SFD Promotion Initiative

Durban
South Africa

Status Final

This SFD Report was created through field-based research by Pollution Research Group (PRG) as part of the SFD Promotion Initiative.

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SFD Promotion Initiative

sustainable sanitation alliance

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On behalf of Federal Ministry for Economic Cooperation and Development

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WORLD BANK GROUP Water

wsp water and sanitation program

WEDC

Loughborough University

CSE

eawag aquatic research

Sandec Sanitation, Water and Solid Waste for Development

Bill & Melinda Gates foundation

SFD Report Durban, South Africa, 2016

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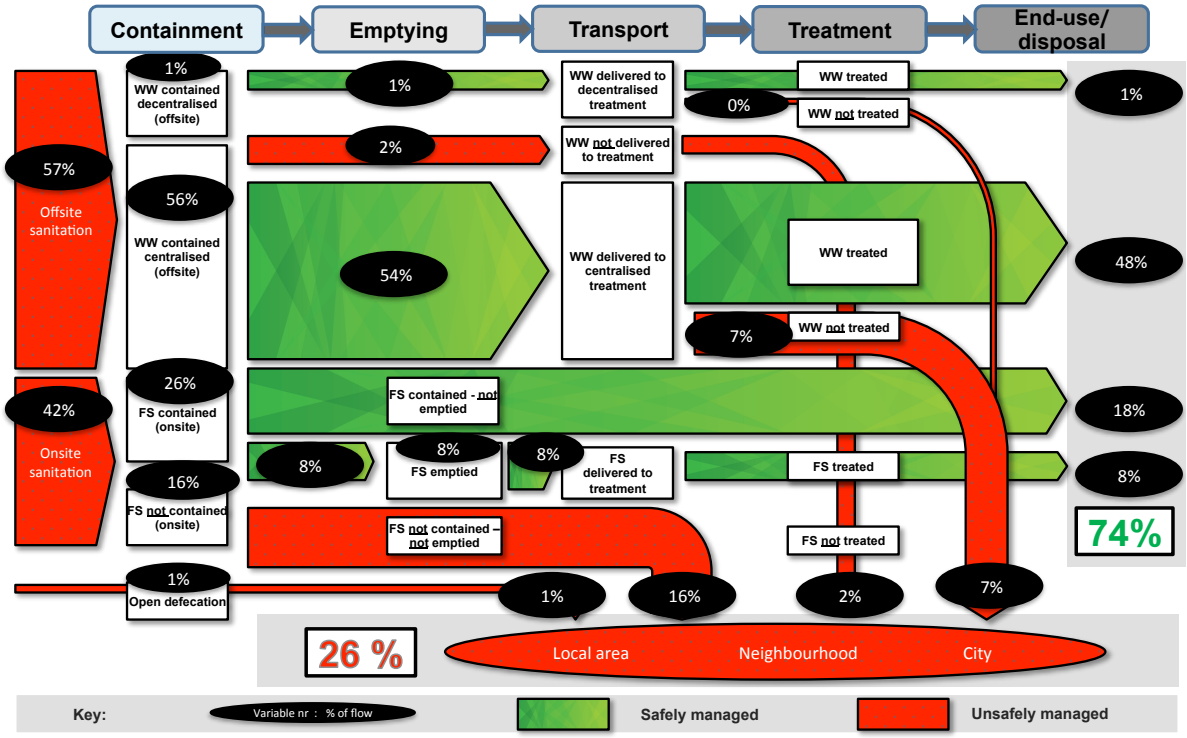
1. The Diagram

Durban, South Africa 26.04.2016
Field based assessment

Status: Final



2. Diagram information

Desk or field based:

This is a field-based study

Produced by:

This Shit Flow Diagram (SFD) was created through a field-based research by the Pollution Research Group (PRG) from the University of KwaZulu-Natal (UKZN) as an internship project for the final requirements of the Integrated Water Resource Management Masters program at McGill University.

Collaborating partners:

EThekwini Water and Sanitation Municipality (EWS)

Eawag: Swiss Federal Institute of Aquatic Science and Techology; Sandec: Department of Sanitation Water and Solid Waste for Development

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3. General city information

The city of Durban is managed by the eThekwini Municipality, which covers a wider area including 55% urban and 45% rural sectors. This area was chosen for the SFD analysis as it has a central public municipality responsible for managing and supplying basic sanitation services to the entire region.

In 2015 the population was estimated from projections of the last census count in 2011 as being approximately 3.55 million people (eThekwini Municipality, 2015a). Most of the influx of people to the city accumulate in the peri-urban and rural areas due to more affordable land in the traditionally owned rural areas and due to the historical distorted urban planning arrangements from the Apartheid era (eThekwini Municipality, 2015b).

The informal settlements are scattered all over the city and are situated mainly on steep land or flood plains which are high risk areas and present a challenge to service delivery and infrastructure development (eThekwini Municipality, 2015a).

4. Service delivery context

National policies and legislation specifically focused on sanitation exists to guide the delivery of these services in an equitable and fair manner, including the policy on free basic services for all (Department of Water Affairs and Forestry, 1994). There are clear policies and guidelines that have been adapted at a local municipal level that make the city primed for good sanitation service delivery, although 17% of the population remains unserved with basic toilet and hand-washing services (Gounden, 2016). Because of this the eThekwini Water and Sanitation (EWS) municipality largely provides the service delivery in sanitation throughout the sanitation chain, although private enterprises (alongside EWS paid services) are responsible for the collection and transport of faecal sludge (FS) from septic tanks and the operation of private decentralised treated plants and landfills.

The lowest acceptable form of sanitation system set by EWS is the dry urine diversion (UD) toilet, but the goal is to allow for everyone to achieve waterborne toilet systems (eThekwini Municipality, 2015a). There are goals and plans in place to improve the access to sewers, increase indigent access to basic sanitation (even if that means the use of communal ablution blocks as a temporary solution), and to upgrade the treatment facilities as well as the sludge disposal/reuse facilities. There are few clear goals on maintaining or upgrading the expanding sewer network. There are procedures in place to implement sustainable FS management for the growing number of on-site containment systems. The emptying services that are provided free of charge by the municipality are still failing at keeping up with the growing number of people. The private sector services are becoming more controlled and standardized as the relationship between these private organizations and EWS improves. There are also plans to use Black Soldier Fly (BSF) sludge treatment and Decentralised Wastewater Treatment System (DEWATS) passive treatment and to increase the capacity of the Latrine Dehydration and Pasteurization (LaDePa) treatment of ventilated pit latrines (VIP) FS. There are also plans to pelletize the sludge from the centralised treatment works.

There is extensive spatial GIS data for each household that is on the billing system for water services. There is also a GIS database that identifies areas of sanitation infrastructure/facilities as the household level. This is currently being updated with the UD toilet locations. An aerial photograph of the eThekwini area is taken each year and used to count the existing households that have access to improved toilet facilities in order to estimate the backlog figures. Permits and licenses allow for monitoring of the private septic tank emptying services as well as the decentralised treatment works, known as package plant. Regular monitoring is carried out in all the rivers, the estuaries and around the coastal region to assess the environmental impact of the effluent from the wastewater treatment works (WWTW).

While many innovative designs are in the final stages of being developed to help reduce the proportion of unserved people in eThekwini, delays in the environmental impact assessment (EIA) process are preventing implementation. The municipality has been forced through the historical politics of the country to be in a reactive position rather than a proactive position in providing basic services, but they are using all of the resources available to them to try to make an impact in reducing it.

5. Service outcomes

In Durban, 74% of excreta is managed safely, with 48% coming from waterborne toilets on the central sewer network. The bulk of the excreta that is not safely managed is from the 17% of households that do not have improved toilet facilities or access to an emptying service (making up 16% unimproved, community-built pits that are not emptied or buried and 1% open defecation) as well as the estimated overflow from blocked sewer lines.

The containment systems for the 42% on-site sanitation are in the form of septic tanks, conservancy tanks (sealed tanks), UD toilets and VIPs. The UD toilets are considered in the SFD as sealed tanks when the faeces are collected for the BSF treatment or as ‘pits that are safely closed’ when the contents are buried safely on-site (the latter making up 18% of safely managed excreta).

Emptying and transport of FS from septic tanks, conservancy tanks and VIP toilets is well managed and considered to be a strong private and public industry, with VIP toilets sludge being treated and then sold as fertilizer pellets from the LaDePa treatment facility. The other FS is taken to the centralised treatment facilities where the FS is mixed with the liquid wastewater from the sewer network and is either sent out to sea through the sea outfall (considered safely disposed of by the legal regulations) or treated at the WWTW. This along with the small portion of UD toilets that

are sent to the BSF treatment make up 8% of the safely disposed of excreta.

While 56% of off-site sanitation is sent to the central sewer system, because of blockages that occur in the gravity driven sewer lines, it has been estimated that 2% of the excreta is not transported to the treatment works. This is estimated from assuming that there are 140 blockages per day on average, with trunk sewers equivalent to 60Ml/d fully blocked for an average of 14 hours (Gounden, 2016). There is little data on the flow through the trunk sewers; therefore this value could be improved with more knowledge on the system.

From the Green Drop reports and the annual average inflow to each central WWTW, it was estimated that 88% of the WW is treated effectively at these works, making 7% of the total excreta not safely treated on disposal (Department of Water and Sanitation, 2014). While there are sludge treatment methods for the wastewater sludge at all of the treatment works (aside from the Central and Southern works that utilize the sea outfall pipes to dispose of the sludge), there is little reuse currently and the sludge either accumulates in ponds or is dried and stockpiled. There is a project in place to implement a pelletizing contract to allow for reuse of the sludge at many of the treatment works (Dyer, 2016).

6. Overview of stakeholders

The municipal council delegates responsibility of the city services. Septic tanks, conservancy tank and decentralised treatment outside of the urban development area are the responsibility of the private household or developer (Dlamini, 2016; Wilson, 2016; Fennemore, 2016).

The municipal policy and practices document lays out the responsibility of EWS with regards to water and sanitation access and their role of providing those in need with free basic services. Sewer network maintenance and operation, wastewater and sludge treatment works and providing of toilets for low-income areas with collection and sludge treatment of these toilets is all under the responsibility of EWS.

Innovative designs and trial projects are carried out by external agencies such as the Pollution Research Group within the University of KwaZulu-Natal and other academic institutions. These external stakeholders work with EWS in order to develop better means of treatment, containment and management of the sanitation systems.

There are good policy and frameworks in place to identify the roles of the various players in sanitation services. The biggest challenge is servicing the rapidly increasing population and urbanized areas. This challenge also implies tackling corruption, addressing bottlenecks in the bureaucratic processes and working within budget constraints (Buckley, 2016; Dyer, 2016; Fennemore, 2016).

Key Stakeholders	Institutions / Organizations
Municipal Authority	eThekwini Water and Sanitation
Private Sector	Septic tank emptying companies and Package Plant companies
Academic Institution	Pollution Research Group from UKZN

Table 1: Key Stakeholders

7. Credibility of data

Data around the policy, plans and capacity increases were sourced from the numerous policy, legislation and framework documents available online. Estimations for the SFD were based on data and key figures provided by the key informants when interviewed. There were 13 key informant interviews done in order to gather the data required and gain a full understanding of all the sanitation systems. These interviews were almost all with the public water services authority EWS as they are responsible for majority of the systems along the sanitation chain.

Most of the values used for the SFD were derived from data records from the backlog figures that are counted off the aerial photograph from 2011. Some data was taken from the 2011 census and from GIS data from EWS.

Assumptions had to be made regarding the private septic tank and conservancy tank services and the package plant treatment abilities due to lack of contact personnel or a central data source. Assumptions also had to be made around the proportion of treated WW and the proportion of WW delivered to the treatment works, as these were gaps in the available knowledge.

In terms of estimation figures, the field study was essential for the development of this SFD study as the desk study revealed an abundance of knowledge on policy and

procedures, but very little on actual proportions of sanitation systems used.

8. Process of SFD development

The SFD study was developed with the active engagement of EWS, with hopes to integrate the development of a SFD into their regular reporting procedures. This engagement was done through one-on-one interviews with key divisions within EWS. No focus group discussions were performed.

One area of weakness in the estimations is regarding the proportion of WW that is not delivered to the treatment works due to overflow from blockages at pump stations. This figure should be further investigated to represent a more accurate description of the amount of waste actually delivered to the treatment works.

9. List of data sources

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Abbreviations

BSF	Black Soldier Fly
BORDA	Bremen Overseas Research and Development Association
DOH	Department of Health
DBE	Department of Basic Education
DEWAT	Decentralised Wastewater Treatment
DWS	Department of Water and Sanitation
EA	Environmental Affairs
EIA	Environmental Impact Assessment
EWS	eThekwini Water and Sanitation Municipality
FGD	Focus Group Discussion
FS	Faecal Sludge
FSM	Faecal Sludge Management
GDP	Gross Domestic Product
GW	Ground Water
HH	Household
IDP	Integrated Development Plan
LaDePa	Latrine Dehydration and Pasteurization
KII	Key Informant Interview
NGO	Non-Governmental Organization
NEMA	National Environmental Management Act
OD	Open Defecation
PPE	Personal Protection Equipment
PPP	Public Private Partnership
PRG	Pollution Research Group
ZAR	South African Rand

SIP	Strategic Infrastructure Plan
SFD	Shit Flow Diagram
UKZN	University of KwaZulu-Natal
WSDP	Water Services Development Plan
WSA	Water Services Authority
WSP	Water Service Provider
WSP	Water Stabilization Pond
WT	Water Table
WW	Wastewater
WWTW	Wastewater Treatment Works

1 City context

This Shit Flow Diagram (SFD) report presents results from field-based research done in the city of Durban and the surrounding areas within the eThekwini Municipality in South Africa. This area is approximately 2300km^2 and includes both rural and urban districts (eThekwini Municipality, 2015a).

Durban was ranked the 3rd most populated city in South Africa in the 2011 National Census (Statistics South Africa, 2011). According to the 2011 National census, the population of eThekwini was 3.4 million people, which is just over a third of the KwaZulu-Natal province population (eThekwini Municipality, 2015a). The population of South Africa was found to be 54 million (Statistics South Africa, 2014). Figure 1 shows that the population is concentrated in the Central (34.4%) and Northern (33.6%) regions, with the South and Outer West holding 22% and 10% of the population respectively (see Figure 10 for layout of the regions in Appendix 5) (eThekwini Municipality, 2015a). The population pyramid is that of a developing population, with high birth rates and high infant mortality rates with relatively short life expectancy (eThekwini Municipality, 2015a).

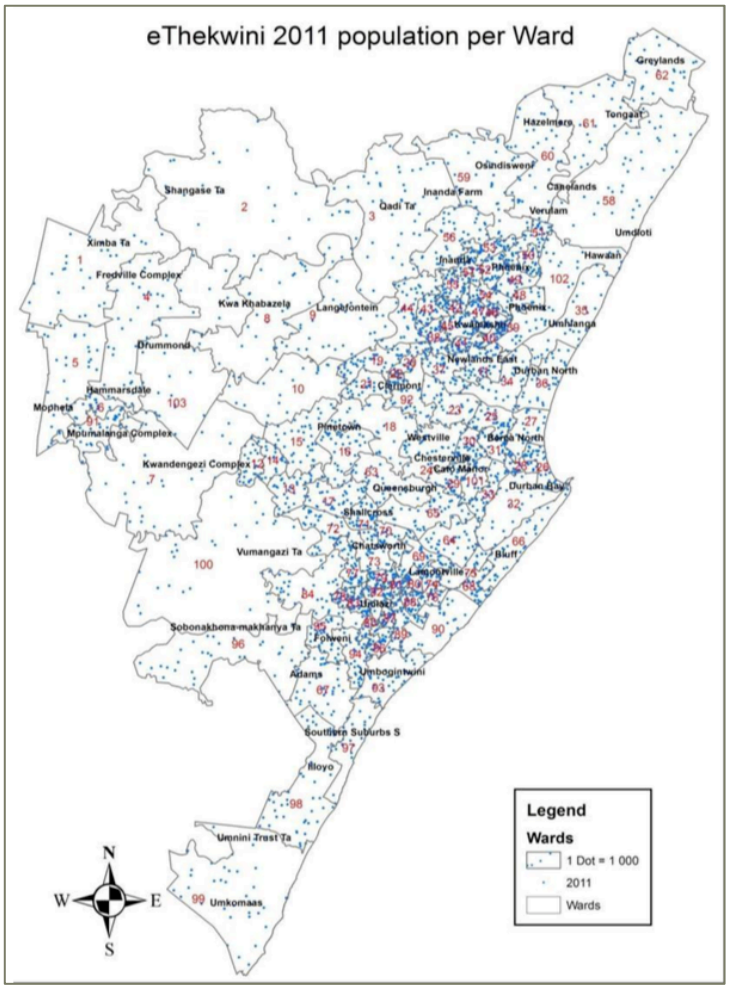

Figure 1: Population density in eThekwini (eThekwini Municipality, 2015a)

The rural area makes up 45% of the region, which the peri-urban and urban areas make up 30% and 25% respectively (eThekwini Municipality, 2015a). The city of Durban experiences significant urbanization from the rural areas, other cities and town in the country and from other countries, especially from other parts of Africa (eThekwini Municipality, 2015a). The population growth between the 2001 and 2011 census showed an increase of 1.13% (eThekwini Municipality, 2015a). There is a large amount of traditional land holdings in the rural areas under the Ingonyama Trust, which presents a challenge with land and urban management and service provision (eThekwini Municipality, 2015a). With both rural and urban landscapes, there is a wide range of settlement types and there has been an increase in urbanization and settlement growth on the urban periphery and in the rural areas (eThekwini Municipality, 2015a).

