Opportunities for integrating Sustainable urban Drainage Systems (SuDS) in informal settlements as part of stormwater management

by

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Declaration

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Abstract

The lack of stormwater drainage systems in South Africa's informal settlements has negative implications for human life and livelihoods due to flooding, resultant relocation, and the increased potential for water-borne diseases. Informal settlements, expected to exponentially increase in numbers and size due to urbanisation trends and lack of housing for low- and no-income groups, are often located in areas not suited to human habitation, such as wetlands. In addition, they are often located in topographical areas that are difficult to service, such as steep slopes, and configured in a way that makes it difficult to impose conventional systems. Besides the physical challenges to implementing systems in these contexts, South African municipalities face cost and capacity challenges regarding basic service provision. South Africa's guiding document to implementing and upgrading these settlements, the Upgrading Informal Settlements Programme, focuses almost entirely on issues of water, sanitation, energy and housing provision. Drainage is also marginalised in the general policy discourse focused on improving the living conditions of those in informal settlements. The need to find and implement alternative drainage solutions is paramount. This study seeks to motivate for such an alternative approach and to explore the options available.

The study, using a mixed-methods approach, examines the potential for incorporating sustainable urban drainage systems into the Upgrading Informal Settlements Programme, the benefits offered by these systems, their alignment with sustainable development principles and the challenges to implement them in the informal settlement context. It does this using a sustainability framework and a complexity theory lens. The interactions between urban water cycles, drainage solutions and behavioural aspects combine to create a 'wicked' problem – one that is complex and cannot be reduced to simple parameters. An understanding of systems and complexity thinking was therefore needed to ascertain the contribution that a sustainable urban drainage system could make in the informal settlement context. The informal settlement of Enkanini, Stellenbosch is used as an illustrative example of the need for such systems and the Century City drainage system is given as a real-world example. A predominantly qualitative approach was used as there is a dearth of literature on the subject and no current application of sustainable urban drainage systems in the informal context available to examine in literature. A literature review provided a theoretical framework for the study and three main policy documents were analysed using the Nvivo 10 software package to gather both quantitative and qualitative data by coding and categorising the content, which was then substantiated by content analysis, a review of associated grey literature and personal interviews.

The study outlines the consequences of a lack of drainage systems in the informal context, the need for alternatives to the current conventional system, the benefits such a system could offer, as well as its limitations. It contributes to filling a gap in available literature on the subject in the South African informal settlement context and hopes to help escalate the call for stormwater drainage systems to be incorporated into the Upgrading Informal Settlements Programme.

Keywords: Stormwater, sustainable urban drainage systems, informal settlement, complexity theory, water-sensitive urban design, flooding, sustainability, urbanisation, conventional drainage systems, Nvivo 10

Opsomming

Die gebrek aan stormwaterafvoerstelsels in Suid-Afrika se informele nedersettings hou negatiewe implikasies vir mense se lewens en lewensbestaan in weens vloede, gevolglike hervestiging en die verhoogde potensiaal vir waterverwante siektes. Informele nedersettings, wat na verwagting aanmerklik in getalle en grootte sal toeneem weens verstedelikingsneigings en die tekort aan behuising vir lae- en geeninkomstegroepe, is dikwels geleë in gebiede wat nie vir mensebewoning geskik is nie, soos moeraslande. Hierbenewens is hulle dikwels geleë in topografiese gebiede waaraan dienste met moeite gelewer word, soos op steil hellings, en die vorm daarvan maak dit dikwels moeilik om konvensionele stelsels toe te pas. Buiten die fisiese uitdagings om stelsels in hierdie konteks te implementeer, kom Suid-Afrikaanse munisipaliteite voor koste- en kapasiteitsuitdagings rakende basiese diensverskaffing te staan. Suid-Afrika se riglyndokument vir die implementering en opgradering van hierdie nedersettings, die Opgradering van Informele Nedersettings-program (OINP), fokus byna uitsluitlik op kwessies van water, sanitasie, energie en behuising. Afvoer word ook in die algemene beleidsdiskoers gemarginaliseer, waarin die fokus is op die verbetering van die lewenstoestande van inwoners in informele nedersettings. Daar is ʼn dringende behoefte daaraan om alternatiewe afvoeroplossings te vind en te implementeer. Hierdie studie het gepoog om motivering te bied vir sodanige alternatiewe benadering en het ondersoek ingestel na die beskikbare opsies.

Die studie het, met ʼn gemengdemetode-benadering, die potensiaal vir die inkorporering van volhoubare stedelike afvoerstelsels in die OINP ondersoek, asook die voordele wat deur hierdie stelsels gebied word, die ooreenstemming daarvan met volhoubare ontwikkelingsbeginsels en die uitdagings om dit in die konteks van informele nedersettings te implementeer. Dit is aan die hand van ʼn volhoubaarheidsraamwerk en ʼn kompleksiteitsteorielens gedoen. Die interaksie tussen stedelike watersiklusse, afvoeroplossings en gedragsaspekte span saam om ʼn ‘bose’ probleem te skep – ʼn probleem wat kompleks is en nie tot eenvoudige parameters verklein kan word nie. Begrip van stelsels en kompleksiteitsdenke was dus nodig om die bydrae wat ʼn volhoubare stedelike afvoerstelsel in die konteks van informele nedersettings kan lewer, te bepaal. Die informele nedersetting Enkanini in Stellenbosch is as voorbeeld van die behoefte aan sodanige stelsels gebruik en die Century City-afvoerstelsel is as ʼn werklike voorbeeld gebruik.

ʼn Kwalitatiewe benadering is hoofsaaklik gebruik, aangesien daar ʼn gebrek aan literatuur oor die onderwerp is en daar geen huidige toepassing van volhoubare stedelike afvoerstelsels in die informele konteks beskikbaar was om te ondersoek nie.

ʼn Literatuuroorsig het ʼn teoretiese raamwerk vir die studie verskaf, en drie vernaamste beleidsdokumente is met die Nvivo 10-sagtewarepakket ontleed om sowel kwantitatiewe as kwalitatiewe data in te samel deur die inhoud te kodeer en te kategoriseer, wat daarna deur inhoudsanalise, ʼn oorsig van verwante grys literatuur en persoonlike onderhoude gestaaf is.

Die studie beklemtoon die gevolge van ʼn gebrek aan afvoerstelsels in die informele konteks, die behoefte aan alternatiewe vir die huidige konvensionele stelsel, die voordele wat so ʼn stelsel kan bied, asook die beperkings daarvan. Die studie vul ʼn gaping in die beskikbare literatuur oor die onderwerp in die konteks van Suid-Afrikaanse informele nedersettings en sal hopelik help om die beroep op die inkorporering van stormwaterafvoerstelsels in die OINP te versterk.

Sleutelwoorde: stormwater; volhoubare stedelike afvoerstelsels; informele nedersetting; kompleksiteitsteorie; watersensitiewe stedelike ontwerp; oorstroming; volhoubaarheid; verstedeliking; konvensionele afvoerstelsels; Nvivo 10

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CSIR	Council for Scientific and Industrial Research
IISD	International Institute for Sustainable Development
ISUG	Informal Settlements Upgrading Group
IDP	Integrated Development Plan
LLFASEE	Lead Local Flood Authorities of the South East of England
SANRAL	South African National Road Agency Ltd.
SuDS	Sustainable urban Drainage Systems
TSAMAHub	Transdisciplinary, Sustainability Analysis, Modelling and Assessment Hub
UISP	Upgrading of Informal Settlements Programme
WCED	World Commission on Environment and Development

Chapter 1: Introduction

The significant problems we face cannot be solved at the same level of thinking we were at when we created them.

Albert Einstein, 1946

1.1 Introduction

The issue of stormwater management is generally excluded from discussions and policies focused on provision of basic services in informal housing settlements; South Africa's Upgrading Informal Settlements Programme (UISP) is no exception to this trend with its primary focus on issues of housing, water, energy and sanitation issues. The consequences of sidelining the issue of stormwater management in the discourse include an increased potential for stormwater flooding and related emergent health risks. This study is an attempt to escalate the issue of stormwater management into the discourse around basic service provision in informal settlements and ultimately into South Africa's UISP.

