&M plan, prepare a detailed O&M manual for Operators, and establish necessary system to implement it 6.1.2 Train and equip Operators prior to official handover from Builder 6.1.3. Provide guidance to Users and Municipal Officials, including other Departments (e.g. Health, Human Settlements) so that all relevant parties understand each other's responsibilities and roles 6.2.1 Procure O&M equipment and spare parts timeously
7	**Infrastructure Handover**	7.1 Inadequate capacity to assess facility readiness 7.2 Services do not meet building specifications or Users' and Owner's expectations (snags) 7.3 Facilities damaged prior to official handover from Builder 7.4 It is unclear who is responsible for O&M tasks	7.1.1 Ensure PM and Users jointly, in terms of participatory planning, assesses how system is constructed and should function 7.2.1 Identify and resolve design, construction or maintenance problems that must be addressed by Users, PM, Designer, or Builder prior to handover 7.3.1 Take necessary precautions to reduce risk of damages prior to transfer, including not allowing use of facilities prior to handover 7.4.1 Identify which department(s) or contractors will be responsible for ongoing O&M prior to Builder's handover
	O&M AND ADAPTIVE MANAGEMENT		
8	**Day-to-day operation and maintenance**	8.1 O&M responsibilities neglected and facilities become unusable 8.2 Communication breakdown between Owner, Users and Operators 8.3 Operators unable to cope 8.4 Lack of adequate O&M budget, equipment, and spare parts 8.5 Loss of institutional memory consequent on staff turnover 8.6 Connecting sewer network fails 8.7 System capacity is exceeded	8.1.1 Ensure that suitably trained Operators are appointed and that they follow the O&M manual 8.2.1 Establish reasons and introduce appropriate management rules and consultation protocols 8.3.1 Ensure correct number and type of operators are deployed 8.3.2 Provide suitable support to Operators 8.4.1 Ensure costs for daily operation and long-term maintenance are budgeted 8.5.1 Train staff on an on-going basis 8.6.1 Maintain sewage infrastructure 8.7.1 Evaluate system capacity; upgrade if required
9	**Breakdown avoidance and recovery (Monitoring, evaluation and adaption)**	9.1 Lack of information to evaluate services 9.2 Changes are needed but system cannot be adapted 9.3 Recommendations for changes are overlooked or ignored 9.4 Incapacity to assess services and adapt management where required 9.5 Poor coordination of functions due to municipal restructuring and personnel change and/or User turnover	9.1.1 Gather data, including GIS and usage information 9.1.2 Evaluate whether service continues to meet need 9.2.1 Plan for decommissioning and replacement 9.3.1 Adapt procedures based on lessons learnt from troubleshooting and evaluation of service's appropriateness 9.4.1 Arrange for skills development where required 9.5.1 Appoint suitable PM to take charge of restructuring
	DECOMMISSIONING		
10	**End service: Close and replace facility**	10.1 Service becomes dysfunctional 10.2 Users left without functional sanitation 10.3 Curtailment of informal settlement residents' sanitation based employment opportunities	10.1.1 Decide when existing sanitation services must terminate 10.2.1 Identify and ensure installation of replacement service, considering recyclability of decommissioned facility's parts 10.2.2 Ensure a smooth transition from old to new service 10.3.1 Ensure that new service provides local employment opportunities where possible