The number of households counted in the 2011 census were 956 713 although the aerial photo count accounts for only 945 910, and this is where most of the figures regarding proportion of sanitation type used are derived (eThekwini Municipality, 2015a) (EWS, 2016). South African cities have an unusual density distribution in their cities due to the warped urban design strategies of the Apartheid government in the past, with population densities rising with distance away from city centres, resulting in marginalized and poor communities situated at some distance from the central services (see Figure 11, Appendix 5) (eThekwini Municipality, 2015b). The metropolitan area has an overall density of 4du/ha (dwelling unit per hectare).

The topography is typically characterized as steep and dissected in the eThekwini area, with 90% of rural land having hilly and rugged terrain (eThekwini Municipality, 2015a). The informal settlements are scattered all over the city and are situated mainly on steep land or flood plains which are high risk areas and present a challenge to service delivery and infrastructure development (eThekwini Municipality, 2015a). The area is already prone to flooding, and this is expected to increase with the effects of climate change (O'Donoghue, 2014). EThekwini is located on the Eastern seaboard of South Africa (eThekwini Municipality, 2012a). The climate is characterized as hot Mediterranean subtropical with a high-pressure system (ClimaTemps.com, 2015). The total annual precipitation averages 828mm and the monthly averages can be seen in Figure 2 (ClimaTemps.com, 2015).

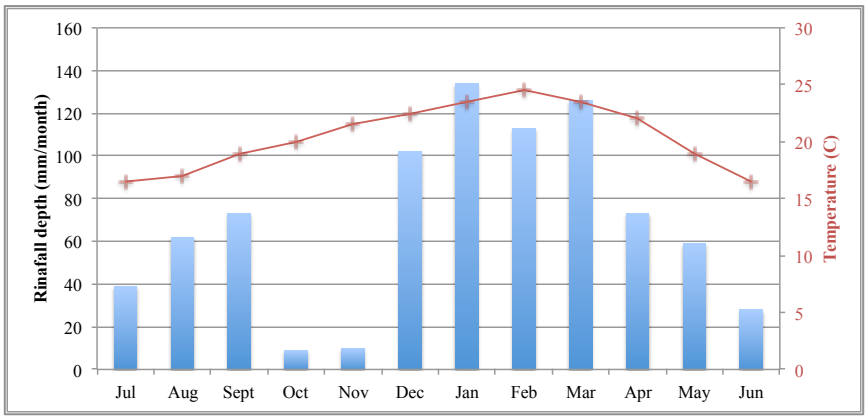

Figure 2: Monthly rainfall and temperature averages for Durban (ClimaTemps.com, 2015)

2 Service delivery context analysis

2.1 Policy, legislation and regulation

2.1.1 Policy

The South African Bill of Rights states that every citizen has the right to access to basic water and inherent dignity along with the right to an environment that is not harmful to their health or the wellbeing of their future children (Department of Water Affairs and Forestry, 1997). South Africa is unique in that sanitation has been interpreted as a legal right under the Water Services Act 108 (1997). From this Act, the right to basic sanitation is integrated into the White Paper on Basic Household Sanitation (2001) and the Strategic Framework for Water Services (2003), which updates the White Paper on Water Supply and Sanitation Policy (1994). These policies were the first to set out the free basic water and sanitation services policy that was announced in 2000. Other important national policies include the National Environmental Management Act 107 (NEMA) and developed from this act is the Sectorial Environmental Management acts and numerous more specific legislation such as the Integrated Coastal Management Act and the Waste Management Act (South Africa, 1998). These policies are then integrated down to provincial and local governmental legislation through the Municipal Structure Act 117 (1998) and the Municipal Systems Act 32 (2000). At this point, the municipalities and provincial government departments are responsible for setting up their own policies that need to be in-line with the national documents, and develop strategies to achieve these policies.

The Water Services Act 108 lays out that sanitation refers to the principles and practices relating to the sanitation chain (collection, removal, disposal and treatment) of human excreta and that sanitation is more than simply waterborne sanitation, but is linked to dignity, hygiene, behaviour and the people (South Africa, 1997). Sanitation is seen as having both hardware (infrastructure) and software (promotion of health and hygiene) and in serving the people of South Africa; the society and environmental impacts have a significant role (South Africa, 1997). This act and the policy documents were created out of a need to acknowledge and correct the injustices of the Apartheid era in South Africa, where significant divisions were made through basic service provision, and these policies aim to enhance equity in the provision of water and sanitation to correct this (Department of Water Affairs and Forestry, 1997). The White Paper on Basic Household Sanitation reiterates the need for community participation in decision-making around sanitation and links sanitation to health, the environment and socio-economic development due to the spread of diseases, abundant nutrient contamination in water systems and the economic and social cost of poor sanitation respectively (Department of Water Affairs and Forestry, 2001). While the free basic water policy was announced in 2000, indicating that 25 l/ca/day of potable water is required within 200m of every household, the free access to sanitation policy was developed later within the Strategic Framework for Water Services, although it is not clear what the definition of free basic sanitation services are at this level (Department of Water Affairs and Forestry, 2003).

At the municipal level the definition of what the local authorities are willing to provide for free for their citizens is established more firmly as they are the primary sites for delivery of services in South Africa (eThekwini Municipality, 2015a). EThekwini Water and Sanitation water utility in Durban was the first municipality to offer free water services to the poor that

was later adopted into national policy (Galvin, 2012). The Policy and Practices of eThekwini Water and Sanitation document lays out the policy of the water service provider regarding regulations of water services, the tariff structure and the rights of the water services authority (eThekwini Municipality, 2012b).

There are 14 guideline documents that focus on the specific regulations, application and design procedures for all forms of sanitation systems from containment through to treatment and reuse. All of these policies and regulations can be found easily on the EWS website. The guidelines cover the following areas: sewer connection for developers, sanitation provisions to communities, monitoring procedures on sewage disposal and treatment, re-use of treated effluent from treatment works, the treatment and disposal of sludge at treatment works, the design and approval of sub-surface onsite disposal, subdivision approval for wastewater disposal, submission of alternative on-site waterborne sanitation systems, the use of uPVC sewer pipes in the urban area, road tankers discharge to sea outfall, installation on privately owned low volume domestic sewage treatment systems and the design and construction of toilets where basic level of services are appropriate. It is clear that each step in the sanitation chain from appropriate income level containment supply through to transport and disposal are considered in the municipal policies and guidelines.

The eThekwini Municipality has developed water supply and sewage disposal bylaws that specify the laws of the council to manage the water and sanitation services that the city provides (eThekwini Municipality, 2011). The Sewage Disposal Bylaws lay out the terms for use of the sewage disposal system as well as the payment calculations for the sewage service (eThekwini Municipality, 1999). There are also clear water and sanitation tariff structures that have been developed and can be easily accessed at the eThekwini Municipality website.

2.1.2 Institutional roles

In the National Water Services Act no. 108, it is stipulated that the management of water as a resource is a local government responsibility (South Africa, 1997). The eThekwini Municipality is the Water Service Authority (WSA) and the eThekwini Water and Sanitation Municipality Unit (EWS) is the Water Services Provider (WSP) for the municipal area (eThekwini Municipality, 2012b). EWS aims to provide equitable services that are both economically sustainable and cause no detrimental impacts to the environment and the society it serves, as it is their constitutional responsibility (eThekwini Municipality, 2012b). The structure of EWS is laid out in the organogram in Figure 3. The city of Durban and the surrounding areas have a centralised, formalized public sector system.

The municipal policy and practices document lays out the responsibility of EWS with regards to water and sanitation access and their role of providing those in need with free basic services. The eThekwini Municipality has an established City Planning Commission, with an advisory think-tank body in order to help the municipality achieve long-term goals (Frankson, 2015). The City Planning Commission comprises of part-time external commissioners who are highly skilled and experienced and can contribute towards ensuring the development and efficient functioning of the city (Frankson, 2015). Sewer network maintenance and operation, wastewater and sludge treatment works and providing of low-income toilets with collection and sludge treatment of these toilets is all under the responsibility of EWS.

The council delegates responsibility in the city services; and in Durban, septic tanks, conservancy tank and decentralised treatment outside of the urban development area are the responsibility of the private household or developer (Dlamini, 2016; Wilson, 2016; Fennemore, 2016). The ownership, management and operation of landfills and agricultural land that sludge is disposed to are also the responsibility of the private companies that own the land.

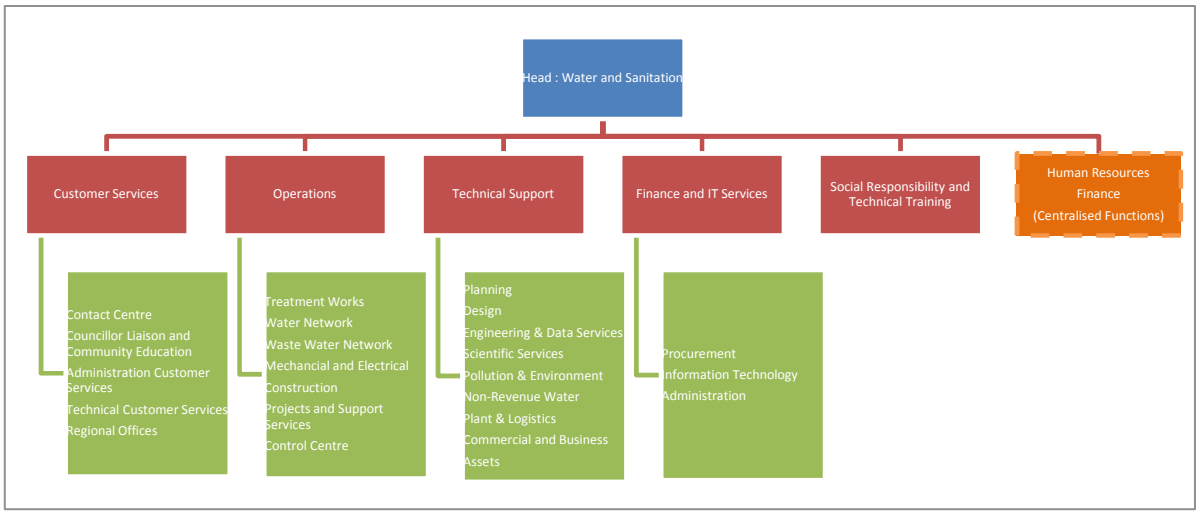

Figure 3: eThekwini Municipal Water and Sanitation Unit (South Africa, 1997)

While there is good policy and frameworks in place to identify the roles of the various players in sanitation services, the biggest challenge is catching up to the rapidly increasing population and urbanized areas with the required services and working through challenges such as corruption, delays in the bureaucratic processes and budget constraints (Buckley, 2016; Dyer, 2016; Fennemore, 2016).

Part of the problem with mass urbanization in the peri-urban and rural areas of the municipality is due to the traditional land ownership under the Ingonyama Trust. The Trust was established in 1994 in terms of the KwaZulu Ingonyama Trust Act (no.3 KZ of 1994), which entitled the Trust to hold the land previously owned by the KwaZulu Natal Government for the benefit and management of the people living on the land (Ingonyama Trust Board, 2016). The land owned under the Trust is not required to adhere to the same rules of land ownership and title deeds as the metropolitan land owned by the municipality, which means that development can progress largely unchecked while remaining within the area that the municipality is responsible to provide services (Dyer, 2016; Ross, 2016). This becomes problematic when land is developed in contradiction to the services development, making it difficult for the municipality to maintain their services, provide new services to the rapidly developing area and to control the urban sprawl in these areas. Due to the highly political and sensitive nature of these land agreements, it is not an area that is addressed often.

2.1.3 Service provision

There is a strong enabling environment in the eThekwini Municipality area for excreta management. Clear policy and planning is in place; there are providers that are known in the sanitation system and financing partners in place. The sludge management and treatment field is still developing, but is starting to become a more stable system. The Policy and

Practices document lays out the level of service provision that is set by the city. It is stipulated that the sanitation level should match the water service level, which is determined by the financial situation of the household, as well as the location with regards to urban facilities and the existing water supply or existing sanitation system (eThekwini Municipality, 2012b).

It is the responsibility of the Department of Health (DOH) and the Department of Basic Education (DBE) to ensure that toilets are built and maintained in schools, but EWS has been appointed as an implementing agent under a memorandum of agreement to assist in providing both water and sanitation services to schools that do not have functioning services (Gounden, 2016). This is an area that is often problematic due to the lack of skills and follow-through from the DBE on a local level.

EWS has the primary responsibility of delivering on-site and sewerage sanitation services for households within the eThekwini area, but exceptions regarding areas of responsibility are stipulated in the Water Services Development Plan (eThekwini Municipality, 2012a). While the sewer network and centralised treatment works operation and maintenance are the responsibility of the water and sanitation municipality, all piping to and operation of low-volume, decentralised package plant treatment facilities are the responsibility of the owner (eThekwini Municipality, 2012a). Developers of new package plants are required to have a financial guarantee to the municipality of a sum of 1.5 times the package plant cost (design, installation and commissioning), which helps reduce the outcome of an ineffective treatment facility under the responsibility of the owner with no funding to enable compliance with the effluent standards of the General Limit Values (eThekwini Municipality, 2005) (Fennemore, 2016).

The septic tank and conservancy tank emptying and construction services are specified to be within the private sector and so are only within the municipal system with regards to regulation compliance, licenses and permits for the tankers and tariffs for treatment of the FS in the municipal treatment facilities; although EWS does offer this service for an assigned tariff (Dlamini, 2016). The sludge and liquid effluent should be taken to a centralised treatment facility that accepts sludge, (these are all operated by EWS). This is a procedure that is encouraged and enforced through permits to septic tank companies, but has in the past been a problematic area (Ross, 2016; Ncgobo, 2016).

Treatment of wastewater and sludge are the responsibility of EWS. The National policy lays out effluent standards that are required to be met through treatment. The design of the treatment facilities is guided by the national building codes. The environmental restrictions around the estuaries, which are labelled as sensitive areas, limit the capacity development of the treatment works (Fennemore, 2016). The EIA procedure, while providing a service in limiting detrimental environmental impacts in new projects, also delays and limits the innovative approach to treatment due to the lengthy and slow bureaucratic process of attaining approval (Buckley, 2016).

Outside of the sewer reticulation network, decentralised treatment facilities are used and it is the responsibility of the HH to manage, maintain and pay for the services from the private package plant owners. Although the standards and regulations that the package plants need to follow are set by EWS. There is involvement and stakeholder engagement that occurs

annually between the municipality and these companies, but this is a developing area (Ncgobo, 2016).

2.1.4 Service standards

The policy documents clearly lay out the service standards expected from the municipality and the standards regarding the design and construction of septic tanks, conservancy tanks, sewer networks and treatment levels before discharge.

The urban development line, which shows the divide between where waterborne sewerage and UD toilets systems are implemented, can be seen in Figure 4.