Chapter 1 introduces the context of the study by providing a background to the problem of inadequate or no stormwater management systems in informal settlements. The informal settlement of Enkanini, Stellenbosch in South Africa is used an illustrative example of the consequences. This settlement is flooded frequently, which causes people to be displaced and to lose their livelihood opportunities and escalates the potential for outbreaks of waterborne diseases. Those living in informal settlements, such as Enkanini, will increasingly be at risk of natural disasters of this sort as the climate changes and they are the least able to adapt with minimal resources (Parkinson et al., 2007). For this reason, a sustainability lens is used to analyse the problem and possible solutions – with a focus on Sustainable urban Drainage Systems (SuDS) which are sequences of management practices and/or control structures or technologies designed to drain surface water in a more sustainable manner than conventional techniques. Conventional techniques/drainage systems have a single objective, which is to control floods during large storms. However, this objective of flood control fails to address the environmental effects caused by increased runoff volumes and velocity which is increased by development. As such, frequent storms erode urban streams, water eroded sediments and other constituents from the urban landscape into downstream receiving waters and often tends to damage property, impairing their usage by wildlife and people. In addition, given that social and ecological systems are so closely interlinked (Audouin et al., 2013) in informal settlement contexts, complexity theory is used to untangle the web of interconnections (Cilliers, 2008) between urban water cycles, drainage solutions and behavioural aspects that combine to create this ‘wicked’ problem.

A ‘wicked’ problem is one that is difficult to solve because the information required to solve it is not complete or contradicts itself, it can involve many stakeholders with conflicting agendas, have a heavy economic cost attached and can be connected to other problems or even cause them (Wickedproblems.com, n.d.). Wicked problems are problems that do not necessarily hold a high degree of complexity, however, they are regarded as a fundamentally different kind of challenge, in which the solution is secondary whilst the understanding of the problem is central (Pryshlakivsky & Searcy, 2012). Therefore, the level of wickedness can help in the explanation as to why no level of linear thinking…would ultimately ever present a workable solution to some problems (Palmer et al., 2007). Sustainability in itself can be chracterised as a wicked problem because its solution is either true or false, the resources and constraints for a solution have the possibility of changing over time, no clear definitive formulation of the problem exits. Moreover, the lack of tractability in sustainability gives raise to the question of how people can produce something that is beyond the conventional notions of structure and definition (Peterson, 2008).

The chapter further outlines the objectives and research questions of the study, as well as providing an outline of the remaining chapters and a glossary of key terms.

1.2 Background and rationale for the study

In 2011 a group of masters and PhD students interested in the service delivery challenges faced by those living in informal settlements and in ways to institute *in situ* upgrading using sustainable alternatives in a country battling to clear a backlog in service provision formed the Informal Settlements Upgrading Group (ISUG). I joined the group in 2012. Stellenbosch University’s Hope Project and Transdisciplinary, Sustainability Analysis, Modelling and Assessment (TSAMA) Hub oversaw the ISUG. The National Research Foundation awarded funding to the group under its Community Engagement Programme from 2011 to 2013 (Von der Heyde, 2014). The funding was used for projects run in the informal settlement of Enkanini, Stellenbosch in which residents had been staging service delivery protests for several years. The projects ranged from those focused on energy and waste management to sanitation service delivery, but excluded stormwater drainage, which residents had identified in the 2012 Enkanini (Kayamandi) Household Enumeration Report as one of their more urgent needs (Stellenbosch Municipality, Community Organisation Resource Centre & The Informal Settlement Network, 2012).

Burgeoning informal settlements are a reality for many developing countries in the global south and they exist because of a lack of municipal planning for increased urbanisation rates and the need for affordable housing; they often come about as a result of land invasions (Armitage, 2011). Moreover, in South Africa a housing backlog dating back to before the time of independence and thereafter, has seen people moving into informal settlements as a meaning of living in an affordable shelter. As the urban population increases exponentially (Bolnick, 2010) with an estimated growth of about 4.9 billion by the year 2030 (Butala et al., 2010) so will the demand for housing from low- and no-income groups, leading to "escalated overcrowding" (Abbott, 2002:306). Most of those moving to informal settlements could be forced to live in deplorable conditions (Armitage et al, 2010; Butala et al., 2010).

There is an urgent need to dignify these living conditions starting with provision of providing basic services, and this is supported by the South African bill of rights in which everyone has a right to an environment not harmful to their wellbeing and in which the prevention of pollution and ecological degradation is addressed. However, provision for basic services often excludes stormwater drainage systems and the issue of drainage rarely makes it to the discussion platform until it becomes a problem. There are social and economic implications associated with inadequate or no drainage infrastructure (Parkinson et al., 2007). Water brought into any human settlement – formal or informal – needs to be disposed of safely (Adegun, 2013) to avoid the unintended consequences of flooding, which can lead to displacement of people, or an outbreak of water-borne diseases.

The rationale for the study and the motivation to explore the potential of SuDS are that the associated techniques provide multiple benefits beyond the conveyance of stormwater into the nearest watercourse and thus minimising flooding. These benefits and the system's flexible alignment with the complexities of implementing drainage in an informal settlement context are outlined further in chapter 2. SuDS are also in line with the developed world's increasing need to recognise that the management of stormwater needs to be catered for in a manner that mimics the natural process, which has been distorted by urbanisation, to ensure sustainable hydrological flows and maximise water usage.

Enkanini, Stellenbosch is used as an illustrative example of an informal settlement context with its inherent complexities when it comes to finding and implementing sustainable basic service solutions. The conditions and management of stormwater in informal settlements, is the complete opposite of the global south, but provides a starting point of allowing SuDS discourse to be discussed and implemented in a place where stormwater drainage has become an urgent need as it displaces people.

1.2.1 Introducing Enkanini, Stellenbosch

The informal settlement of Enkanini is located on the slopes of the Onder Papegaaiberg (mountain) on the outskirts of Stellenbosch. The Enkanini settlement, which means 'taken by force' in isiXhosa, originated when shack dwellers from the adjoining Kayamandi settlement moved onto the municipal-owned vacant land in 2006 (Wessels, 2015). The municipality attempted to stop the wave of people moving in by demolishing shacks, but to no avail (Stellenbosch Municipality et al., 2012). Kayamandi is an established settlement that originated in the 1950s to house the formerly segregated black community that served as farm labour on white-owned farms. To the east of Enkanini is the Plankenbrug industrial area, which is connected to the Plankenbrug River that runs down to the Eerste River.

To the south is the Papegaaiberg Nature Reserve. The settlement has expanded onto part of the nature reserve, the deed to which belongs to the municipality. The municipality has subsequently fenced off the settlement to prevent further encroachment and it has erected a watchtower at the fence (Malulu, 2012).

The figure below provides a profile illustration of Enkanini and surrounds.

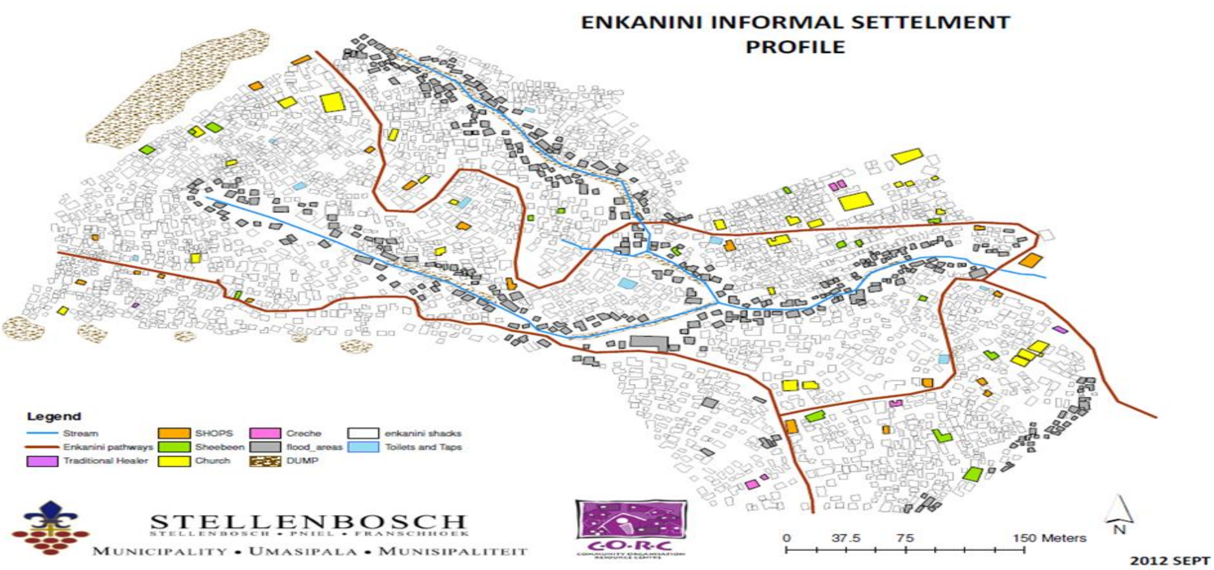


Figure 1: Enkanini informal settlement profile map, Stellenbosch
Source: Stellenbosch Municipality et al. (2012)