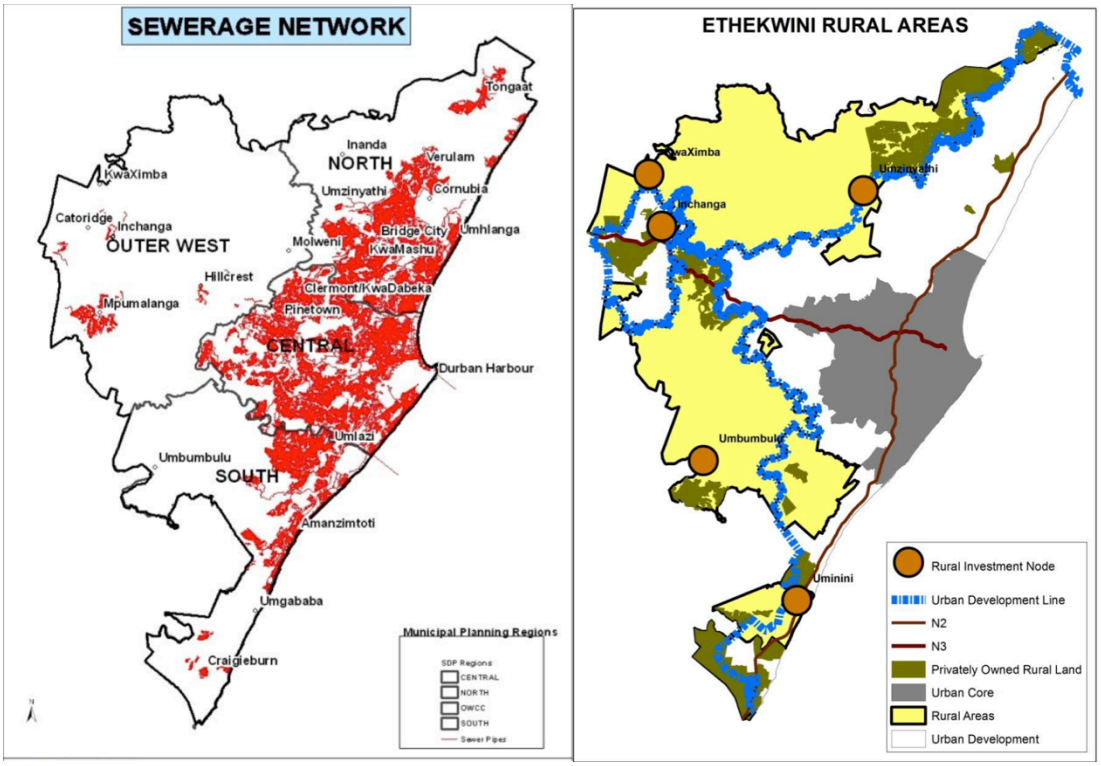

Figure 4: Sewerage network and Urban Development Line dividing urban from rural areas (eThekwini Municipality, 2015b)

Groundwater risk should not present a problem if the procedures for implementing boreholes, VIP toilets and septic tanks are followed, which is most often the case (Wilson, 2016). No underground containment system is permitted in the event of groundwater contamination risk, but in informal rural areas and in some cases where corruption might occur, these regulations could be ignored. This is not a common occurrence as there are very few boreholes in the area due to the nature of the soil type (Fennemore, 2016).

Septic tank design needs to follow guideline 6 from the municipality that is in keeping with the standardized designs in the SABS 0400 codes (eThekwini Municipality, 2001). Conservancy tanks require a minimum capacity of 7000L and a 7-day retention by the policies of eThekwini Municipality, although this form of on-site sanitation containment is being phased out and new conservancy tanks are not longer allowed (eThekwini Municipality, 2012b).

The sewerage disposal bylaws indicate the need for permits by private companies to discharge tanked sludge in municipal treatment works (eThekwini Municipality, 2015).

Guidelines 10 lays out the standard procedure for applying for a permit to dispose of septic tank and conservancy tank sludge transported by tankers by private companies to the municipal treatment works. These guidelines ensure that permitted septic tank companies are financially liable for the sludge delivered to the treatment works (which is currently priced by tanker load). The guidelines require that the vehicles and equipment comply with safety standards and give clear indication that the type of effluent is domestic waste only (eThekwini Municipality, 1996). Fines are issued and permits revoked if permitted septic tank companies are found to be dumping the sludge illegally. The public is encouraged to use permitted companies, although this is not a major focus of the municipality (Fennemore, 2016).

EWS manages and operates the 27 centralised treatment facilities that exist in the metropolitan area. Water quality limits are prescribed in the Policy and Practices document along with the minimum requirements for the treatment plant installation (eThekwini Municipality, 2012b). There are standard in the policies and frameworks such as the Green Drop Reports and River Quality reports that allows for these standards to be monitored and maintained. The standards of these WWTW and the package plants are monitored by EWS to ensure compliance. The decentralised, privately owned package plants are required to operate at specified standards, but few actually do at present (eThekwini Municipality, 2012b).

There are clear quality standards laid out in the South African Water Quality Guidelines for Coastal Marine Waters that measure the recreational water quality as a guide rather than assessing the quality of the effluent being discharged, as this provides better insight into the assimilation capacity of the receiving environment and prevents pollution at this point (Department of Environmental Affairs, 2012). One of the conditions of the sea outfall discharge permit is that the municipality must implement and report on an environmental monitoring programme that evaluates the impacts on the receiving environment (CSIR, 2015).

The management and standards around the package plant development is not a main focus of the municipality, and it is still a debated field with regards to the quality of treatment that the package plants produce (Fennemore, 2016).

2.2 Planning

2.2.1 Service targets

While the Millennium Development Goal of reducing the percentage of people without access to sanitation by a half was achieved by 2015, the self-set target of universal sanitation access by 2014 was not reached and revealed a potential problem arising from the idea of actual service provided to the people versus simply supplying toilets that indicate access is achieved (Tissington, 2011). Currently the goal is to increase to 90% the portion of households with access to functional sanitation services by 2019, which is up from 84% in 2013 (Republic of South Africa, 2014). There are a number of strategies in place that define the National and District level targets for sanitation.

The targets throughout the national, provincial and local strategies aim towards reducing the backlog in providing basic sanitation services to all. The backlog of sanitation infrastructure is

159 603 households, and the target in the current Integrated Development Plant (IDP) is to deliver between 8000 to 10 000 units per year (determined by budget constraints) to address the backlog in 18 to 23 years (eThekwini Municipality, 2015a). In Plan 3 (Creating a Quality Living Environment) of the Municipal Eight Point Plan, the target is to upgrade informal housing, in which a quarter of the municipal population reside, to ensure access to sanitation and basic services and in the interim provide communal ablution blocks while the backlog is being addressed (eThekwini Municipality, 2015a). This plan aims to provide basic services to many rather than a high level of services to few (eThekwini Municipality, 2015a).

One of complications in identifying the targets and strategies around sanitation specifically and monitoring its progress is due to the fact that sanitation is connected to so many areas in the national and local government sectors aside from water and sanitation. Sanitation goals are embedded in housing development planning, health development and infrastructure, education infrastructure, spatial urban planning, agriculture and the environment, and many of these departments do not focus on the sanitation aspect specifically in their target goals.

While the Policy and Practices document states that the long-term aim is towards waterborne systems, there are no clear targets in place for upgrading sewer lines aside from the budget breakdown of these planned upgrades in the capital budget section of the Water Services Development Plan (eThekwini Municipality, 2012b; 2012a). The expected load increase that the treatment works need to meet for 2030 scenario and the infrastructure plans for the 27 treatment works are laid out in the Water services Development Plan (eThekwini Municipality, 2012a).

2.2.2 Investments

Funding for basic sanitation services comes from the equitable share grant from National Treasury and there is also a tariff structure to cross-subsidize the indigent services (eThekwini Municipality, 2015a). Figure 12, in Appendix 5, shows the income received by the municipality for operating costs in sanitation for 2014-2015. There is a clear distinction in the development plans between funding for water projects and sanitation projects. The eThekwini Municipality has a strong city sanitation policy and budget, with many years of experience working with private public partnerships in the sanitation field.

Sanitation projects are assigned 11% of the total capital budget at R641.7 million for 2014/15 as can be seen in Figure 5, but in the Water Services Development Plan the capital budget for sanitation is predicted to be R962 million (eThekwini Municipality, 2015a; 2012a). Further breakdown of the budget exists for only some aspects of the sanitation such as the treatment works upgrades and ablution blocks, but the specific allocation to sanitation is unclear (eThekwini Municipality, 2012a).

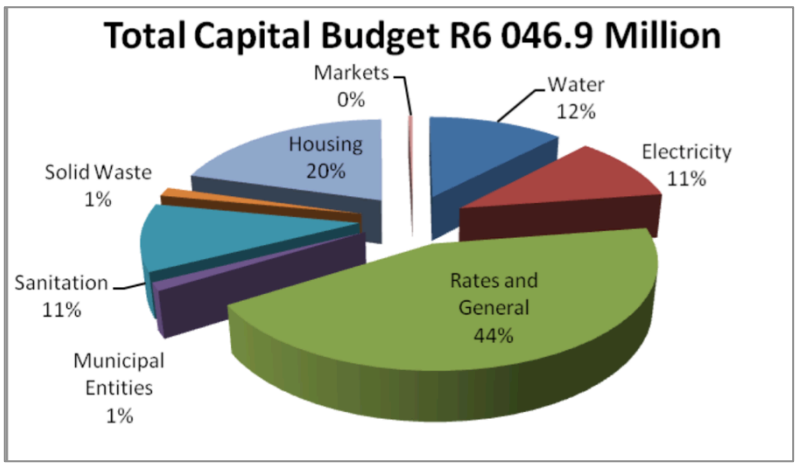

Figure 5: Capital budget for 2013/14 - 2015/16 for eThekwini Municipality (eThekwini Municipality, 2015a)

2.3 Reducing inequity

2.3.1 Current choice of services for the urban poor

Where there is access to the sewer network, waterborne sewerage with flush toilets will be provided by the municipality through formal housing development to either semi-pressure or full-pressure water supplied households (eThekwini Municipality, 2012b). Due to the backlog in developing these housing units, communal ablution blocks are installed in order to provide waterborne sanitation (with one block set up with a dry VIP toilet system) to serve 75 surrounding households (at a maximum distance of 200m) as a temporary means of sanitation service for households that are not on the housing development list and will not be formalized in the near future (eThekwini Municipality, 2012b). While this is the level of sanitation service that most of the South African public prefer, there is not a high range of choice for urban poor sanitation that might be more appropriate for mass development. The cost of this waterborne sanitation is free if the water used in the household is less than the allotted 9kL per month (eThekwini Municipality, 2012b).

In low-income areas that lie outside of the urban development line and therefore outside of the sewer reticulation network, the minimum level of basic sanitation is the urinary diversion (UD) toilet (eThekwini Municipality, 2012a). While VIP toilets exist in some rural areas in eThekwini, the municipality has specified that no more will be built unless under unusual circumstance with good motivation (eThekwini Municipality, 2012b).

Trial projects are currently underway to test the applicability and feasibility of using pour flush or low-volume flush toilets as an alternative to both the UD toilet and the flush toilet for urban poor housing (Wilson, 2016). The UD toilet design could be adapted to work at a pour-flush toilet in order to save on infrastructure development costs (Buckley, 2016).

EWS has taken the responsibility of emptying the VIP and UD toilets that exist in the area once every 5 or 2 years respectively, as well as supply required UD toilets to rural areas. It is also within their responsibilities to treat the collected sludge from these facilities or contract a private organization to perform this task for them (eThekwini Municipality, 2012a). The municipality has also taken on the costs of treatment of the sludge from the VIP toilets by means of the innovative LaDePa facility that is operating by a private contractor (Wilson,

2016). These services have been set up in order to allow for the commitment of free basic services to be met.

While the level of free services is a powerful means of allowing for low-income households to acquire access to improved sanitation, this system relies heavily on the ability for middle and high-income households to pay rates that cross-subsidize these costs. There is also a limitation in the fact that the basic level of urban poor sanitation is waterborne sewerage, when the mean to develop and expand the formalized housing is limited by budget and therefore creates an increasing backlog.

2.3.2 Plans and measures to reduce inequity

The key framework and strategic development plans that are compiled by the eThekwini Municipality are the Integrated Development Plan, the Spatial Development Framework and the Water Services Development Plan. These documents are requirements of the Municipal Systems Act no. 32 of 2000 and Water services act 108 of 1997. All of these plans are created every 5 years and are aimed at assessing the progress made on the municipal development mandate and to set targets for the current term of office (eThekwini Municipality, 2015a; eThekwini Municipality, 2015b; eThekwini Municipality, 2012a). In these frameworks, the key issues that are addressed in eThewkini municiplaity related to sanitation are the limited access to basic household services in informal settlements, the limited funding available to deal with the backlog of people unserved by basic sanitation and the inability for households to pay basic services due to high levels of poverty and unemployment (eThekwini Municipality, 2015a). From this framework it is clear that there is considerable effort going into reducing inequity through supply of basic services at the cost to the municipality.

The GIS division in EWS progressively monitors the urban growth and takes annual aerial photographs that are then analysed in order to count the number of houses that require sanitation and water services (Pietersen, 2016). These efforts are in place to try and get a better idea on the backlog in service delivery that the entire country faces (Tissington, 2011). There are plans to allow for more GPS coordination of UD toilets that exist in the municiplaity in order to monitor where sanitation has been provided and to follow up on the successful use of these toilets (Wilson, 2016).

A means of reducing inequity is by lowering the cost of services. Basic water and sanitation is provided free of charge, which means that no sewerage charge is levied if the water provided is less than 9kL per month, and beyond the urban edge UD toilets are provided free of charge with emptying plans every 2 years paid for by the municipality (eThekwini Municipality, 2012b). These systems are in place to encourage access to sanitation in order to improve the lives of the marginalized communities.

The municipality actively experiments with means of expanding and improving their services for emptying on-site sanitation and treatment of the sludge from these systems in a safe and financially sustainable manner. In the emptying of VIP and UD toilets, local contractors are used in order to provide economic upliftment of local companies in the indigent areas that require this service (Wilson, 2016). The development of Decentralised Wastewater Treatment System (DEWATS) by BORDA is in the final EIA stages of acceptance and should be used to treat wastewater in low-income areas outside of the sewer network area (Buckley,

2016). The sludge from these facilities would still need to be collected and treated at the wastewater works. There are a number of expansion projects that are awaiting acceptance in the EIA process. This results in significant bottlenecks; a systemic problem that needs to be addressed. Another project that is in the final stages of being rolled out is the Black Soldier Fly (BSF) treatment facility that will run as a trial project until it is fully implemented. The Black Soldier Fly project will receive a significant portion of the sludge from the UD toilets and convert the sludge into a viable protein feed product for purchase from livestock farms (Wilson, 2016). These projects are focused on improving the treatment methods for low-income sanitation systems and provide more cost effective treatment solutions to reduce inequity in the city.

2.4 Outputs

2.4.1 Capacity to meet service needs, demands and targets

There are plans for development and capacity growth in most of the sanitation systems and along the sanitation chain in order to keep up with the rapidly increasing population in the urban area. The municipality has a shared focus over the entire sanitation chain, and while it manages to maintain the services to the rate-paying affluent community, its focus lies in providing access to sanitation to the indigent and unserved population.

UD toilets continue to be provided and surveys are done to assess the number of UD toilets per household as often multiple toilets are required for multiple wives in traditional households in the rural areas (Pietersen, 2016). Ablution blocks are being provided to try and fill the gap that exists between urban growth and housing development projects (eThekwini Municipality, 2015a). The municipality is continuously in a reactive position and it is anticipated that the interim services for informal settlements could overtake the housing delivery programme (eThekwini Municipality, 2015b). There are also education initiatives and information pamphlets created to educate the public on the approriate use and acceptance of UD toilets.

Clear plans are not in place to ensure upgrading or maintenance on the sewer lines, and this might present a problem in the future with more formal housing being connected to the sewer network.

The centralised treatment facilities have significant upgrades and capacity increases planned with projects set to improve the level of treatment and reduce the inflow of storm water that causes overflow and blockages during high rainfall (Dlamini, 2016; eThekwini Municipality, 2012a). There is a plan currently in development for pelletization of sludge for reuse on agricultural land (Dyer, 2016). This program will pelletize sludge for reuse on agricultural land from the Southern works, Umbilo works, Northern works (still to be confirmed), Amanzimtoti works, Kinsburgh and Isipingo works (Dyer, 2016).

There is also capacity development in the treatment of sludge collected from VIP toilets and UD toilets with 3 more LaDePa treatment facilities being commissioned and the Black Soldier Fly treatment facility coming into action in the near future (Wilson, 2016). The DEWAT off-the-grid treatment facilities are in their final stages of acceptance as a viable treatment design for peri-urban low-income areas that should increase the treatment of wastewater,

although the sludge will still have to be collected and sent for treatment at the centralised works.

2.4.2 Monitoring and reporting access to services

The billing system has been made into spatial data and can be used alongside the houses counted by aerial photography to calculate the number of houses that are not receiving sanitation services (eThekwini Municipality, 2012a). This is an exercise done by the GIS department at eThekwini, but the method used to count the unserved houses assumes that every household within 200m of a water source, or some form of toilet facility, is considered served (eThekwini Municipality, 2015a; Pietersen, 2016). This method may not properly account for the real number of households that are lacking services.

UD toilets are being delivered to rural indigent households. Because of high levels of disgust in handling human faeces when the toilets were initially required to be emptied by the households, many of these toilets have been abandoned or converted into informal septic tanks that do not follow the SABS 0400 design codes (Wilson, 2016). There is currently a project in place to map the existing and functional UD toilets and those that have been converted into other containment systems (Wilson, 2016). This project will provide the municipality with more accurate figures on the functioning level of the UD toilets, although they already have a clear indication from their recent emptying service of the number of toilets that are being used regularly.