1.2.2 Conditions on the ground in Enkanini, Stellenbosch

According to the Enkanini (Kayamandi) Household Enumeration Report (Stellenbosch Municipality et al., 2012), there were about 4 204 people living in Enkanini in 2012 – 53% were men and 47% women. They were living in about 2 215 shack structures. The municipality has provided 32 taps and 80 toilets to date, which equates to a one tap for every 69 people and 1 toilet for 27 households (Wessels, 2015). This is far from the ideal ratio of 1:1 for basic services provision according to the residents of Enkanini as stated in the (Stellenbosch Municipality et al., 2012). There is no electricity grid connection to the settlement and residents use paraffin as their primary source of energy. There is no health clinic and no stormwater drainage system. The unintended results of this level of service provision are that residents use the bucket-system for sewage disposal and there have been a series of shack fires and instances of flash flooding.

Prior to 2012, 356 households were affected by floods and 111 by fire (Wessels, 2015). There are high levels of unemployment in the settlement and most people survive on the government social grant. Waste is deposited into open skips and often gets blown away on windy days; it is not collected regularly (Von der Heyde, 2014).

Enkanini has a relatively high population density of about 1.9 square metres per person and the influx of people looking to live there is expected to continue, which implies that these problems will be exacerbated (Stellenbosch Municipality et al., 2012).

For most residents the distance to the nearest tap or ablution facility is a steep and lengthy walk. This has been cited as one of the contributing factors to muggings and attempted rapes (Wessels, 2015). The density of the shacks has also contributed to the quick spread of fire (Wessels, 2015). Children often play in the open waste skips and the spread of rubbish around the settlement has resulted in rat infestations (Von der Heyde, 2014). The waste situation exacerbates instances of flash flooding during the rainy season as it acts as a barrier for waste and stormwater runoff. The steep gradient on which Enkanini is located is also eroded and so has very little top soil that can be used for garden patches (Von der Heyde, 2014).

During the 2012 enumeration, residents identified access to water, grid electricity and alternative sites for those affected by flooding as their priority concerns. In addition, blocked sewers and the lack of refuge collection were listed (Stellenbosch Municipality et al., 2012).

1.3 Problem statement

During the Roman Empire, drainage systems where built on the principle of ‘combined systems” in which surface water runoff from precipitation was mixed with that of industrial waste and domestic foul sewage (Jones & Macdonald, 2007). However, at the turn of the 19^{th} century as the population grew, the dumping of raw sewage directly into the watercourses became extremely problematic and this was largely compounded by the fact that engineering design has largely been founded on the basis of hard engineering sciences and the cost of cleaning up the pollutions effects was expensive and detrimental to the environment. Although this lead to the separation of stormwater from that of industrial and domestic sewage, more attempts kept being made to ultimately, find ways of purifying the water before discharging in back into the watercourses systems. This separation of the systems eventually became known as the conventional drainage systems as they became the norm in which drainage of stormwater was founded. Although these systems focused on the safe disposal of the water from the urban areas and they resulted in creation the concept of ‘out of sight out of mind’. As such especially in the case of stormwater, its potential as a valuable resource became overlooked and underutilised.

There saw a need to shift the paradigm of thinking about drainage from a conventional approach to one that is cost-effective, environmentally viable and able to adapt within increasingly complex parameters. This required acknowledging the intrinsic linkages between ecological services, sustainability and the greater ecosystems services in which water was acknowledged a valuable resource (Edward & Burns, 2002; Jones & Macdonald, 2007; Novotny, 2008, Hoyer et al., 2011; Bettini, Brown, de Haan & Farrelly, 2015). This saw the need to harness waste and waste water in a mean that eventually saw water being send back into the greater water cycle.

Moreover, there was little reliance on the ecological sciences and its interrelations with the greater ecosystem and this required an interdisciplinary approach, so that mutually beneficial interacts could be attained (Beechman, 2003). As such the breaking down of traditional engineering borders of knowledge required an interdisciplinary approach in which the concepts of integrated land and water management, were founded with particular focus on integrated urban water cycle management. This was the space in which SuDS and the umbrella of Water Sensitive Urban Design (WSUD) were founded.

Problems caused by inadequate or lack of stormwater drainage systems are nowhere more apparent or more harmful to humans and the environment than in informal settlements. My experiences in Enkanini have prompted this study’s search for suitable drainage systems that can be implemented in an area where relational and functional complexity aspects exists (see chapter 2, section: 2.6.3 for an in-depth explanation of both concepts). Inclusion in policy documents such as the UISP would provide traction for implementing these types of systems.

1.4 Aim of this study

This study aims to understand the problems caused by the lack of stormwater drainage in informal settlements in South Africa. Furthermore, it seeks to explore sustainable alternatives that would be appropriate for implementation in complex socio-environmental locations. It also aims to explore the possibilities for including stormwater drainage provision in the UISP.

If successful, it will contribute to shifting the service provision agenda to a holistic approach to upgrading incorporating all the necessary aspects which include, water, electricity, sanitation and storm and waste water drainage for sustainable living. In addition, the study aims to emphasise the importance of stormwater drainage systems being ones that are socially and environmentally just, while able to also generate multiple benefits – some of an economic nature.

For this reason, the study positions SuDS within a framework of water-sensitive urban design as a viable alternative to conventional systems. The framework targets engineering and land-use planning designs for urban water-cycle integration that include stormwater, wastewater, ground water and water supply. These systems are seen from the view point in which, they are able to cater to both relational and functional complexity and focus on the social domain in which techniques are placed. The study further aims to illustrate the potential high optimisation levels for a resource like stormwater. It challenges the conventional paradigm of thought and looks at how these systems can bring about sought-after social and institutional arrangements regarding drainage systems, which are traditionally regarded as merely technical systems (Armitage, 2011).

1.5 Research objectives and questions

The objectives of this study are to:

- To analyse how complexity and informality affect the holistic approach to upgrading of drainage systems in informal settlements.
- To understand how ecosystem services and the urban water-cycle can benefit from SuDS techniques.
- To illustrate that inclusion of these techniques in policy would help provide traction for implementation.

To fulfil these objectives, the following research questions were formulated:

1. Is there room to incorporate SuDS in South Africa's UISP?
2. What potential do SuDS have to address drainage issues in informal settlements?
3. What other services can SuDS link to and provide benefits?

1.6 Outline of the remaining chapters

Chapter 1 has provided a background and rationale for the study, presented Enkanini as an illustrative example of the informal settlement context with its inherent complexities around service provision, and outlined the problem statement along with the research aims, objectives and questions.

Chapter 2 presents a comprehensive literature review on associated topics ranging from the informal settlement context, an introduction to sustainability and complexity theory and an overview of ancient, modern and alternative drainage systems to outlining the need for alternatives and introduces SuDS and the associated benefits. It also presents an overview of relevant policy, regulatory and strategic documents that either include or should include stormwater management.

Chapter 3 expands on the chosen research design and methodological approach before presenting details on each of the chosen methods.

Chapter 4 presents the data results and analysis with a focus on the potential for SuDS to be included in national policy, the projected benefits and the hindrances to its implementation in the informal settlement context.

Chapter 5 summarises the findings, confirms that the research questions have been answered and provides recommendations for further research.

1.7 Definition of terms/concepts

Terms commonly used in the discourse around stormwater are presented below. They are drawn from Wong (2006), Woods-Ballard, et al., (2007), Armitage et al. (2012) and Zhou, 2014.

Conventional drainage system refers mainly to a single-objective oriented design with its focus on water quantity control. The main purpose of these systems Conventional drainage systems is to collect and transport water runoff from urban areas as quickly as possible via sewer networks and water treatment facilities to nearby receiving water bodies. The goal is to manage water volume in order to avoid urban flooding in city areas. The water is treated as a nuisance in the landscape and thus transported in a manner of "out of sight and out of mind". As such the design of conventional drainage system is limited to the concern for water quality issues and even less for its amenity and recreational values.

Flood or flood water refers to any temporal rise in water levels of either/or ground water or overflow of water onto land spaces usually not covered by water.

Runoff is water that flows on the surfaces as a result of precipitation events.

Stormwater is water that results from natural precipitation and/or accumulation and includes rain water, groundwater and spring water.

Stormwater management is inclusive of both quantitative and qualitative management of stormwater and the functions associated with planning, designing, constructing, operating, maintaining and financing stormwater management systems.

Stormwater management systems refers to both constructed and natural facilities that collect, convey, store, control, treat, use and dispose of stormwater.

Water-sensitive urban design refers to the incorporation of interdisciplinary interactions between landscape planning, water management and urban design.

Sustainable urban drainage systems encompass a sequence of management practices and/or control structures or technologies designed to drain surface water in a more sustainable manner than conventional techniques.

Chapter 2: Literature review

The difficulty of literature is not to write, but to write what you mean; not to affect your reader, but to affect him precisely as you wish.

Robert Louis Stevenson, 1909

2.1 Introduction

The Millennium Development Goals and the development agendas of most developing countries focus on issues around health, sanitation and water provision. However, urban flooding due to lack of adequate drainage systems poses one of the greatest threats to human settlements today (Parkinson, 2003); a threat that will exponentially increase as the climate changes and weather patterns become more erratic and intense (Pelling & Wisner, 2008; Sakijege, Lupala & Sheuya, 2012). This issue remains sidelined, particularly in the literature focused on informal settlement upgrading (Ziergevol & Smit, 2009; Armitage, 2011). Traditional drainage systems focus on making surfaces smoother to increase runoff to the nearest water course (Wentzel, 2013) and stormwater drainage has essentially been regarded as a technical intervention linked to roadworks and one meant to handle destructive surface water. In essence, stormwater is not viewed as a valuable resource, but rather as a nuisance.

As such, there is a need to find alternative drainage systems that align with sustainable development goals whilst viewing water as a valuable resource within the greater economy. Moreover, increased urbanisation trends have led to increased stormwater runoff within the urban areas, in which informal settlements exist. Unfortunately, most informal settlements do not possess stormwater drainage facilities. This is attributed to the fact that stormwater drainage is regarded as a technical system although it holds the potential to bring communities, government and other relevant stakeholders together to in order to bring about alternative drainage systems that are efficient. In short, the system itself should force co-generation of solutions. .

In this context, the notion of SuDS emerges as a key intervention with a holistic consideration of runoff encompassing water quantity, quality, amenity and biodiversity aspects (Armitage et al, 2013). It is also a more affordable intervention, particularly in informal settlements, and thus applicable to financially constrained municipalities. SuDS encompass a range of management practices and technologies that drain surface water in a sustainable manner, while also providing value-added benefits (shown in Figure 18, Page 42).

Stormwater drainage is but one element in a system driven by urbanisation and exacerbated by shack sprawl in an environment where municipalities are overburdened and under-capacitated. It is in the space that non-structural adjustments (including institutional, educational and awareness-raising initiatives) could be better understood using complexity theory and systems dynamics modelling to identify the key actors, their interactions and the subsequent consequences of a lack of stormwater drainage. Furthermore, there is the need to understand how these non-structural adjustments in drainage can be used to understand the greater issues of urbanisation and flooding from a holistic point of view within a system.

2.2 Sustainability and complexity theory

2.2.1 Need for sustainable solutions

The 1987 report *Our Common Future*, released by the United Nations' World Commission on Environment and Development (WCED) (1987), elevated the concept of sustainable development to the international agenda and coined the most accepted definition to date: "[sustainable development] is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (International Institute for Sustainable Development [IISD], n.d.) The definition contains two key concepts (IISD, n.d.):

- "The concept of needs, in particular the essential needs of the world's poor, to which overriding priority should be given; and
- The idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

For the purpose of this thesis, those living in informal settlements are considered as part of the 'world's poor' with basic service needs and living in a particular built environment, which is affected and shaped by human activities. The basic needs of informal settlement dwellers are still unmet in South Africa, hence, the formation of the Upgrading of Informal Settlements Programme which is aimed at improving the lives of informal settlements dwellers (UISP, 2009). The needs in UISP where aligned with those set out as most crucial by the Millennium Development Goals, namely water, sanitation and health (United Nations, 2012); in South Africa these needs include housing and energy provision – however, there is little regard given to drainage in both documents especially in the case of South Africa (Stellenbosch Municipality et al., 2012; United Nations, 2012) until the lack of it becomes problematic. Therefore, the problems relating to flooding are usually written as part of disaster management literature, after the fact (Pelling & Wisner, 2008; Ziervogel, & Smit, 2009; Jha et al., 2012).

2.2.2 Informal settlements – a complex system

An informal settlement is a sub-system within a greater urban system. It is identified as a system because it has "…an interconnected set of elements that are coherently organized in such a way that it produces its own pattern of behaviour overtime" (Meadows, 2008:2). Within this system, flooding emerges as an unintended consequence of inappropriate drainage (as it is not perceived as part of the package of basic services) and increased levels of shack sprawl.

Some may argue that informal settlements should rather be defined as complicated, as opposed to complex systems, because the problem of basic services can be 'individually distinguished' (Poli, 2013). In other words, the 'problem' can be isolated into parts and a permanent solution found for each discrete challenge (Poli, 2013). However, this is a short-sighted view of informal settlements and one that has led to numerous failed attempts to improve service delivery in these contexts. By not viewing the settlement as a complex system, the interactions between elements/components of the water system (wastewater and stormwater, which both require drainage, (Armitage, 2011) when combined with high densities and poverty can result in health risks and displacement.

Complexity theory allows us to challenge current beliefs regarding a phenomenon and to make sense of difficult tasks that often require abstract thinking (Hmelo-Silver & Pfeffer, 2004). In this case, complexity theory, which requires the comprehension of the relationship between the whole and the sum of its parts because knowledge of the whole as a whole is not enough (Morin, 2007 in Cilliers, 2008:43), enables the positioning of stormwater drainage as an element in a system with connections to other elements as well as being an element affecting the functioning of the whole – for example, the health of the community. Cilliers (2008) notes that in order to recognise complexity one has to 'decomplexify' it. He outlines some general characteristics of complex systems as (1998 in Preiser, 2014):

- Open systems – ones that interact with external elements and/or systems.
- Generally comprising a large number of heterogeneous components.
- Having dynamic and usually rich interactions between components.
- Experiencing non-linear interactions in that the effects are disproportional to the cause.
- Having no direct link necessary for distant elements to interact.
- Having an abundance of non-linear routes.
- Being influenced by the history of the system.

Complexity thinking helps us understand that intervening in a system in a linear way can result in the emergence of new problems (Poli, 2013) as disturbing any component will affect the other components as well. Complex systems thus require systematic management (Poli, 2013). Hmelo-Silver and Pfeffer (2004:129) stress the importance of making sense of complex systems by "…constructing concepts and principles about some domain that represents key phenomena and the interrelationships among different levels of a system, whether it is macro to micro or structure to function."

In short, provision of basic services within a context of an informal settlement needs to be addressed in an inter-related manner. This includes the issue of stormwater drainage.