The ablution blocks that are in place are all metered and are monitored and managed by municipal employees (Pietersen, 2016).

In the emptying step of the sanitation chain, septic tanks are encouraged to get permits in order to deliver sludge to the municipal treatment plants. This is a form of monitoring these companies and ensuring that they regulate their safety standards and processes. The tankers need to submit a pink form that details the number of tanker volumes that have been discharged and the time of discharge at the treatment works, which is used for monitoring and billing purposes. (Ncgobo, 2016).

For the emptying services of the VIP toilets, the payment structure is set up that eThekwini will pay the emptying contractor on delivery of the sludge to the LaDePa treatment facility, which prevents illegal dumping in the environment (Wilson, 2016).

The sewer network pump stations are monitored for blockages, but due to unchecked connections of storm water into the sewer network, provide limited information that can be helpful in regulating and maintaining the sewer system. The upgrading of sewer networks and regular monitoring of these systems is a weak point.

The treatment works have good monitoring and regular reporting done on the influent and effluent quantity and quality. The Green Drop Regulation programme, which is a programme in place in all municipalities and water service providers in South Africa, aims to ensures that both monitoring and auditing of the treatment works is maintained and regular reports are developed (eThekwini Municipality, 2015a). This system allows for the assessment of the wastewater from source, conveyance through to treatment each year and publically rewards treatment facilities that are keeping up treatment standards (eThekwini Municipality, 2015a). These reports are aligned with the minimum monitoring requirements for treated effluence

that is laid out in the Policy and Practices Document (eThekwini Municipality, 2012b). Package Plant treatment works are encouraged to correspond with the municipality and are required by the guidelines to monitor their effluent to show that they are meeting the treatment standards (eThekwini Municipality, 2005).

In keeping with the sea outfall license, CSIR monitors and reports annually on the environmental conditions of the surrounding coastal area and organisms that could be affected from the disposal of domestic and trade effluent out to sea (CSIR, 2015). EWS also monitors the river quality in order to get a clear perspective on the areas where trade and domestic waste treatment might be causing contamination of the rivers in the area through illegal discharges, solid waste dumping, or poorly working wastewater treatment works (eThekwini Municipality, 2015a).

2.5 Expansion

2.5.1 Stimulating demand for services

The White Paper on Basic Household Sanitation calls for a demand-driven approach to sanitation through education and community empowering, but since 2003, the Strategic Framework for Water Services encourages a shift to more municipal driven, supply-focused sanitation projects (Tissington, 2011). While this means that more facilities and sanitation services are provided for people, there are also continued problems with vandalism and misuse of these municipally provided systems.

EWS has a multitude of brochures on the toilet systems they provide and there are hygiene and education campaigns that encourage safe and clean sanitation and enable EWS to understand the challenges of misuse and wastage (eThekwini Municipality, 2012a). The customer care facilities are available to the public to raise concerns and also to access the services that the municipality provides. The municipality acknowledges that non-payment and vandalism are acts that voice a concern for the marginalized members of the community (eThekwini Municipality, 2012a).

In the past eThekwini Municipality has been given the United Nations Public Service Award for improving transparency and for the delivery of services by creating a system that allowed for encouraging of paying customers by wiping significant debt (na, 2007).

2.5.2 Strengthening service provider roles

The emptying service of the VIPs is regulated to ensure that the contractor uses the correct safety equipment and procedures as the pits are emptied manually due to the cost effective nature given the difficult terrain and condensed nature of the informal settlements (Wilson, 2016). This strategy enables local development of skills in the informal areas and encourages local businesses and safe hygiene. If the VIP or UD toilets require emptying more often than what is provided by the municipality, then it is their responsibility to arrange and fund this activity (eThekwini Municipality, 2012a). It is the HH's responsibility to manage and fund the upkeep and emptying of septic tanks and conservancy tanks that exist in the area (eThekwini Municipality, 2012a).

The decentralised treatment facilities, which are known as package plants locally, have recently been encouraged to form a joint organization called SewPackSA, which allows for a

single correspondence and interaction with the municipality and allows for better regulation of the private industry (Ross, 2016). The private septic tank companies have also recently been encouraged to form more solid relationships with EWS and to buy into the permit process that allows for the tankers to be monitored and gives access to the municipal sludge treatment facilities (Ncgobo, 2016).

Treatment of the VIP sludge using alternative treatment methods such as the LaDePa is an example of EWS unit's innovative approach to sanitation management (eThekwini Municipality, 2015a). These innovative designs are often trial tested by smaller programs and companies by means of a Memoranda of Agreement that are able to get external, donor funding from global development agencies to develop (Pollution Research Group, 2015). One key stakeholder involved in these projects is the Pollution Research Group that works within the University of KwaZulu-Natal. The use of contracted companies to operate the LaDePa facility ensures the skills required to run the technology, but with the municipality paying for the sludge delivered to the treatment facility; there is an incentive to discourage illegal dumping of sludge after collection by the local contractors.

3 Service Outcomes

3.1 Overview

The eThekwini Municipality has one of the best delivery programs for basic services in Africa (eThekwini Municipality, 2015a).

The housing types are classified into formal, informal or rural areas with sub-types of single dwellings shacks, houses, flats, rural cluster homes (also known as Umuzi), backyard extension shacks and formal dwellings in informal areas (eThekwini Municipality, 2015a). There are predominantly formal houses, although there are a significant number of single dwelling informal shacks, and this sub-type of house is growing significantly. The population proportions would be slightly different from these dwelling proportions due to the fact that the occupancy rate in rural areas and cluster dwellings are larger than those in urban areas (eThekwini Municipality, 2012a).

Table 2: Breakdown of housing types in eThekwini Municipality (eThekwini Municipality, 2015a)

Type	Sub Type	Dwellings	Percentage of total
Formal	Houses	414357	44%
	Flats	110225	12%
Sub total		***524582***	***55%***
Informal	Single dwelling/ shack	265542	28%
	Backyard shack	48975	5%
	Formal dwelling in informal area	3096	0%
Sub total		***317613***	***34%***
Rural	Cluster	70317	7%
	Single dwelling	26949	3%
	Formal dwelling in informal area	6449	1%
Sub total		***103715***	***11%***
Total number of dwellings		**945910**	**100%**

3.1.1 Containment

It is reported in the 2015 backlog figures that 83% of the dwelling units in the eThekwini area have access to basic services such as improved toilets, hand-washing facilities and sewer access or safe containment and collection of FS. The remaining 17% of the population that are not provided with toilets or emptying services from the municipality are forced to use available facilities that they can find, defecate in the open or develop their own makeshift pit latrines that tend to contaminate the groundwater and surface water by runoff; but it is unclear what the divide is between these options. This backlog figure is calculated by counting the number of households that exist outside of 200-meter sewer network reticulation, which implies that there might be a larger backlog due to households not having access to the sewer within this limit. The backlog figure can be further divided into 22% rural backlog of units and 78% informal urban backlog, which shows that more of the unserved proportion might revert to informal unlined communal pit latrines rather than open defecation.

The containment systems that exist are waterborne flush toilets (71% of dwelling units), dry UD toilets (9%) and VIP toilets (4%). These systems combine to make the 83% of dwellings with access to basic improved sanitation services (84% due to rounding errors).

The systems that direct wastewater to separate centralised sewers are 48% of all households. Where sewerage is not available for more affluent homes, on-site privately owned sewage disposal systems are prescribed, such as septic tanks or decentralised package plants from private sewer lines (eThekwini Municipality, 2012b). In order to build a septic tank, the building standards call for a groundwater assessment to prevent groundwater contamination. Septic tanks and decentralised package plant treatment via private sewer lines are used by 11% of the dwelling units in the eThekwini area, most of which are formal houses in the peri-urban area. Where household sanitation can't practically be provided due to the nature of the informal settlement and in settlements that are not on the housing list for formalization, waterborne ablution blocks are provided for a 200m-radius access for 75 houses (12% of dwelling units in eThekwini have this system).

In rural traditional areas and in informal settlements, dry UD toilets are implemented. This makes up for 9% of dwellings. While only 6% of household UD toilets exist in informal settlements, the majority (94%) exists in rural traditional areas. The UD toilets have a soak away where the urine is diverted and the faecal matter is collected in either one or two chambers (the new UD toilets have a single vault because EWS will be emptying the vaults rather than letting them dry for household handling).

In some formalized non-rural peri-urban areas there are VIP toilets, which is a technology that is no longer provided. VIP toilets are used in 4% of dwellings.

3.1.2 Emptying Services

Recently, eThekwini Municipality has committed to emptying the UD toilets once every 2 years free of charge for the households, as there was a significant decline in use due to the taboo around handling human waste (Wilson, 2016). The municipality contracts local companies to manually empty the UD toilets and safely bury the dried faeces on site. Safe burial means that it is covered by soil so won't contribute to a health risk from runoff from the soil. The urine is diverted to a soak away. While there are still social acceptance problems with the UD toilets, the municipality has taken a strong stand to adopt this technology as their

minimum level and is using the emptying service as a compromise to encourage use of this toilet type. There may need to be reassessment on the committed emptying time, or an increase in contracts to provide the emptying service. In 9 months EWS has recorded emptying of just under 10% of the UD toilets (Pietersen, 2016). There is a trial currently in place whereby 20 m^3/d of dry UD sludge is delivered to a Black Soldier Fly Treatment facility where it is converted into protein feed for sale to live-stock famers (Wilson, 2016). This trial is currently in the process of being developed into a full-scale sludge conversion production system for a large portion of the UD sludge.

The 35 000 VIP toilets that exist in the rural areas are currently being emptied once every 5 years free of charge to the household by local companies that are contracted out by the municipality (eThekwini Municipality, 2012a). The pits are emptied manually with the use of specially designed long-handled spades and a modified Gulper as well as the appropriate personal protective equipment (PPE). The sludge from the VIPs is collected by truck, the solid waste is removed and sent to the landfill and the sludge is taken to the LaDePa treatment facility. On delivery of the sludge, the municipality pays the contractors. This payment on delivery structure discouraged illegal dumping of the sludge after collection. A household can determine how rapidly their pits fill depending on whether the pits are used to collect trash. If a household requires their VIP to be emptied after the free program service and before the next scheduled emptying, there is a tariff of R1429.82 charged to the homeowner, this is a means of discouraging misuse of the VIP toilets. Certificates are signed by the household on the emptying of their pits in order to monitor and report on the jobs completed. The pits are all mapped by GPS on the spatial system for EWS.

There are numerous private septic tank, conservancy tank and chemical toilet companies around the eThekwini area that manage and operate over 300 estimated vacuum tankers. There are 18 companies listed on the January log for delivery at all the treatment works where the sludge is treated with along with the sludge from the wastewater (Wilson, 2016). The tankers are typically 2 m^3 volume capacity and the Wastewater Treatment Works charge by the kilolitre (R50 per kL) based on full tanker loads delivered to the works (Fennemore, 2016). The permit system encourages the legal discharge of sludge collected by these private companies and illegal discharging of sludge is considered a criminal offense if caught (Ncgobo, 2016). Permits are available for the Hammarsdale Works, the Umhlatuzana Works, the Southern Works, The Amanzimtoti Works and the Phoenix works (Ncgobo, 2016). Septic tanks should be emptied every 3 years, but are most commonly emptied every 10 to 15 years (Ross, 2016). The EWS cost for a septic tank collection is R548.25 per load (or part thereof) (Ncgobo, 2016). The cost of private emptying of a septic tank is approximately R1200.00 with the dumping fee of R135.45 included in this price (Ross, 2016).

3.1.3 Transport by sewers

The number of households counted from the 2011 aerial photograph show that 71% of all dwelling units have a sewer connection. The sewer network is 8 134 km in length and the layout can be seen in Figure 13 in Appendix 7. While the sewer line is designed to be a separate sewer system, there are houses and properties that have linked storm water systems and sewer systems, which causes significant overflow during high rain.

Payment for sanitation from houses that use more than the basic level of water is charged by volume of water supplied to the house, which is calculated at 70% of the water used at the household (Pietersen, 2016).

The sewers require replacement and upgrading, but these goals and targets are not set in the development plans due to the overwhelming need to provide basic services for the indigent population with the limited resources available. Despite this limitation, this aspect of infrastructure maintenance should not be completely forgotten, as it will become more important as more households are added to the sewer network.

Standard sewer systems exist over the urban portions of the eThekwini area. These sewer lines use gravity to flow within their catchment area and are pumped via pump stations when sewerage needs to be moved into another catchment for treatment. In the Integrated Development Plan for 2015, it is reported that there were 53 780 sewer-spillages that occurred over the 2013 to 2014 year, which took an average time of 48 hours per spill event to attend to (eThekwini Municipality, 2015a). These blockages are caused by peak flows from storm water entering into the separate sewer system or from power failures to the pump station, which is a common occurrence in South Africa.

3.1.4 Treatment

Treatment of the wastewater from these centralised separate sewer lines is done by the 27 centralised wastewater treatment works that use various forms of treatment ranging from primary and secondary settlement treatment, extended aeration for the smaller plants, with one works (Southern works) doing tertiary treatment for reuse of the wastewater for industrial processes (Dyer, 2016). Details on the various treatment methods and the capacities of each works at each plant can be seen in Table 11 in Appendix 7. The centralised wastewater treatment works treat the wastewater that comes from the waterborne toilets linked to the sewer lines as well as the ablution blocks that are linked to the sewer system, making up 59% of dwelling units in the area.

The Green Drop Report for 2014 shows that 13 of the 27 treatment works have their annual average effluent quality compliance over 90%, nine works over 80% and two over 70% (Department of Water and Sanitation, 2014). The Northern Works achieved the lowest level of average annual effluent quality compliance at 55%, while also being 96% of the facility design capacity (measured as operational flow by design flow capacity) (Department of Water and Sanitation, 2014). The Craigieburn treatment works is currently functioning at 177% of the design capacity, despite meeting 92.2% of the annual effluent quality compliance (Department of Water and Sanitation, 2014).

The sludge that is received at the Southern Works from septic tanks and conservancy tanks is mixed with the preliminary treated wastewater (screening and de-gritting), and is sent to sea via the sea outfall pipe (Dyer, 2016). The sludge treatment is not as well monitored or regulated as the wastewater treatment process and because of this if open to fraudulent tenders and corruption as has occurred in the past. This is a gap in the sanitation chain that is often neglected due to the social taboo around sludge waste and also because it is seen as secondary to the wastewater treatment process.

There are some 76 package plants situated around the eThekwini area, with only 32 being monitored by EWS. It is estimated that only the top ten of these decentralised treatment

works are performing to the required effluent quality standards, but there was little data available on the details of this estimation (Fennemore, 2016). While the development of new plants require a financial guarantee so that non-functioning plants can be rebuilt, this action has not been taken yet for the four or five plants to which this regulation applies (Fennemore, 2016). There are two package plants that have been instructed to use tanker trucks to transport the effluent to the centralised treatment works due to their lack of treatment (Fennemore, 2016).

The sludge from the VIP toilets gets delivered to the LaDePa treatment facility that is operated by a private company, but is contracted through EWS. The development of the LaDePa plant has been funded through the Bill and Melinda Gates Foundation, but EWS would be responsible for payment of a gate fee in order to process the sludge from the VIP toilets (Wilson, 2016). This treatment facility has a capacity of 8 000 m^3/yr. (Wilson, 2016). The facility produces pellets that are sold as a fertilizer product for agricultural purposes (Wilson, 2016).

The UD toilet dry solid sludge that is delivered to the Black Soldier Fly (BSF) treatment is processed by the flies to produce a protein feed that can be sold to live-stock farmers. The BSF technology has been funded by EWS and is contractually operated by Agriprotein and will be the treatment method used for UD sludge in the near future (Buckley, 2016).

The BSF technology is an example of how EWS is always actively testing FS disposal. They are currently looking into FSM treatment and resource recovery treatment options for future use. The DEWAT systems, that would allow for passive anaerobic treatment of waterborne wastewater, is being tested by BORDA alongside the PRG within UKZN and is in the final stages of being regulated for official use.

3.1.5 End-use / Disposal

The wastewater that is treated at the centralised treatment works and package plants is either released to the nearest river or estuary, or is partially reused for industrial processes at the Southern Works. There is reuse potential at some of the wastewater treatment works such as the Tongaat works, whereby the treated WW would be sent to the Hazelmere Dam where the Umgeni Drinking Water Treatment Facility is situated (Dyer, 2016). The future plans vary between building more sea outfall pipelines or reuse of wastewater as the estuaries are sensitive environmental areas that cannot take more effluent flow if the capacity of the treatment works increases (Dyer, 2016). The current drought in the country may influence the decision for water reuse.