Figure 2 illustrates the causal loop diagram of the factors resulting from the formation of shacks as a form of alternative housing to the greater problems leading up to issues linked to the lack of drainage. There are some reinforcing loops denoted by an R in the direction in which the loop is flowing, while the B denotes a balancing loop. Figure 2 reinforces the notion that often system subcomponents do not have access to all the information relating to the behaviour of the system as a whole.

Complexity theory can be used to understand the interactions occurring between components within the informal settlement system and lead to an enhanced understanding of the *in situ* upgrading process, which encompasses the problem of drainage. As more pressure is placed on the system by exponential urbanisation (Bolnick, 2010), the issue of basic service provision, including drainage, will assume more importance. Using a complexity lens also allows the links between society and nature to become more apparent and hopefully more appreciated (Swilling & Annecke, 2012).

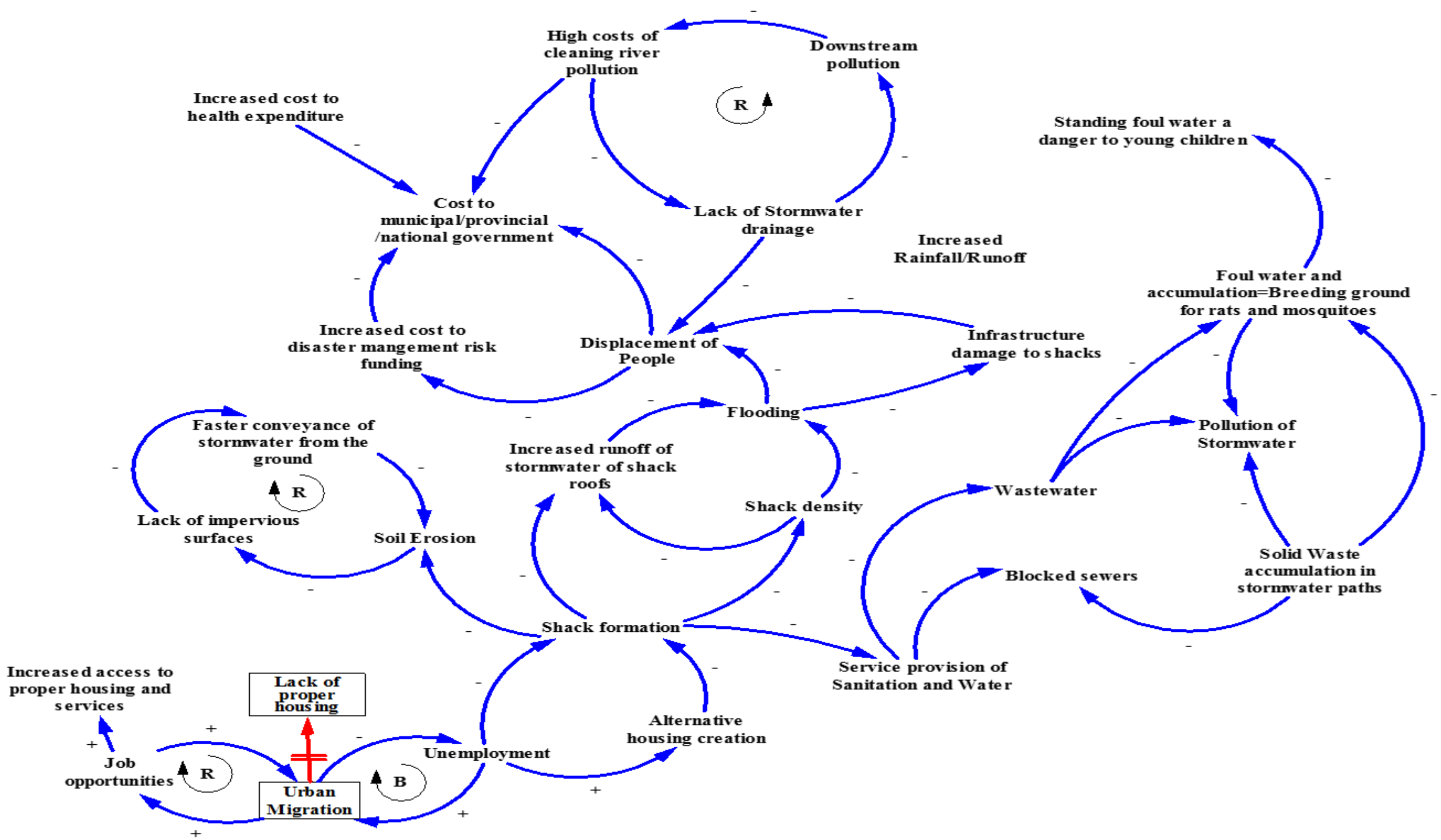


Figure 2: Factors relating to or resulting from a lack of drainage
Source: Author 2015

Human interaction with a system alters the system's general properties given that complex systems are likely to be adaptive and fragile (Margulis & Sagan, 1997 in Swilling & Annecke, 2012:11). Human activities take place within socioecological systems – there is no natural system without people and there is no social system without nature (Stockholm University, 2014). Social and ecological systems are interdependent and constantly co-evolving (Stockholm University, 2014). Audouin et al. (2013:4) reinforce this concept by stating that "the social aspects of a system cannot be studied separately from ecological ones" because these systems retain both 'interior and exterior' aspects that need to be understood thoroughly. Human interaction or actions within a system can have positive and/or negative effects. However, in the case of informality resulting from urban migration the challenge of service delivery becomes more apparent in terms of the negative effects.

2.2.3 Urbanisation driving service delivery challenges in Africa?

More people will move to urban cities (Butala et al., 2010), as a result of employment and investment opportunities which result from economic growth (Luhar, 2014). And for those who cannot afford housing or rent, due to a lack of low cost housing, will be forced to build shacks as a means of housing alternative, resulting in "informal settlement growth and escalated overcrowding" (Abbott, 2002:306). Overcrowding, results from the lack of space within the alternative space sourced for shack dwelling. Most of those moving into informal settlements will be forced to live in deplorable conditions (Armitage et al., 2010; Butala et al., 2010) and the conditions are often made deplorable due to the lack of water, sanitation and waste management facilities. There has been an explicit call on governments to provide water and sanitation services, but very little focus on provision of drainage systems for informal settlements. Urbanisation and increased densities in informal settlements affect water supply in a variety of ways (Overloaded systems should the original area have been developed with a less initial population and low water pressure) and increase the need for drainage systems. The following figures 3 and 4 illustrate the effects of urbanisation, including decreased infiltration, increased run-off and pollutants and decreased water supply over time, which could translate into high levels of water scarcity. Both figures ultimately, show how stormwater runoff increases overtime as more development covers open areas with little to no infiltration happening.