The sea outfalls from Central and Southern works are 3.2 and 4.2 km long respectively (eThekwini Municipality, 2012a). The Central works sea outfall discharges the screened and de-gritted wastewater and combined wastewater and faecal sludge through 18 diffusers that are set at depths of between 43 to 53 m at a design capacity of 135 Ml/d, while the Southern works pipeline discharges through 34 diffusers at depths of 54 to 64 m with a design capacity of 230 Ml/d, which is the capacity of the entire works at both facilities (eThekwini Municipality, 2012a). While this may be considered to be the release of faecal matter directly into the environment, the sea outfall is a legal licensed discharge point that is regularly monitored along with the surrounding aquatic environment in order to assess its impact. In the future it may be more difficult to get another sea outfall license due to increased restrictions

(eThekwini Municipality, 2012a). The sludge from septic tanks and conservancy tanks delivered to these two treatment works, along with the sludge from the Amanzimtoti works is sent to sea via the sea outfall along with the 60 Ml/d and 160Ml/d annual average wastewater inflow to Central and Southern works respectively (eThekwini Municipality, 2012a).

Sludge treatment is not very well recorded or monitored with the results that the end use or final disposal of the sludge is also not clear. From individual interviews, some believed that the sludge was simply being stockpiled at most plants due to contractual issues, while some mentioned that the sludge was already being used on sugar cane fields for farming purposes (Dlamini, 2016; Dyer, 2016; Fennemore, 2016). At the KwaMashu works only, there is a dryer and fluidized bed incinerator that has not previously been functional due to lack of skilled personnel and the expensive nature of this operation (R417 per ton wet sludge with operating costs of R1 500 000 per month) (Dyer, 2016; eThekwini Municipality, 2012a). This disposal method might be in operation at present and there have been plans to include the sludge from the Northern works or Phoenix works as well (Dyer, 2016).

Some of the treatment works still send their dried sludge to the landfill, but the only landfill that is still in operation is the Shongweni landfill operated privately by EnviroServ (Dlamini, 2016; eThekwini Municipality, 2015a; Fennemore, 2016). This option for sludge disposal may be problematic in the future, as the Environmental Affairs will soon be banning liquids on landfill sites and despite being dried, the sludge is still relatively wet on disposal (Fennemore, 2016). Landfill disposal is also quite expensive for the city at R700 to R910 per wet ton (eThekwini Municipality, 2012a). The plan to contract a private company to pelletize the sludge should generate an income to break even (eThekwini Municipality, 2012a).

Farmers reuse the pellets that are currently produced from the VIP toilets from the LaDePa treatment technology as fertilizer. The UD toilet sludge currently only partially supplies the trial Black Soldier Fly treatment facility that produces protein feed for reuse in live-stock farming, but will increase the reuse capacity in the near future. Currently the majority of the UD toilet faecal matter is buried safely on site. The urine from the UD toilets is diverted to a soak away on site.

3.2 SFD Matrix

The final SFD for the city of Durban and surrounding areas in the eThekwini Municipality is presented in Appendix 6.

3.2.1 Risk of GW contamination

There is likely contamination to groundwater from septic tank soak-pits, informal pit latrines, open defecation and leaking sewer pipes, but the risk is relatively low due to the fact that borehole water is not typically used in the urban area (Ross, 2016).

The groundwater levels are not very well monitored or documented, the data is poor and seldom continuous, but the groundwater (GW) levels are generally between 12 to 25 m, averaging 18 m below ground level (Department of Water Affairs and Forestry, 2008). This lack of monitoring is mainly due to the fact that borehole technology is not used as a drinking water source aside from in rural areas, such as farms. In the urban areas only few industries in the Pinetown and Stanger areas use this source for industrial means. Boreholes are

difficult to acquire as a permit is required from the Department of Water and Sanitation (DWS) and the standards for the positioning and water quality at the borehole site are too strict for it to be feasible. In the eThekwini area, this is especially true due to the fact that the sandstone geology does not allow for a single borehole to supply an abundance of water (Fennemore, 2016). There are 16 active boreholes left in the area and none appeared to be dangerously close to potential contamination from sanitation facilities (Pietersen, 2016).

3.2.2 SFD Matrix explanation

The next section explains how the decisions were made concerning the calculations and values used in the SFD calculation tool in order to create the SFD Matrix. More detailed information regarding this data and decisions can be found in Appendix 8.

Containment Technologies

The proportions of various sanitation systems that exist in the eThekwini area were divided into onsite and offsite containments systems according to the descriptions in Table 3.

Table 3: on-site and off-site containment systems definitions

Sanitation Type	SFD Variable	SFD Description	eThekwini Description
On-site (F1)	F2	FS contained on-site	Septic tank, conservancy tank, VIP latrines and UD toilets
	F10	FS Not contained on-site	Urban Informal pit latrines that are not emptied built in areas that are not served by the municipality
OD	OD9	Open Defecation	Rural open defecation from areas that are not served by the municipality, likely children
Off-site (W1)	W2	WW contained centralised (offsite)	Flush toilets from individual dwelling and from communal ablution blocks connected to the sewer network
	W3	WW contained decentralised (offsite)	Flush toilets that connect to package plant treatment works

The percentage breakdown for each containment system was calculated using the count of dwellings from the 2011 aerial photograph that is used to calculate the backlog figure for the municipality. Because the dwelling count is based on housing units counted, a range of occupancy rates were used to calculate the estimated population in each dwelling count section. The occupancy rates used were from the Water Services Development Plan of 2011 and can be seen in Table 4. Surveys done surrounding the UD toilets showed that 84% of households using this sanitation system had households of between 1 and 10 people, with the average being 6.8 persons per household, which is larger than average eThekwini occupancy rates (Buckley, 2016). This information implies that the UD population might be slightly larger than calculated and this might be an area that needs to be investigated further to get more accurate population divides.

Table 4: Occupancy rate per dwelling type (eThekwini Municipality, 2012a)

Dwelling type	Occupancy Rate
Formal house	3.86
Formal Flat	2.9
Informal single	3.6
Informal Backyard	3.9
Rural	5
Rural formal house	4.65

The population was estimated at 3.6 million people for 2016 in the IDP (eThekwini Municipality, 2015a). This figure was confirmed by calculating the number of people by multiplying an estimated rate of occupancy from informal urban, formal urban and rural areas with the number of dwelling units counted from aerial photography from 2011. These proportions, which can be seen in Table 5, are slightly different to the proportion of dwellings in each category. The table of dwelling counts can be seen in the Appendix 8.

The number of dwellings counted in the category of flats was assumed to be the number of actual individual dwelling units within the total number of flat complexes that were counted from the aerial photograph.

Table 5: Population proportions per containment type per dwelling type

Dwelling type	Population Proportion per dwelling type					
	People with UD	People with ablution	People with VIP	People with Septic or Package Plants	People with Waterborne to central	People Unserved
Informal Settlements	18698	402725			55919	478609
Informal Settlements - Formal Informal				11951		
Backyard Shacks					191003	
Rural - Traditional	385295					133280
Formal houses not in Rural area (A1)			135100	383229	1061222	
Flats (B1)					319653	
Formal houses in Rural area				23934		
Total	**403993**	**402725**	**135100**	**409113**	**1627796**	**611889**
Percentage	**11%**	**11%**	**4%**	**11%**	**45%**	**17%**

The final population proportions used for each containment type in the SFD calculation is shown in Table 6.

Table 6: SFD input of containment proportions

Tab 1 ref	Description of sanitation containment system	Population using this type of system? (no.)	Proportion of population using this system (%)	eThekwini Description
T1A1C2	User interface discharges directly to a centralised foul/separate sewer	2,030,521	56%	Waterborne flush toilets connected to the centralized sewer system
T1A1C4	User interface discharges directly to a decentralised foul/separate sewer	25,147	1%	Waterborne flush toilets connected to decentralized package plants
T1A2C5	Septic tank connected to soak pit	385,584	11%	Waterborne flush toilets connected to on-site septic tank containments and a soak away
T1A3C10	Fully lined tank (sealed), no outlet or overflow	26,339	1%	1) Waterborne flush toilets connected to on-site conservancy tank containments with no outlet 2) Dry UD toilets that are contained in a sealed vault on-site with no outlet that are emptied by contracted companies manually and taken to the Black Soldier Fly Treatment Facility
T1A5C10	Lined pit with semi-permeable walls and open bottom, no outlet or overflow	135,100	4%	VIP latrines with no outlet that are emptied by contracting companies manually
T1B7C10	Pit (all types), never emptied but abandoned when full and covered with soil, no outlet or overflow	386,037	11%	Dry UD toilets that are contained in a sealed vault on-site with no outlet that are emptied by burial of FS onsite by contracted companies
T1B8C10	Pit (all types), never emptied, abandoned when full but NOT adequately covered with soil, no outlet or overflow	587,413	16%	Informal pit latrines that are not emptied
T1B11 C7 TO C9	Open defecation	24,476	1%	Rural areas where no basic sanitation services are provided and no informal pit it used, likely children

Flush toilets connected to a sewer

The waterborne flush toilets that are not contained on-site, but are connected directly to a sewer network was calculated as the sum of the population using waterborne to central systems and the population using ablution blocks. Ablution blocks that use VIP systems are very few and far between as there are 26 ablution blocks (male and female toilets) that are not on sewer network (Pietersen, 2016). Because of the small percentage of users, these systems have been ignored.

Septic tank, conservancy tanks and package plants

The divide between the number of septic tanks, conservancy tanks and package plants was done by counting the residential households of each category using the GIS data from the billing system and categorized sanitation level of service polygons from EWS and finding the proportional divide between these systems. This breakdown can be seen in Table 7.

Table 7: Proportion of Septic tank, conservancy tanks and package plant systems

Type of Containment	Percentage of total
Conservancy	**2%**
Package Plants	**6%**
Septic tank	**92%**

On a field visit to view a septic tank being emptied, it was discussed that it was likely that most septic tanks were not well maintained by the homeowners, although most were probably impervious and built according to the SABS codes due to readily available contracting companies to do so (Ross, 2016). This lack of maintenance can lead to clogging of the soak away and poor functioning of the septic tank, which could cause local ground contamination (Ross, 2016).

Due to SABS building standards and the private homeowner's income level and self-preservation interest, the septic tanks are assumed to be fixed when they are damaged, as this would cause problems for the homeowner. This is not the case for approximately 2000 Septic tanks in a rural area called Tshelimnyama where the septic tanks are not connected to a functioning soak-pit and the residents refuse to pay for the septic tank emptying and maintenance services which leads to overflowing tanks to the environment. 2000 houses were estimated at 0.3% of the population, which was small enough to ignore in the SFD.

Backlog figure

The number of dwellings that are currently not served with basic sanitation in informal settlements and rural areas amounted to 17% of the total population (see Table 5). The sanitation systems used for this proportion of the population was difficult to assess, but it was assumed that in more dense urban settlements, open defecation would be more difficult to practice, while in rural areas this would be a more commonly used practice among children only. In informal settlements (rural and urban) it was noted that male and female communal pits would usually be dug by the community in need. Because of this, the number of unserved population in the informal settlement category was used for FS that is not contained (variable F10 in Table 3), while a small amount of the number of unserved population in the rural category was used for OD (variable OD9 in Table 3).

UD toilets

The population using UD toilets is taken from the backlog figures because while there were 90 000 UD toilets delivered to people, not all of these toilets are used for their intended purpose. Once the study to GPS and empty every UD toilet has been completed, this figure will be more accurate.

Emptying and Transport Methods

Table 8: Emptying and Transport systems definitions

Sanitation Type	SFD Variable	SFD Description	eThekwini Description
On-site (F1)	F3a, F3	FS contained and emptied	1) Septic tanks that are emptied 2) UD toilets that the FS emptied is sent to the BSF treatment 3) Conservancy tanks that are emptied 4) VIP toilets that are emptied
	F4	FS delivered to the treatment plant	1) Septic tank FS that is delivered to the treatment works 2) Conservancy tank FS and liquid effluent that is delivered to the treatment works 3) VIP FS that is delivered to the LaDePa treatment works
	F15	FS not contained and not emptied	Informal pit latrines that are not emptied and not properly closed
Off-site (W1)	W4a	WW delivered to centralised treatment plants	Flush toilets from households and ablution blocks connected to the municipal sewer network
	W4b	WW delivered to decentralised treatment plants	Flush toilets connected to decentralised package plant treatment facilities
	W11a, W11	WW not delivered to centralised treatment plants	Overflow wastewater from pump stations in sewer network

Septic tanks, conservancy tanks and VIP toilets

It is assumed that all of the recorded VIP toilets, septic tanks and conservancy tanks are emptied except for the 2000 households in Tshelimnyama, where no collection is done due to the residents resistance to pay for the service. The proportion of each septic tank, conservancy tank and lined pit that is FS and not liquid effluent was taken as 50% due to lack of further detailed information. According to specialists in the septic tank industry, most households wait until the sanitation systems are causing problems before they are scheduled to be emptied, so this figure might be higher for septic tanks, but no estimated figures were supplied (Ross, 2016).

Illegal dumping after collection is assumed to be negligible due to the fact that the treatment facilities have permit systems with the septic tank companies and because reporting of illegal dumping is minimal when it used to be higher in the past (Ncgobo, 2016). There is little incentive for illegal dumping of the VIP FS, as the contractors are only paid on delivery of the sludge to the LaDePa facility (Wilson, 2016).

UD toilet emptying systems

The percentage of UD toilets was divided into those that have the faecal waste collected and sent to the BSF treatment facility and those that are buried safely onsite. This breakdown was calculated using the estimation that 16 toilets per day are sent to the BSF treatment trial for a working year. The number of people per UD toilet was calculated using the average rate of occupancy between single informal homes and rural homes. The calculations can be seen in Table 9.

Table 9: Calculation of UD to BSF treatment and buried onsite

UD toilet per day to BSF (Wilson, 2016)	16	UD toilets
UD going to BSF in a working year (261 days)	4176	UD toilets
Number of people using UD going to BSF treatment	**17957**	People
Number of people using UD that are buried on site	**386037**	People

Transport by sewer

With regards to the wastewater that is transported by sewer to the central treatment works, not all is actually delivered to the treatment works. It has been estimated that there are approximately 140 blockages per day in the gravity driven sewer lines, with each blockage allowing a maximum of 60 Ml/d from the sewer trunk to spill for the duration that it is unattended (between 4 to 24 hrs.) (Wilson, 2016; Gounden, 2016). Using an average response time of 14 hours, the total overflow each day was calculated. The maximum flow of 60Ml/d is the flow of wastewater received at the largest sewer pump station in Durban (Von Brandis, 2011). This figure was used due to a lack of further information on the average flow in the sewer network pipes. From these figures the percentage of wastewater that is not delivered to the treatment works is calculated. It was determined that 96% of the WW was delivered to the centralised treatment works. The detailed calculations can be found in Appendix 8.

Treatment Technologies & Disposal

Table 10: Treatment and disposal systems definitions

Sanitation Type	SFD Variable	SFD Description	eThekwini Description
On-site (F1)	F5	FS treated	
	F8	FS contained and not emptied	1) UD FS that is buried on-site safely 2) Septic tank supernatant/liquid effluent that is passed through soak away 3) VIP liquid portion that percolates through pervious walls
Off-site (W1)	W5a	WW treated at centralised treatment plants	Wastewater that is treated by the centralised treatment works
	W5b	WW treated at decentralised treatment plants	Wastewater that is treated up to standard at the decentralised package plants
	W12a	WW not treated at centralised treatment plant	Wastewater that is bypassed during high rainfall at the centralised treatment works
	W12b	WW not treated at decentralised treatment plant	Wastewater that is not properly treated at the package plants
	W12	Sum of W12a and W12b	Total wastewater that is not property treated at any of the treatment works

On-site FS

The UD and VIP FS delivered to the BFS facility and the LaDePa facility respectively are considered to be completely treated. UD toilets that are emptied and buried onsite are considered safely disposed of.

Centralised and package plant treatment

The percentage of wastewater that is treated at the centralised treatment facilities was taken as 88%, which was calculated using the average annual daily inflow at each of the treatment plants multiplied by the percentage of annual average effluent quality compliance recorded in the 2014 Green Drop Report (Department of Water and Sanitation, 2014). These calculations can be seen in Appendix 8.

The package plants proportion treated is the most unreliable figure as it was made clear by EWS that some of these facilities are not treating the wastewater to the prescribed level that they are required to, and only two of them have their effluent transported to the central works for further treatment. Because of the containment of the poorly treated effluent from some of the package plants and the fact that the larger facilities are monitored, and appear to be treating the waste at an acceptable standard, a fairly high proportion of the sludge was considered treated. There is such a small proportion of the population using these facilities that this parameter is not a very sensitive one, which means that if the package plants treats to a level of 100% or if they treat to only 75%, the proportion of treated WW from decentralised plants remains at 1% of the population's waste being treated.

Despite the fact that the sludge treatment facilities is an area of limited data, the FS appears to be stored appropriately onsite at the treatment works where no disposal or reuse method is in place. It is assumed therefore that all of the FS delivered to the treatment works are treated. This figure could be investigated further to understand the actual sludge treatment process and disposal and to determine any real risk to the environment due to stockpiling. While there are problems with the final disposal of sludge in reality, the sludge is contained onsite at the treatment works and does not present a significant risk to the public or the environment at present.

3.3 Discussion on quality of data

While there is a significant amount of data collected at the EWS municipality, most of the information used in the SFD calculation was derived from interviews or from the backlog figures calculated off the 2011 aerial photograph. While there might be data on the billing volumes of water from households (inaccurate by 30% due to the non-revenue water loss in the pipes), the intricate calculation and understanding of the assumptions made in developing this data requires a GIS expert with knowledge of the data collection methods and processes. The backlog figures are fairly accurate as these figures are the basis for planned service delivery by the municipality and allow for requests for funding for free basic service grants from the National Government departments.

The backlog data, while fairly accurate, is calculated using the assumption that households within 200 m of a sewer network are considered served by that sewer. This is likely not the reality of the situation, despite the fact that EWS would be obligated to connect that household should they apply for a connection, if the household were to know that they were within 200 m of a sewer network. This implies that the figure of 17% of the population using informal unlined pits that are not emptied or using open defecation might be a larger figure.

Despite this backlog data being clearly divided into sanitation and water services, the general information on the services in eThekwini are still very water-supply focused and more effort is needed to distinguish the sanitation backlog from the housing backlog or the water services

backlog in the development plans. This is especially true in the information presented to justify the budgets for sanitation systems.

There are plans in place and currently being carried out that allow for more accurate mapping of the toilet services that have been provided to people, especially with regards to the UD toilets in rural areas. While this GIS spatial data is quite abundant in mapping the sanitation systems that exist over the eThekwini area, the mapping and accuracy around septic tank households and how much of this FS is actually delivered to the treatment works is a weak area in the data. The collection and monitoring of decentralised Package Plant treatment facilities is improving, but this is also a weak point in the data quality.

The weakest area of data collected in this SFD study is regarding the amount of wastewater that is not delivered to the treatment works. This figure was developed based off second-hand information regarding the frequency of blockages that occur and the estimated overflow of wastewater into the environment at points in the sewer line. This figure is of particular importance because 56% of the population in eThekwini uses the sewer system.

More information and confirming of collected data could have benefited this study, but lack of time and resources prevented this. The interviews with EWS employees were considered reliable, as each interviewee was a specialist in the area of discussion.

4 Stakeholder Engagement

4.1 Key Informant Interviews

Overall, 13 key informant interviews (KII) were conducted, mainly with specialists within the municipal stakeholder due to the fact that Durban is mainly served by the public sector. An introductory meeting was held with the head members of EWS in order to authorize me to conduct interviews and gather information from various divisions in the municipality. Email correspondence and introductory emails were sent to the key sanitation areas within EWS and to specialists in the private sector of the sanitation systems. Dave Wilson who works with on-site sanitation department was interviewed along with Steven Pietersen from the GIS data division to understand the sanitation systems in place. Mduduzi Dlamini and Langa Ngcobo were contacted to find out about the treatment works and septic tank disposal at the treatment works. Chris Fennemore was interviewed from the pollution control group to find out about the environmental effects, regulations of discharge and the control of the municipality over the private septic tank and conservancy tank emptying and the package plants. Rob Dyer was interviewed from planning to find out about capacity development of the treatment works and the various methods of treatment. Claudia Botha and David Gallagher were contacted by email to find out about information on the package plant from the EWS side. Mark Ross was contacted to answer questions on both the septic tanks and the package plants as he has formally been intricately involved in septic tank design, installation and operation but is currently the head of a package plant treatment company called Lilliputs. Introductory letters were emailed to the septic tank companies and a development studies group within UKZN that were not responded to. A complete list of the stakeholders involved in the sanitation sector in Durban can be seen in Appendix 1, although

only the main key stakeholders were contacted due to limitations of resources and time for this study.

Two field visits were done, one to the DEWAT trial treatment works in order to get an idea of the type of treatment technology that is being developed to reduce inequity in the sanitation field and one to witness a septic tank being emptied. On the second field trip the owner of the septic tank company was asked a few questions about his industry in order to confirm some of the research done beforehand in the desk study.

Interviews were mainly done face-to-face with only the interviewee and myself, as this was preferred because it meant that the study could get focused answers to specific areas of the sanitation chain and that the figures could be confirmed with separate departments. There was one interview done over the phone, but this form of communication was reserved for follow-up questions after an initial in-person meeting had been established. Follow-up questions and sharing of data was done via email. It was a difficult time to get interviews with the EWS staff as everyone was busy due to elections preparations, but the department was open to helping due to the initial authority and introductory meeting held at the beginning of the process.

Desk study research was done to understand the private companies involved in the septic tank and conservancy tank collection process and the package plant treatment facilities as well as the landfill companies. An email was sent to some of the septic tank companies with no response. It was found that it was easier to use inside contacts that were more open to sharing their experiences. From working within PRG, Mark Ross was recommended as a contact as he was involved in both Package plants and septic tank services, who provided much help in this area.

The benefit of engaging early with the municipal water services authority helped the project greatly as data gathering is a slow process and it was able to start from the first week of the project. One-on-one meetings were very beneficial to fully understanding the sanitation systems and the differences between similar processes that exist and good relationships were developed between each of the key informants so that people were honest with the information they were supplying and talked freely about the problems involved in the system. These relationships allowed for a back and forth of emails to ask questions about areas that were more difficult to understand.

Prior to these interviews, information about the policy and municipal plans were acquired from reading through the various exhaustive policy documents and legislative acts, which enabled a better line of questions in the interviews.

No interviews or emails were conducted with the ministers in National Government due to the municipal structure of the South African water and sanitation system. Aside from the school toilets, health and permitting aspects, there is little direct interest from the national departments in the detailed sanitation systems aside from the policy. The policy and national level understanding came from online research and was furthered by the local municipal and NGO interviews.

There were no focus group discussions done, although this might have been appropriate for the package plant owners and the septic tank companies. These focus groups would have been difficult to achieve without accurate timing around the annual gatherings of these

private entities and the eThekwini municipality. A discussion with social sciences specialists would have been beneficial as they readily engage with people by surveys regarding their living conditions, housing and services. This stakeholder meeting was initiated but never materialized. With more time and identification of these stakeholders at the beginning of the study, more engagements with key stakeholders might have been achieved.

4.2 Observation of service providers

Site visits were done to the trial DEWAT facilities that are under operation by BORDA, under the guidance of the NGO PRG as research for EWS. This wastewater treatment facility is passive and is one of the innovative developments that is likely to be used to help provide sanitation services to peri-urban and rural homes in the near future. An image of the facility can be seen in Figure 18 in Appendix 9.

Another site visit was done to witness the emptying of a septic tank from a residential home in order to see how the process was done and what standards were maintained. Images of the vacuum tanker and the tools used to empty the septic tank and the emptying process can be seen in Figure 14, Figure 15 and Figure 16 respectively in Appendix 9.

On this same field visit, the Lilliputs decentralised package plant was explained and visited in order to get an idea of one of the types of decentralised treatment options that exist. An image of the bioreactor of the package plant can be seen in Figure 17 in Appendix 9.

A field visit to the Southern Treatment works never materialized despite efforts to achieve this. This would be advised for any further development on the SFD study as it would be good to verify the septic tank discharge process as well as gain a better understanding to the monitoring of the sea outfall discharge and the inflow and outflow of a centralised treatment works.

The field observations were insightful and allowed for questioning of the procedures and failings in the system from first hand specialists in the sanitation field. The septic tank procedures that are laid out in the policy and standards was checked along with the basic figures of the septic tank tanker and rate of emptying that were initially supplied by EWS.

What was clear was that the General guidelines and building standards seemed to be the commonly referred to document that the septic tank and package plant industries follow. This showed that there is regulation and standards adhered to in the sanitation field, even in the private industries. There did appear to be differences of opinion between the municipality service authorities and the private septic tank and package plant companies, but this appears to be lessening with better communication and recognition of the more unheard voices in the private industry.

4.3 Conclusion on Stakeholder Engagement

The field-based research proved to enhance stakeholder engagement as it allowed for personal interactions where people were happy to help provide a clear understanding of the systems that they were working with and where the problems lay. The initial meeting with the key members of the EWS unit was important to allow assigned authority in gaining information and explaining my role in this study and how it might benefit the municipality to help develop a SFD. Engagement with the private sector and with actual staff onsite at the

treatment works and the sewer utility is recommended as it might have lead to a better understanding of what actually happens on a day-to-day basis and a more accurate figure for how much faecal matter is not delivered to the treatment facilities. Interviews with more interconnected social welfare groups may have lead to a more accurate understanding of the form of sanitation systems in households that are not served by the local municipality. Due to the nature of the formalized, predominantly public sanitation service delivery, the focused interviews with EWS staff proved very successful in determining fairly accurate figures on the proportions of sanitation systems used in the eThekwini area.

5 Acknowledgements

This report was compiled as part of an internship under the PRG at the University of KwaZulu-Natal. This internship is part of the Integrated Water Resource Management masters program that is run through McGill University by Professor Jan Adamowski. The study is a late contribution to the SFD Promotion Initiative and the first SFD to be produced outside of this initiative unfunded. Professor Chris Buckley was the supervisor of this internship and played a key role in orchestrating this study along with Lars Schoebitz of Eawag/Sandec.

The SFD Durban report was made possible because of the support and involvement of the EWS municipality and all those who helped provide further information, including Mark Ross from Lilliputs. This study will hopefully lead to further SFD developments for the eThekwini Municipality and provide insights into improvements in the sanitation systems over time.

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7 Appendix

7.1 Appendix 1: Stakeholder identification

Stakeholder identification				
No.	**Stakeholder Group**	**Name of organisation**	**Influence (high/medium/low)**	**Interest (high/medium/low)**
Stakeholder 1	Municipal Authority	eThekwini Water and Sanitation (EWS)	High	High
	Municipal Authority	City Council	High	Medium
	Municipal Authority	City Health	Low	Low
	Municipal Authority	Human Settlements	Low	High
	Municipal Authority	Parks, Recreation and Culture Service Unit	Low	Low
	Municipal Authority	Environmental planning and Climate Protection	High	Medium
	Municipal Authority	Business Support Tourism and Markets Unit	Low	Medium
Stakeholder 2	Ministry in charge of Water and Sanitation	Department of Water and Sanitation (DWS)	High	Medium
	Ministry in charge of Environmental affairs	Department of Environmental Affairs	High	Medium
	Ministry in charge of Environmental affairs	Department of Agriculture, Environmental Affairs and Rural Development for KwaZulu-Natal	High	Medium
	Ministry in charge of education	Department of Education for KwaZulu-Natal	Medium	Medium
	Ministry in charge of finance and economic development	Development Bank of Southern Africa (DBSA)	High	Medium
Stakeholder 3	External Agency/ Academic Institute	UKZN: Pollution Research Group	Medium	High
	External Agency/ Academic Institute	UKZN: BEDS (Development Studies and Population Studies)	Medium	Medium
	External Agency/ Academic Institute	UKZN: Centre for Civil Society	Low	Medium
	External Agency/ Academic Institute	Durban University of Technology	Medium	Medium
	External Agency/ Academic Institute	UKZN: Public Health Medicine	Low	Low
	External Agency/ Academic Institute	UKZN: Crop/Life Science	Low	Low
Stakeholder 4	External Agency/ Donor	Bill and Melinda Gates Foundation	High	High
	External Agency/ Donor	Borda	High	High

Stakeholder 5	External Agency/ NGO	DUCT	Low	High
	External Agency/ NGO	SDCEA (South Durban Community Environmental Alliance)	Low	Medium
	External Agency/ NGO	GroundWork	Low	High
	External Agency/ NGO	Organisation of Civic Rights (O.C.R)	Low	Low
	External Agency/ NGO	Shack/Slum Dwellers International	Low	Medium
	External Agency/ NGO	CORC (Community Organisation Resource Centre)	Low	Medium
	External Agency/ NGO	WESSA (Wildlife and Environment Society of South Africa)	Medium	Medium
	External Agency/ NGO	SewPackSA (Small Wastewater Treatment Works Suppliers Association	Medium	High
Stakeholder 6	External Agency/ Research institute	CSIR (Council for Scientific and Industrial Research)	Medium	Medium
Stakeholder 7	External Agency/ Consultant	Hatch Goba	Low	Medium
	External Agency/ Consultant	Golder Associates Africa		
	External Agency/ Consultant	Aecom		
	External Agency/ Consultant	Bosch Stemele]		
	External Agency/ Consultant	Partners in Development (PID)		High
	External Agency/ Consultant	Khanyisa Projects		High
Stakeholder 8	Service Provider/ National Government Business Enterprise	Umgeni Water	Low	Low
Stakeholder 9	Service Provider for rural water and sanitation	Amanz'abantu Services	Low	High
Stakeholder 10	Service Provider for Pit Emptying	Various community based service providers	Low	High
Stakeholder 11	Service Provider for disposal of faecal sludge	Interwaste	Medium	Medium
	Service Provider for disposal of faecal sludge	Wasteman		
	Service Provider for disposal of faecal sludge	Energy Engineering International		
Stakeholder 12	Service Providers of toilet technology for onsite sanitation	Envrioloo	Low	High
	Service Providers of toilet technology for onsite sanitation	Envriosan		

Stakeholder 13	Service Provider for operation and maintenance of treatment infrastructure	Veolia	Low	Medium
Stakeholder 14	Service Provider for emptying and transport of faecal sludge	Septic Tank Services	Medium	High
	Service Provider for emptying and transport of faecal sludge	Septic Tank Durban		
Stakeholder 15	Service Provider for rural and peri-urban treatment of sanitation	Lilliputs	Medium	High

7.2 Appendix 2: Tracking of Engagement

Stakeholder	People involved in the meeting	Date of Engagement	Purpose of Engagement
PRG	Professor Chris Buckley	22/01/16	Introduction and Planning
EWS	Dr. Vishnu Naidu	22/01/16	Introduction and Initial informal meeting
EWS	Teddy Gounden, Siobhan Jackson, Sibusiso Vilane, Mervin Govender, Ednic Msweli, Chris Buckley	29/01/16	Introduce the SFD and request their participation
EWS	Chris Fennemore	11/02/16	Review the information that Pollution Control can contribute get an overview of who is responsible for various areas within the Sanitation sector of EWS
EWS	Teddy Gounden Lungi Zuma Brian Neale Dave Wilson Mduduzi Dlamini Mlungisi Mthembu Rob Dyer Steve Pietersen	15/02/16	Meeting with EWS sections that are connected to the sanitation system data and information
PRG	Susan Mercer	18/02/16	Meeting to discuss sanitation projects that are on-going
EWS	Dave Wilson	18/02/16	Meeting to get figures for on-site sanitation
EWS	Rob Dyer	18/02/16	Meeting to go over WWT works designs and what happens to the sludge
EWS	Mduduzi Dlamini (Junior)	22/02/16	Meeting to go over WWT figures
BORDA	Carley Truyens	23/02/16	Field Visit to DEWAT plant trial
EWS	Langa Ngcobo	03/03/16	Phone call to talk about the septic tank discharge process at the WWT works
EWS	Steve Pietersen	10/03/16	Data collection meeting in his office
Lilliputs	Mark Ross	14/03/16	Meet to discuss his role in the package plant and septic tank private companies
EWS	Chris Fennemore	16/03/16	Follow-up meeting to discuss policy and guidelines for pollution control
Lilliputs	Mark Ross	29/03/16	Field visit to witness septic tank being emptied and tour Lilliputs package plant

7.3 Appendix 3: Policies, acts, regulations and guidelines related to excreta management in the eThekwini Municipality*

Name of the Policy or Framework Document	Date	Level applicable	Comments
Constitution of the Republic of South Africa (Act no. 108)	1996	National	Right to access to basic services and an environment that is not harmful to oneself
National Environmental Management Act 107	1998	National	Overarching act to protect the environment and limit the pollution of waterways with faecal discharge
National Environmental Management: Integrated Coastal Management Act 24	2008	National	Legislation in place to prevent environmental damage to the oceans and estuaries
National Environmental Management: Waste Act 59	2008	National	Legislation to provide norms, standards and procedures to dealing with waste to prevent damage to the environment
National Guidelines for the Discharge of Effluent From Land-Based Sources into the Coastal Environment	2014	National	Guidelines that were developed from the NEM Integrated Coastal Management Act 24 to layout the ground rules and help with controlling pollution in the coastal waters and estuaries
Environmental Conservation Act 73	1989	National	Legislation to protect the environment and its resources
Guidelines for the Utilization and Disposal of Wastewater Sludge (Volume 1 to 5)	2006 - 2009	National	Guidelines that help with the type of management methods used, the requirements for agricultural reuse, the different qualities of on-site and off-site sludge and requirements when high loading of sludge occurs
National Water Policy	1997	National	Focus on equity to right wrongs of the past
Water Services Act 108	1997	National	Citizens have right to basic services
School Health Policy and Implementation Guidelines	2011	National	Responsibility of DOH (Department of Health) and DBE (Department of Basic Education) work with provincial department of health and district level to support health programs in schools.
Integrated School Health Policy	2012	National	Lays out aim to improve development and upliftment of children at school level. Includes responsibility on DOH. Will develop a 5-year plan, technical support to provinces, guidelines, monitoring and review. Provincial team (ISHP Team) will ensure school health services are reached.
Municipal Systems Act 32	2000	National	Municipal council must levy fees and deliver services. And must adopt bylaws to give effect to implementation and enforcement of tariff and services
Municipal Structure Act 117	1998	National	Allocates responsibility of getting people water and sanitation access to the municipalities
Strategic Framework for Water Services	2003	National	Free basic level of water included
White Paper on Water Supply and Sanitation Policy	1994	National	First document to address the division in sanitation service delivery from the Apartheid era
White Paper on Basic Household Sanitation	2001	National	Defines sanitation as the entire chain, including the social aspects and links to health and the environment.
Free Basic Services Policy	2000	National	Lay out each household gets 6000litres of water per month at no cost. 35l/ca/d for a family of 8 per household.
National Framework for Municipal Indigent Policies	2005	National	Addressing gaining access to services, maintaining access and targeting the poor in terms of revenue mechanisms.