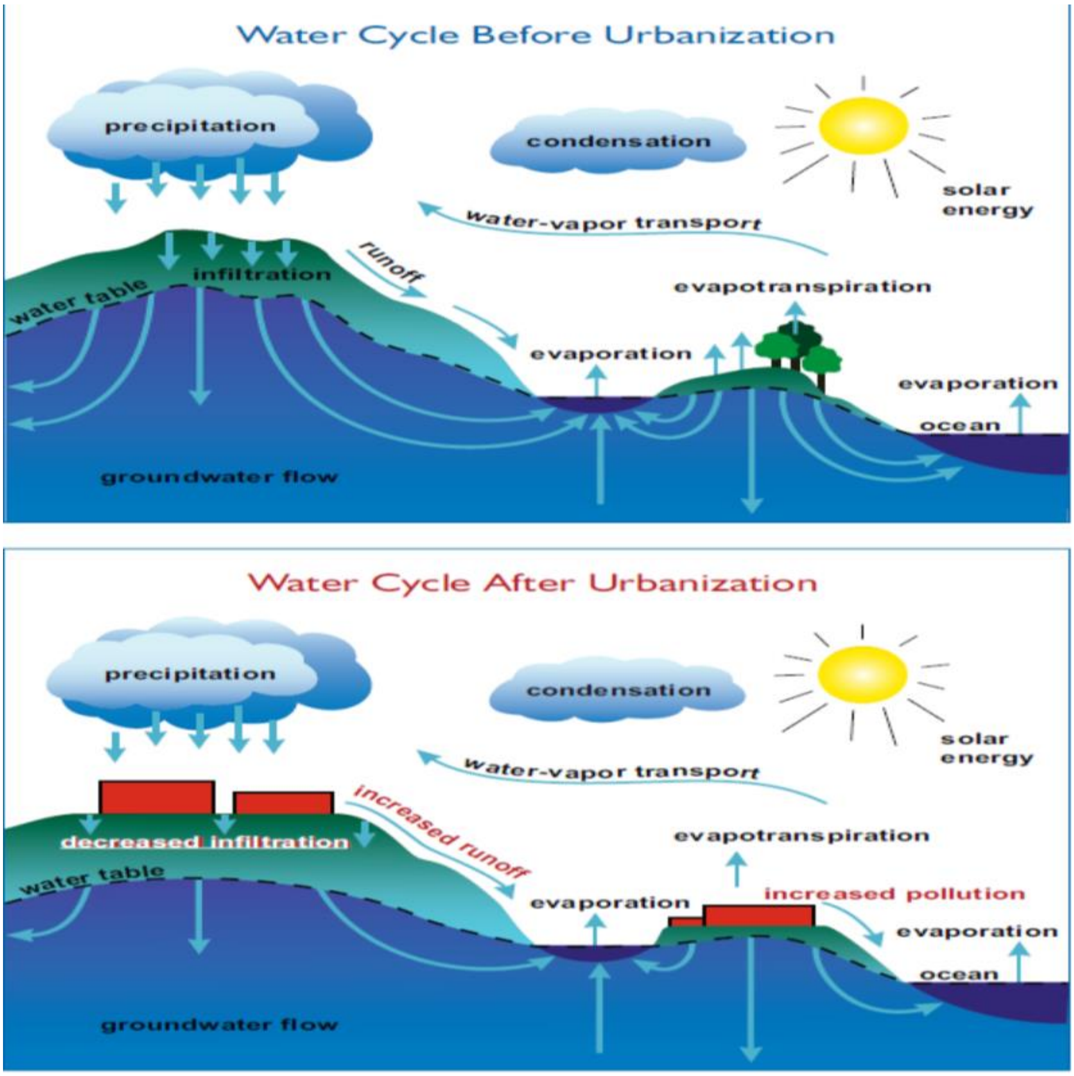
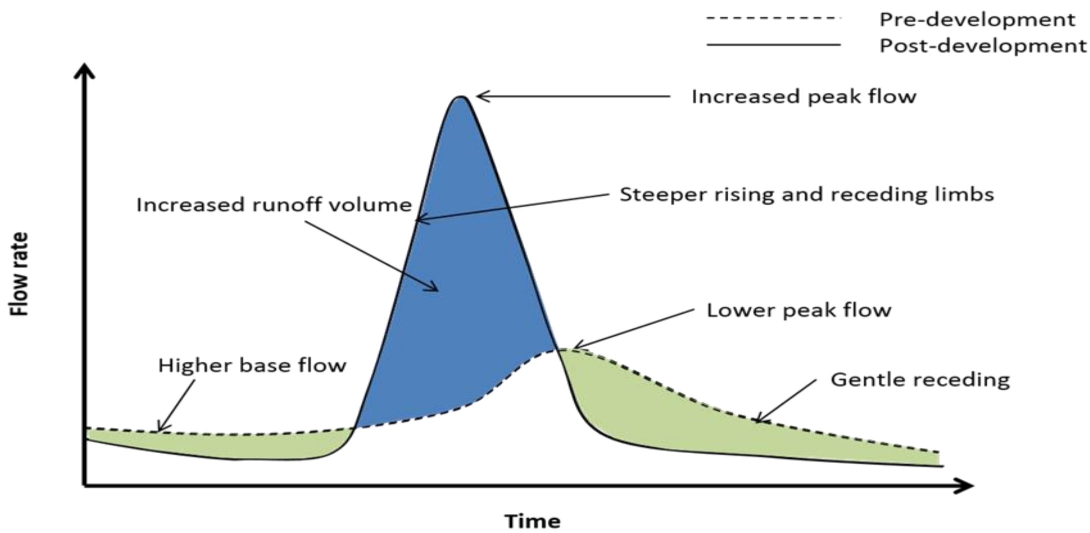


Figure 3: Effects of urbanisation on the water cycle
Source: Donaldson & Cooperative (2004)



Source: WSUD.co.za (2013)

Figure 4: Typical hydrology associated with pre- and post-development with conventional approach to stormwater management

Urbanisation increases the fraction of runoff because the ground becomes impervious (Butler & Parkinson, 1997; Reed, Parkinson & Nalubega, 2001; Silveira, 2002; Daniel, Augustina, Anthony & Kayode, 2012) resulting in decreased infiltration and water table replenishment. An increase in urban density is linked to an increase in stormwater; the formation of increased density settlements and impermeable soil surfaces has a domino effect, of augmented land occupation, which has an even greater effect on hydrology (Silveira, 2002). These emergent vulnerabilities and risks need to be understood so that they can be mitigated, particularly in the case of flooding (van Huyssteen, Roux & Van Niekerk, 2013). This entails linking drainage components to the water cycle and moving away from end-of-pipe solutions, which also require big investments in treatment because of the pollutants accumulated along the stormwater drainage course. Drainage should in effect encourage increased water infiltration to restore groundwater levels and replenish aquifer storage (Butler & Parkinson, 1997; Perlman, 2013). The ideal notion of urban drainage is that it acts as a preventative measure and whilst mimicking the natural infiltration of the ground and should be incorporated into the urban plan whilst "… following principles that conserve natural drainage, preserving strips of vegetation along river banks, minimising impermeable surfaces, and making use of installations for infiltration and detention runoff" (Silveira, 2002:34). Sadly, the notions of urban drainage for informal settlements is lagging behind and less so because of the lack of it's empathises in the Upgrading of Informal Settlements Programme.

2.2.4 Upgrading of informal settlements

A shift in perception is needed to recognise that informal settlements should not only be viewed from the perspective of a housing problem requiring a housing solution (Huchzermeyer, 2006). There is no concise or clear definition of informal settlement upgrading because what municipality might upgrade might not necessarily be viewed by the community as a deliverable worthy of being called an upgraded service (Stellenbosch Municipality et al., 2012). However, Abbott's (2002:307) definition is useful as it describes the process as a term applying to "any sector-based intervention in the settlement that results in a quantifiable improvement in the quality of life of the residents affected"; drainage management thus fits into this definition as its services can be quantified and it helps improve the living conditions of residents.

The reality is that basic provision especially in South Africa will always be riddled by a backlog because no informal settlement upgrading policy was initiated for post-apartheid South Africa (Marais & Ntema, 2013). The Reconstruction and Development Plan (1994) focused on new developments.

In 2004 the Breaking New Ground initiative, a comprehensive plan for the development of informal settlements, was initiated under the housing policy (Marais & Ntema, 2013). This advocated for *in situ* upgrading of settlements, but placed the emphasis on water, electricity, sanitation and housing, with no mention of drainage.

2.2.5 Flood risks in informal settlements

Informal settlements are particularly vulnerable to flooding and those living in them are less able to mitigate the aftermaths (Parkinson, Tayler & Mark, 2007; Pharoah, 2008 in Pelling & Wisner, 2008). The seasonal rains in the Western Cape continue to displace people as increased runoff of stormwater results in flooding (Ziergevol & Smit, 2009); however, people often settle in hazardous areas with full knowledge of the potential for flooding, but ignore this hazard as it only occurs seasonally (Nchito, 2007).

Impermeable structures (Daniel et al., 2012), stormwater run-off and poor or no drainage results in adverse effects on the environmental surrounds (Reed et al., 2001), including soil erosion, and damage to settlement infrastructure, which is already dilapidated (Reed et al., 2001; Sakijege et al., 2012). Infrastructure, also a vital determinant for economic development, plays an equally important role in mitigating urban floods (Brooks in Daniel et al., 2012:138). Consistency is key!