Policies and Practices of the EThekwini Municipality Water and Sanitation Unit	2012	Municipal	Sets out policies and practices that the municipality follows in sanitation and water decision making and implementation
Integrated Development Plan (every 5 years)	2012-2017	Municipal	Collects current status and sets targets for city development, including budget
Water Services Development Plan (every 5 years)	2012-2017	Municipal	Collects current status data and targets for water and sanitation in particular in larger municipal plan, including budget
Spatial Development Plan (every 5 years)	2012-2017	Municipal	Collects current status data and targets for urban plan of the eThekwini area. Housing and services and growth of the city, includes budget
eThekwini Guidelines	1996 - 2005	Municipal	Sets out guidelines to assist developers and private entities in sanitation processes such as sewer connections for subdivision, sanitation provisions for low-income communities, monitoring procedures for discharge and development of septic tank and treatment facilities. These guidelines also cover discharge standards and procedures for tankers to the sea outfall, the design criteria of new alternative toilets and treatment of faecal sludge and reuse of treated wastewater.

*This list is not exhaustive

7.4 Appendix 4: Geology, Topography

The geology of the eThekwini area is made up of predominantly sandstone and diamictite that is Dwyka tillite, which forms fractured aquifers (Department of Water Affairs and Forestry, 2008).

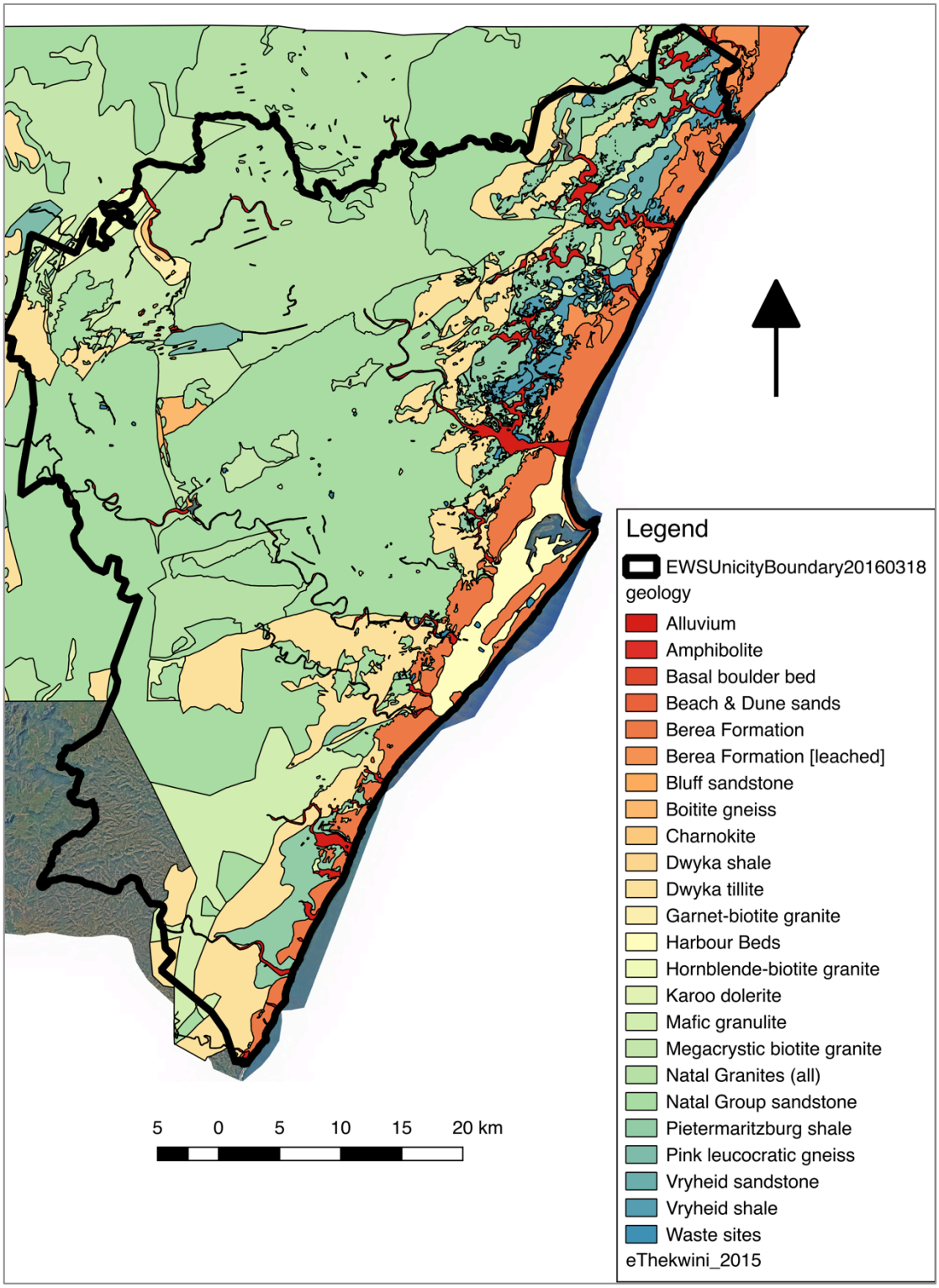


Figure 6: Geology of the eThekwini area

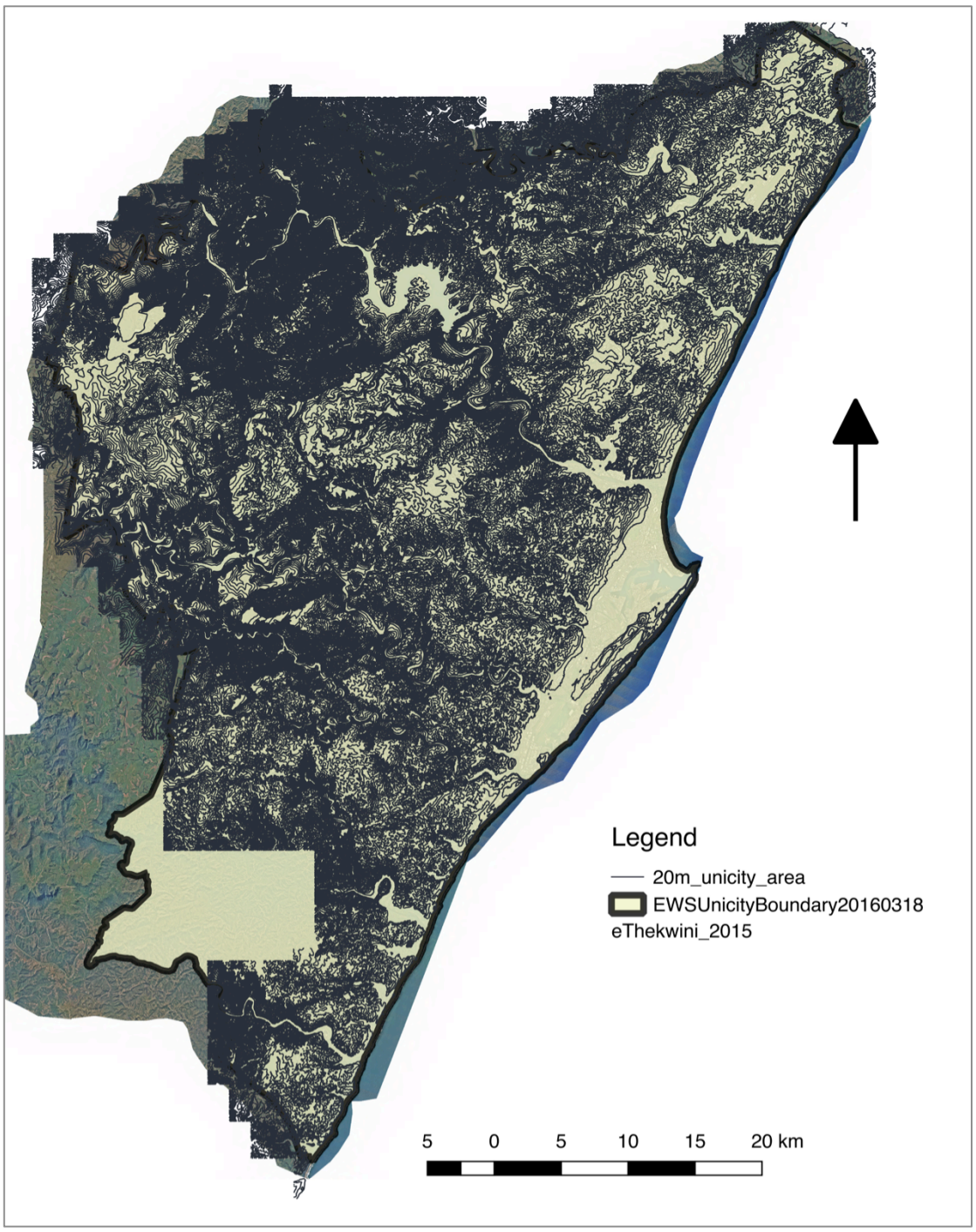


Figure 7: Topography showing 20m contours over the Unicity region of eThekwini

7.5 Appendix 5: eThekwini Municipality Maps and Graphs

EThekwini has the largest number of people living below the food poverty line out of the major cities in South Africa, consisting of mainly black Africans; but boasts the lowest levels of unemployment with a rate of 13.8% in 2013 (the highest being in Cape Town at 24.9%) (eThekwini Municipality, 2015a). eThekwini's GDP is projected at R230.8 Billion in 2014, and has 67% of the population within the working age bracket of 15 – 59yrs (see Figure 8) (eThekwini Municipality, 2015a).

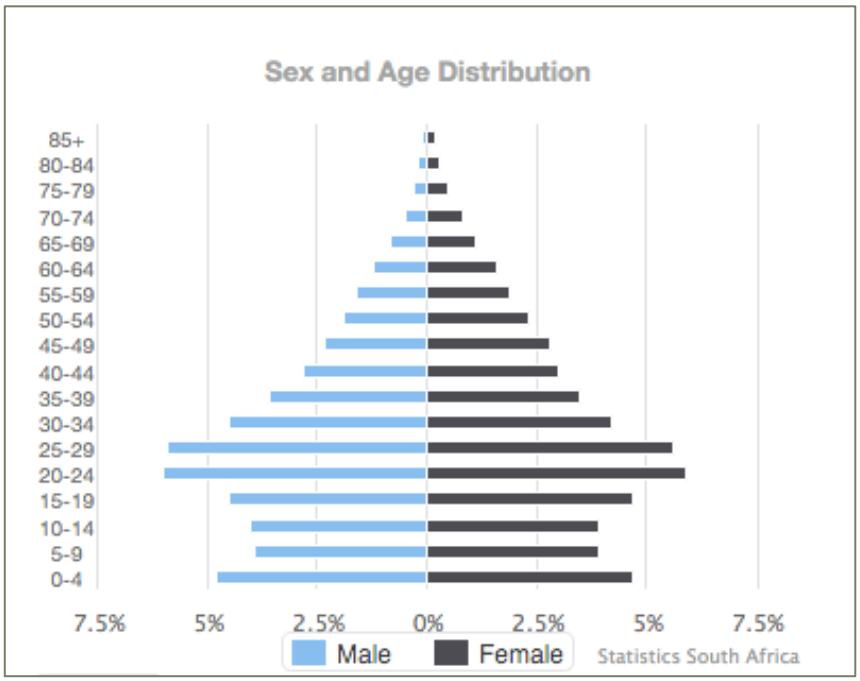


Figure 8: Sex and age distribution in eThekwini (Statistics South Africa, 2011)

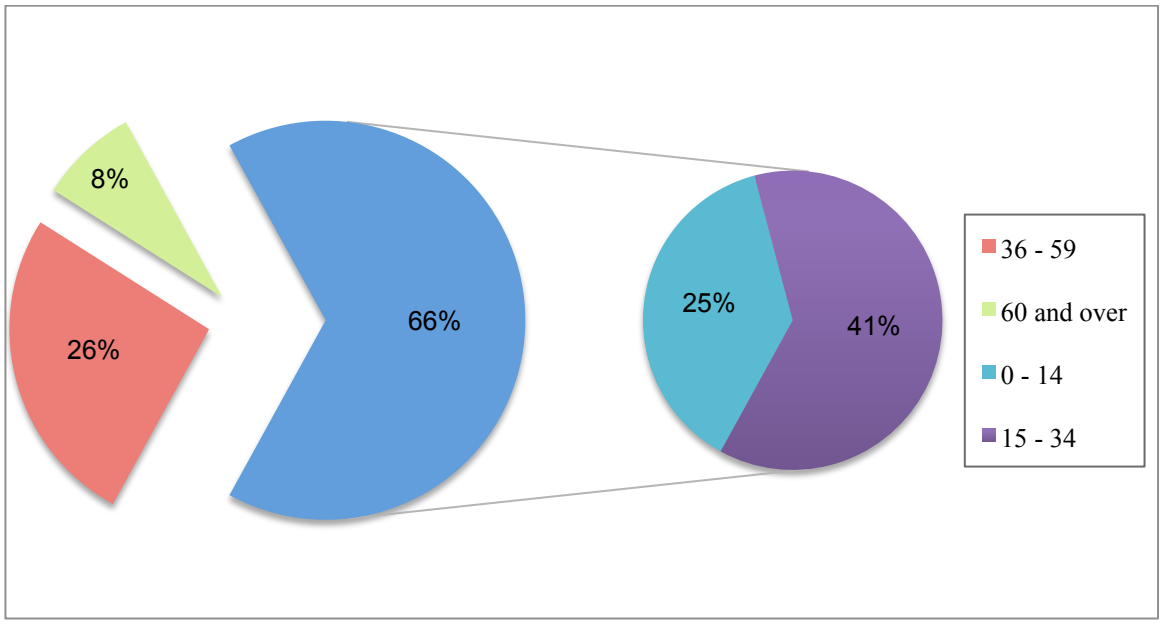


Figure 9: Age breakdown of eThekwini population

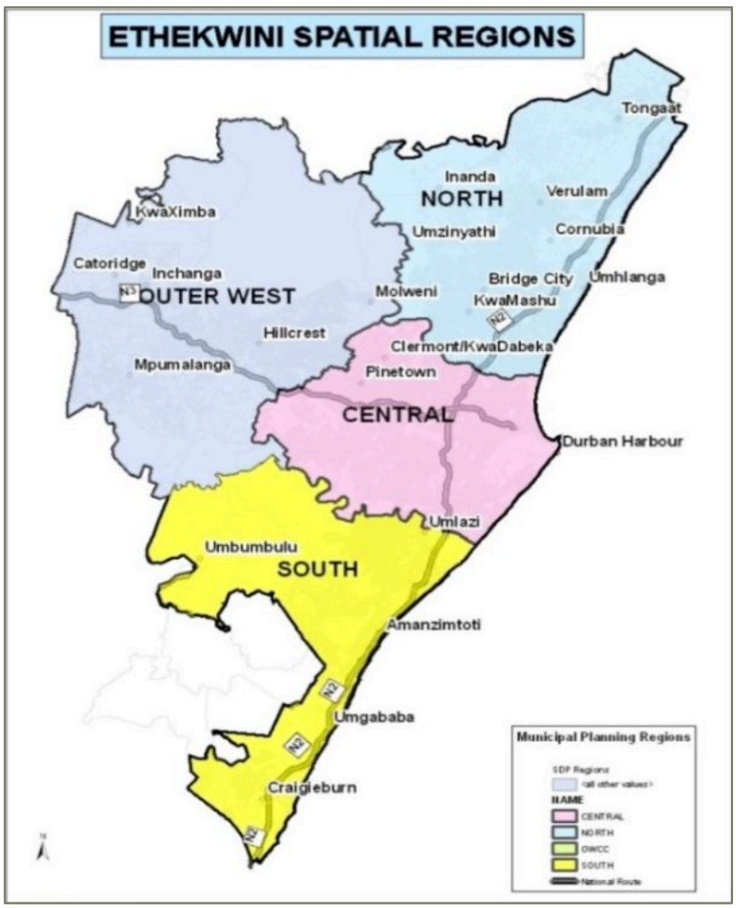


Figure 10: Spatial regions of eThekwini (eThekwini Municipality, 2015b)

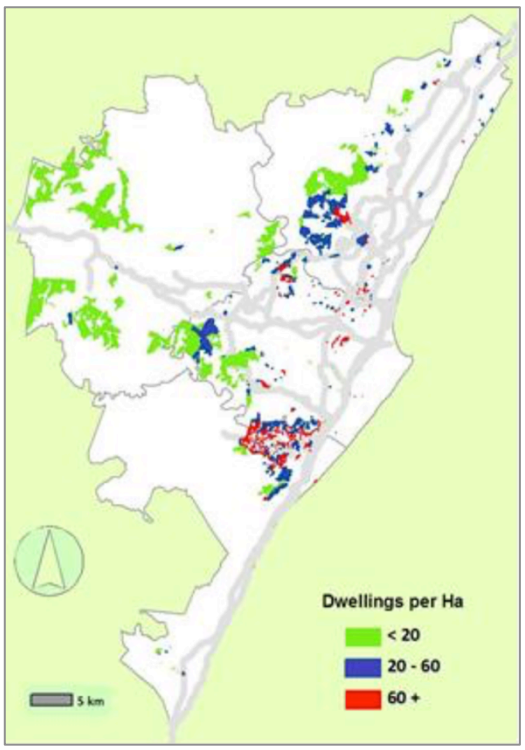


Figure 11: Spatial layout of population density across eThekwini (eThekwini Municipality, 2015b)

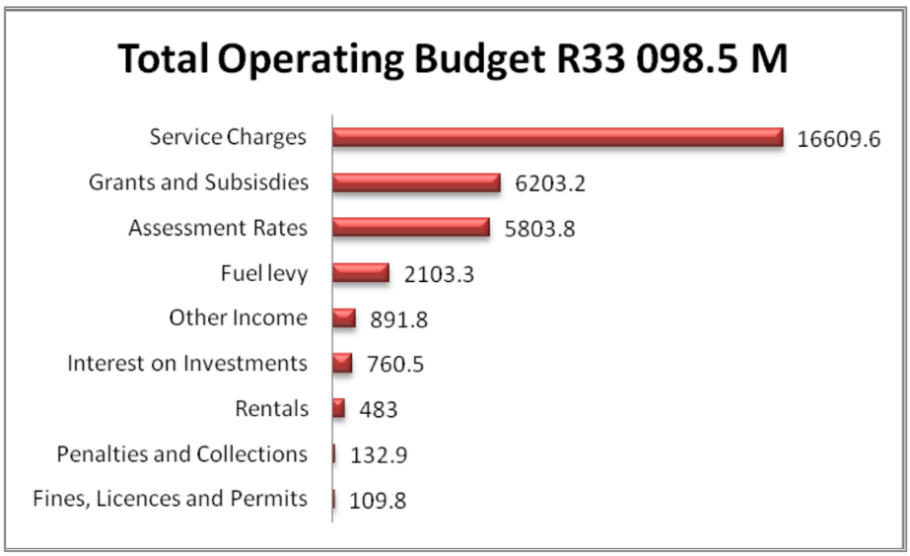
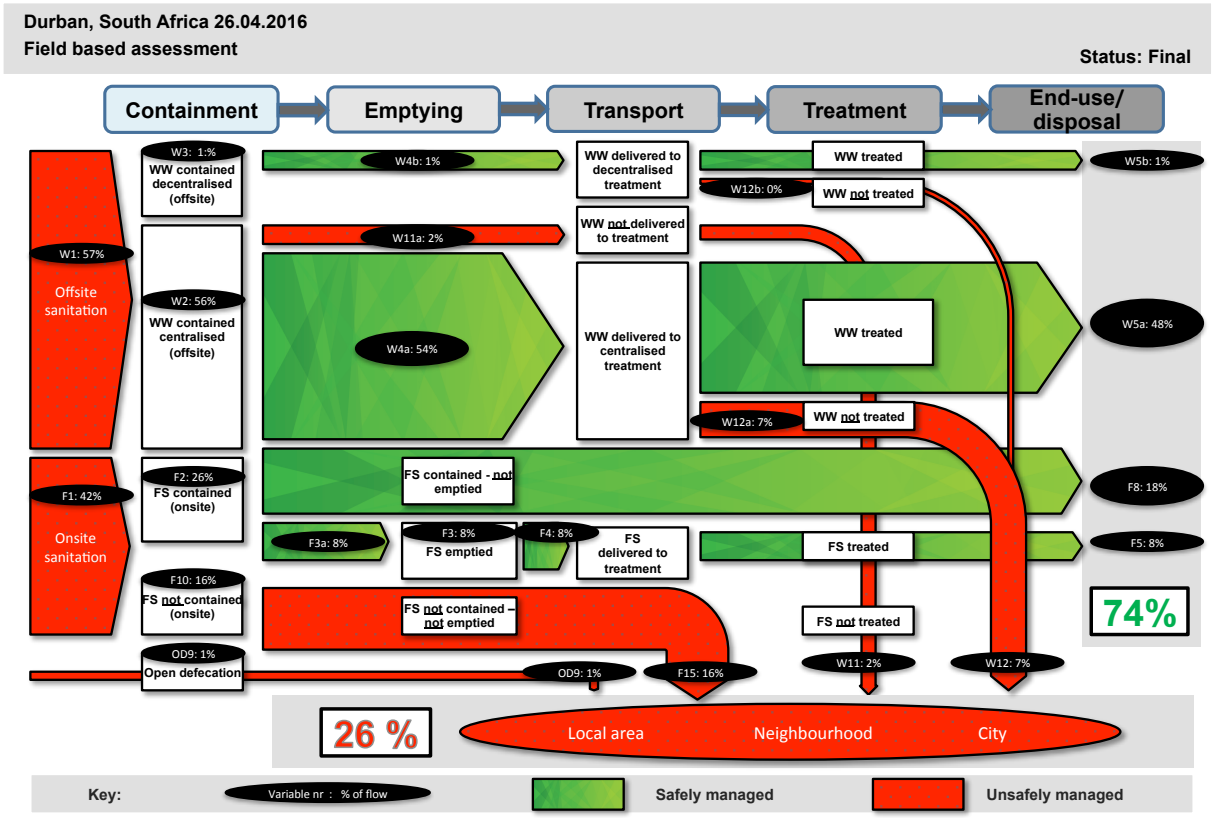


Figure 12: Income received for operating costs (eThekwini Municipality, 2015a)

7.6 Appendix 6: SFD Matrix



7.7 Appendix 7: Sanitation Network, Facilities and Treatment Methods

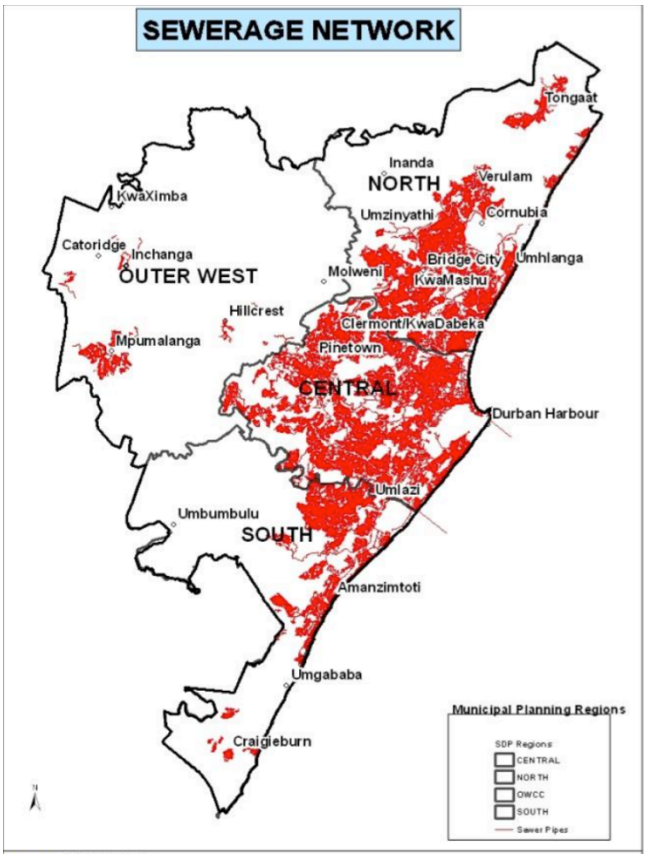


Figure 13: Sewer Network for eThekwini Municipality (eThekwini Municipality, 2015b)

Table 11: Treatment Methods at Centralised Treatment Works (eThekwini Municipality, 2012a)

Works	Design Capacity	Pre-liminary	Primary Settling	Activated Sludge	Secondary clarification	Bio-filters	Sludge Digestion (Primary)	Sludge Handling
Northern Coastal								
Genazzano	1.80	-	N/A	Extended Aeration	Y	N	N	6 x Drying Beds
Phoenix	25.0	-	Yes	Conventional	Y	N	Y	Belt Press dewatering
Tongaat Central	12.50	-	N/A	Extended Aeration	Y	Y (Old)	Y	Screw Press dewatering
Umdloti	3.00	-	N/A	Extended Aeration	Y	N	N	5 x Drying Beds
Umhlanga	6.80	-	N/A	Extended Aeration	Y	N	N	Dissolved Air Flotation (DAF) Unit and centrifugal dewatering
Verulam	13.0	-	Yes	Conventional	Y	N	Y	Screw Press dewatering

Central Coastal								
Central	135	Only	N/A	No	N	N	N	Thickener and Sea Outfall Used
Southern total	230.0	Only	N/A	No	N	N	N	Sea Outfall Used
Southern 2nd class	48.00		Yes	Conventional	Y	N	Y	
Umbilo [old]	23.2	-	Yes	Conventional	N	Y	Y	DAF thickening and Belt Press dewatering
Umbilo [new]		-	Yes	Conventional	Y	Y	N	
Umhlatuzana -Shallcross	4.90	-	N/A	Extended Aeration	Y	N	N	Pumped to Southern Sea Outfall
Umhlatuzana -Mariannridge	9.90							
Lower Umgeni								
KwaMashu [Old]	15.00	-	Yes	Conventional	Y	Y	Y	DAF unit and Screw press dewatering
KwaMashu [New]	50.00	-						
New Germany	7.00	-	Yes	Conventional	Y	N	Y	Thickener and sludge pumped to Northern Works
Northern	70.0	-	Yes	Conventional	Y	N	Y	Gravity Thickener and Belt press dewatering
Southern Coastal								
Amanzimtoti	30.0	-	Yes	Conventional	Y	N	Y	DAF unit and Thickener
Craigieburn	1.00	-	N/A	Extended Aeration	Y	N	N	18 x Drying Beds
Isipingo	18.8	-	Yes	No	N	Y	Y	26 x Drying Beds
Kingsburgh	7.80	-	N/A	Extended Aeration	Y	N	N	Gravity Thickening
Magabheni	0.80	-	N/A	No	N	N	N	Oxidation pond, Sludge Lagoon
Umkomaas	1.00	-		Extended Aeration	Y	N	N	8 x Drying Beds
Inland								
Cato Ridge	0.50	-	N/A	No	N	N	N	Oxidation ponds, accumulates in sludge lagoon
Dassenhoek	5.00	-	N/A	Conventional	N	N	N	Sludge Lagoon
Fredville	2.00	-	N/A	Extended Aeration	N	N	N	Sludge Lagoon
Glenwood Road	0.04	-	N/A	No	N	N	N	Rotating Biological Contactors, no specified sludge handling method
Hammarsdale	27.0	-	N/A	Conventional	Y	N	N	Centrifugal Thickening
Hillcrest	1.20	-	N/A	Extended Aeration	Y	N	N	Screw Press Dewatering
KwaNdengezi	2.40	-	N/A	No	N	Y	Y	Drying Beds
Mpumalanga	6.40	-	Yes	No	Y	Y	Y	Drying Beds

The HHs in the eThekwini area are counted each year off of an aerial photograph that is taken in order to establish the number of dwellings that have not been served basic services (water, electricity and sanitation). In this process, the sanitation types have been identified by dwelling unit and can be seen in Table 12.

Table 12: Dwelling types and proportion of dwellings counted in eThekwini

Dwelling type	Total number of dwellings	Sanitation type per dwelling					
		Serviced with Urine Diversion Toilets	Within 200m of Ablution Block	Serviced with VIPs	Serviced with Septic Tanks & Package Plants	Serviced with Waterborne Sanitation	Backlog in Sanitation Service
Informal Settlements	265542	5194	111868			15533	132947
Informal Settlements - Formal Informal	3096				3096		
Backyard Shacks	48975					48975	
Rural - Traditional	103715	77059					26656
Formal houses not in Rural area (A1)	409210			35000	99282	274928	
Flats (B1)	110225					110225	
Formal houses in Rural area	5147				5147		
Total	**945910**	**82253**	**111868**	**35000**	**105525**	**449661**	**159603**
Percentage	**100%**	**9%**	**12%**	**4%**	**11%**	**48%**	**17%**

7.8 Appendix 8: SFD Matrix Creation Methodology

Table 13: Calculation of proportion of WW not delivered to the centralised treatment works

Time to react (hrs.)	Days of spillage (days)	Estimated overflow from trunk sewer (Ml/d)	Number of Blockages per day	Total overflow each day (Ml/d)	Total inflow to all treatment works (Ml/d)	Percentage that is not delivered to the treatment works	Percentage that arrives at treatment works
24.00	1.00	60	140	8400	114600	7%	93%
14	0.58	60	140	4900	114600	4%	96%
4	0.17	60	140	1400	114600	1%	99%

Table 14: Proportion of inflow treated at each treatment works (Department of Water and Sanitation, 2014)

Treatment Works	Average Annual Inflow (Ml/d)	Annual Average Effluent Quality Compliance (2012-2013)	Total Treated to Effluent Quality Compliance (Ml/d)
Northern Coastal			
Genazano	1.20	91.40%	1.0968
Phoenix	24.7	90.80%	22.4276
Tongaat Central	6.58	86.30%	5.67854
Umdloti	1.11	89.40%	0.99234
Umhlanga	4.66	93.10%	4.33846
Verulam	6.37	66.60%	4.24242
Central Coastal			
Central	60.7	100%	60.7
Southern	138.1	91.80%	126.81252
Umbilo	6.23	82.60%	5.14598
Umhlatuzana	10.32	96.30%	9.93816
Lower Umgeni			
KwaMashu	62.00	93.30%	57.846
New Germany	1.53	64.20%	0.98226
Northern	54.1	55.00%	29.755
Southern Coastal			
Amanzimtoti	23.7	96.30%	22.8231
Craigieburn	1.50	92.20%	1.383
Isipingo	12.5	95.90%	11.9875
Kingsburgh	4.52	87.90%	3.97308
Magabheni	0.42	80.60%	0.33852
Umkomaas	0.80	96.40%	0.7712
Inland			
Cato Ridge	1 (design capacity)	71.50%	0.715
Dassenhoek	2.20	96.80%	2.1296
Fredville	0.40	86.50%	0.346
Glenwood Road	0.04 (design capacity)	86.50%	0.0346

Hammarsdale	4.10	86.80%	3.5588
Hillcrest	0.87	86.70%	0.75429
KwaDengezi	1.26	76.80%	0.96768
Mpumalanga	2.35	93.90%	2.20665
Total	**433**	**-**	**382**
Percentage Treated			**88%**

7.9 Appendix 9: Selected pictures taken during observation

Figure 14: Vacuum tanker in place for septic tank emptying

Figure 15: Opening the first compartment of the septic tank and the equipment used

Figure 16: In tact invert level in the second chamber and watering down to loosen the sludge

Figure 17: Example of a the bioreactor of a Lilliputs, decentralised package plant

Figure 18: DEWAT trial plant