Ziervogel and Smit (2009) note that although there has been a somewhat effective response in finding temporary solutions for victims of floods, attempts to reduce instances of flooding in informal settlements have been less effective. Informal settlement dwellers vulnerability in terms of flooding and their lack of resources to recover from the effects leads the poor into 'exacerbated conditions of poverty' (Parkinson et al, 2007) and affects their livelihood opportunities (see figure 5). Sakijege et al. (2012) note that government's failure to learn from successive flooding incidents and address the backlog of housing placements *in situ* will result in the number of flood victims continually increasing.

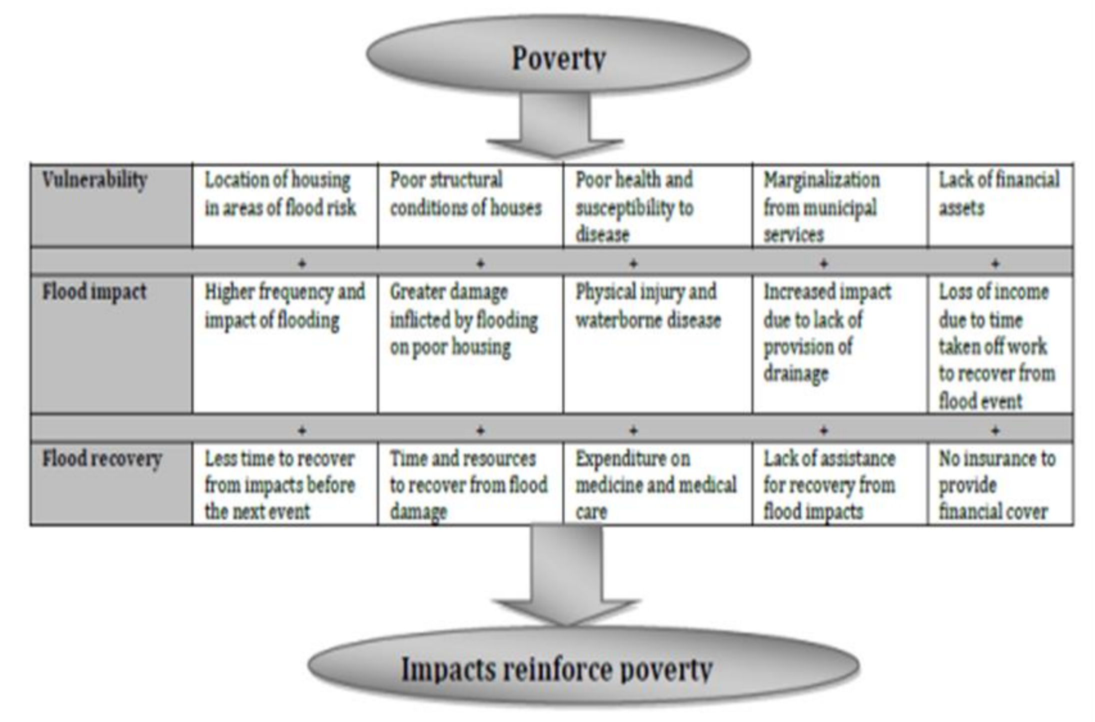


Figure 5: Livelihood impacts of flooding reinforce conditions of poverty
Source: Parkinson & Mark (2005)

People use "...different logics to recognise and evaluate competing risks which is why there should be a need to identify the constraints and solutions to disasters like flooding" (Pelling & Wisner, 2008:5). It is apparent that there is a linear relationship between flood risks and vulnerability (van Huyssteen et al., 2013) and so the lack of drainage, particularly given changing rainfall patterns, poses a further risk. Complexity thinking and systems dynamics modelling are useful tools within this space as they provide a visualisation to support the untangling and work on the greater issues embedded in this particular system (Shown in figure 2, page 14).

There is a need to "...reduce the risk of disasters rather than responding to the impact", which aligns with the need to adapt to climate change (Ziervogel & Smit, 2009:2). The urban poor are the most vulnerable to climate change (Jabeen et al., 2010 in Sakijege et al., 2012:2) and it is likely that their livelihood and living conditions especially for those informal settlements will deteriorate as a result of flood, increased need for energy, water and sanitation. Even further and unintended social ills, such as crime, intensify as a consequence (Huchzermeyer, 2009; Adegun, 2013). By implementing SuDS in informal settlements, the area can begin to strat mimicking the natural process that existed in nature before the shack developments, and could provide an opportunity to address the issue of stormwater drainage in the same breathe (Biomimicry, 2013).

Unfortunately, informal settlements systems do not focus on each and every drop of water in the system (Fisher-Jeffes, 2013; Novotny, 2008) and this includes stormwater, even though the stormwater has the potential to improve settlement conditions through the creation of green spaces, which could also offer the potential for generating tourism interest (Fisher-Jeffes, 2013), this could translate into income generating opportunities for informal settlements dwellers , thus ‘speaking’ to the economic and social aspects of sustainable development.

2.3 Ancient, modern and alternative drainage systems

2.3.1 A historical perspective on drainage systems

According to Burian and Edwards (2002), drainage systems were used to collect rainwater, dispose of wastewater and prevent flooding as early as 3000BC. The systems were designed through a process of trial and error, which has shaped the drainage systems of today. Although there is not enough evidence to present a picture of the drainage systems in totality, some ideas can be deduced from archaeological evidence from those times (Burian & Edwards, 2002). The issue of storm water drainage was clearly recognised as a cause for concern because it resulted in the flooding of cities (Gray, 1940 in Burian & Edwards, 2005; Scullard, 1967; Strong, 1968 in Burian & Edwards, 2002:4).

The description given of these drainage systems by the above authors indicates use of a sustainable approach, although not perfected to the level made possible by available current techniques. In that sense, the concept of sustainability was apparent in those times and sustainability criteria may have been viewed as a norm for technical advancements.

The drainage systems of the Roman Empire were the first documented systems that were seemingly planned and organised (Burian & Edwards, 2002) and then combined with other systems, despite the reduction of capacity within each. Due to the capacity problem experienced with combined sewers, drainage for wastewater and stormwater was separated as the treatment of the wastewater in the combined system was too costly (Wentzel, 2013). These systems were "…neither sustainable nor resilient to large storms and hurricanes" (Novotny, 2008:3).

This separated system is what has been used in the modern world and the one proposed for implementation in South Africa's informal settlements.
The high costs of treating water prompted the shift towards use of alternative drainage systems in the early 1990s (Hoyer et al., 2011; Bettini, Brown, de Haan & Farrelly, 2015).

2.3.2 Understanding conventional drainage systems

The issue of stormwater drainage systems is being elevated in discourse due to the changing climatic conditions (Hetz & Bruns, 2014). According to Reed et al. (2001), Reed (2004) and Novotny (2008), conventional systems serve little other purpose other than to increase run-off to the nearest water course. Despite this minimal function, conventional systems are expensive to design, build and maintain and their capacity cannot readily be increased (Reed et al., 2001; Reed, 2004). The implication is that municipalities are unlikely to use their already limited resources to implement conventional drainage in informal settlements (Wentzel, 2013). However, it is important to recognise that the provision of stormwater cannot be blamed on funding alone. Other major factors include the lack of accessible roads into settlements which are needed to supply any materials or services that will be used, high density in the settlement to supply services. Additionally, because informal settlement dwellers rank their basic service delivery priorities as housing, electricity, water and sanitation, there is also a risk that they will not welcome stormwater drainage solutions prior to those identified needs being met.

In South Africa, the cost implication is compounded by the lack of national legislation and policy regarding the management of stormwater and then further exacerbated by the lack of clarity regarding which national department should be responsible for stormwater management. Table 1 gives a summary of the relevant legislation, policies and funding sources and responsible institutions for basic service provision. The current debate dictates that stormwater should fall under the auspices of the Water

Services Development Plan, documents developed by municipalities, but instead it falls under the mandate of the Department of Transport, where it is not prioritised. There is even less clarity regarding provision for stormwater infrastructure in informal settlements in legislation, policies and plans. The result is that the UISP neglects the issue of stormwater drainage.

Table 1: Summary of relevant legislation, policies, funding sources and responsible institutions for basic service provision

	Legislation	Policy	Responsible national department	Management at local government level	Funding	Local policy/plan
Electricity	Electricity Regulation Act (2006)	Integrated resource plan	Department of Energy/National Energy Regulator of South Africa	Local authority electricity department/Eskom (50/50)	User fees; grants	No specific requirement/by-laws
Water	Constitution Section 27(i)/National Water Act (1998)/National Water Services Act (1997)	National Water Resource Strategy/free basic water	Department of Water Affairs	Local authorities act as Water Service Authorities and Water Service Providers	User fees; grants	Water services development plans/by-laws
Sanitation	No specific framework	No policy guidelines	Transferred from DWA to DHS, but still DWA	Local authorities and water and sanitation department	Rates; grants	Should be part of water services development plans/by-laws
Stormwater	Constitution Schedule 4B/No national legislation	None	Unclear	Local authorities roads department	Rates	None – should be part of water services development plans
Solid Waste	Nat Environmental Management Waste Act (2008)	National Waste Management Strategy	Department of Environmental Affairs	Local authorities waste department	Rates	Integrated Waste Management Plan/by-laws

Source: Palmer et al. (2013)

A further complicating factor is that “conventional systems are interconnected and complex and require a relatively high level of design expertise with computer modeling softwares that are able to optimize the design, but this requires large amounts of detailed topographical and hydrological data” (Reed et al., 2001:345). This information is not available for most informal settlements and Enkanini is no exception. However, it is not to say its unobtainable, it will just be costly to obtain the information, but this could also be seen as an opportunity for employment in which informal settlement dweller can be given a chance to earn an income.

Given the high costs of building and maintaining these systems (Reed et al., 2001; Parkinson, 2003; Reed, 2004), the need for detailed topographical and hydrological data (Reed et al., 2001; Reed, 2004) and the lack of auxillary systems – such as sewers, waste management and wastewater infrastructure – conventional drainage systems may not be relevant solutions for low-income communities. In addition, conventional systems do not contribute towards building sustainable service provision infrastructure.

Butler and Parkinson (1997:58) note that separation of aspects such as amenity, quantity and quality of water in conventional systems (see figure below) has contributed to the failure of such systems to “…to exploit stormwater as a resource”. In this context quantity applies to the flow of stormwater in any given season, quality relates to pollution levels and amenity relates to the aesthetic and environmental value, including biodiversity and ecosystem services (Woods-Ballard et al., 2007; Armitage et al., 2013).

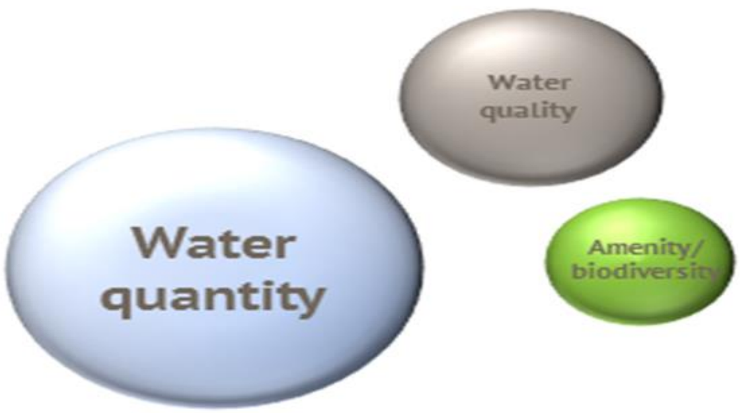


Figure 6: Lack of connectedness within the conventional drainage system

Source: Susdrain (2013)

This disconnect translates into the current drainage management infrastructure being "…unsustainable because it leaves water resources severely damaged and often unusable for future generations" (Novotny, 2008:2). In addition, 'hard conveyances' infrastructure, such as conventional drainage, normally has a limited life span of between five and ten years and "are usually unable to safely deal with the extreme events" sometimes failing with serious consequences (Novotny & Brown, 2007 in Novotny, 2008:2). They "fail to take the potential for flooding into account" (Kolsky 1998 in Parkinson 2003:120). In other words, conventional drainage management systems are not sustainable.

2.3.2 The implications of a lack of stormwater drainage systems

As drainage systems are not prioritised in the informal settlement context, the spillover effects of blocked sewers, for example, can have drastic consequences, because should SUDS for example be the chosen approach all the spillover from the sewers would end up in the stormwater paths ultimately lead to the pollution of the nearest watercourses. If sanitation and water services are provided in an informal settlement, but not stormwater drainage, people will often dispose of food down the toilet if line sewers are blocked or use newspaper instead of toilet paper; the sewer capacity was also not built to cater for the large flux of people into the urban areas (Goldenfum et al, 2007; Wentzel, 2013). This matter speaks to two issues, behavioural (educational campaigns can be made in which residents are informed on the negatives of such behaviour) and urban development trends over time (speaks to migratory patterns overtime, which puts pressure on systems especially these build with a minimal capsize of utilisation) . Wentzel (2003) notes that settlements with drainage systems put in before the influx of people have a low capacity. The resultant spillover goes into existing natural drainage channels and contaminates stormwater. The increased flow of stormwater erodes, over time, the natural drainage alleyways, which can lead to homes collapsing. The municipality will often pour lime over the blocked sewer to sterilise, but this can take days or sometimes weeks to address (Stellenbosch Municipality et al., 2012). In addition, the municipality often lacks the financial and human capital necessary to extend services, such as drainage systems. Greywater accumulated from domestic use is also often disposed of in the nearest watercourse where it mixes with stormwater and ends up polluting downstream water flow.

The main focus in conventional drainage systems discourse has been on quality (waterway quality and pollution) and quantity of stormwater (optimising infrastructure for efficient flood control); however, towards the end of the last century, the notion of sustainability of stormwater started raising its head – these three tiers are illustrated in the following figure 7. The current sustainability discourse is presented as part of integrated urban stormwater management (Brown, 2005).

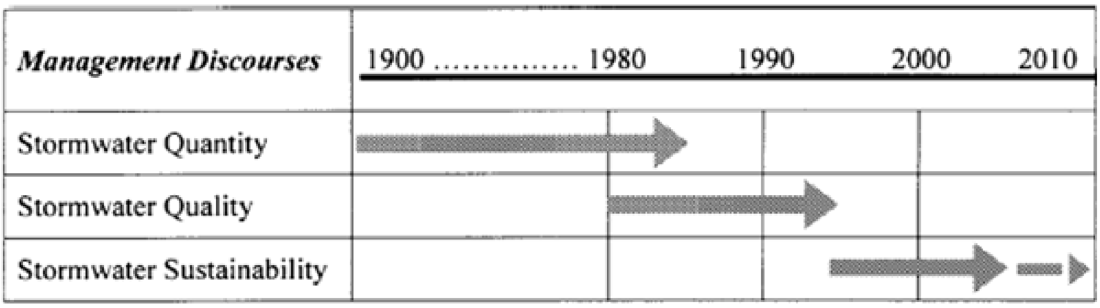


Figure 7: Urban stormwater management discourses over the 20th century
Source: Brown (2005)

Complexity and systems thinking should frame the application of this model (Figure 7 sustainable stormwater) in the South African context given that systems are "woven together and are self-organizing, non-linear [in that they] are inherently unpredictable" (Meadows, 2001 in Manguwo, 2013:4). A 'prediction and control' scenario cannot be achieved (Manguwo, 2013), without modelling the situation and identifying all the main actors. Complexity theory reaffirms that even if approaches are to be mimicked, they [systems] will need to be tailor made to cater to South African conditions and realities.

2.4 The need for alternatives: water-sensitive urban design

The concept of water-sensitive urban design has evolved over the last two decades from a sole focus on stormwater management to encompass a broader, holistic framework including the urban water cycle and its integration into urban design (Wong, 2006) and the use of techniques such as SuDS (Wong & Eadie, 2000). Alternative systems will need to align with the *Our Common Future* report's identification of the need to "reorient technology and manage risks", which speaks to the notion of sustainable development (WCED, 1987:47).

The outcomes of implementing such systems should be beneficial to both end-users and cash-strapped municipalities. However, implementation of alternatives will present its own levels of complexity, which will need to be dealt with through a multidisciplinary approach requiring inputs from academics, experts and practitioners (Armitage et al., 2013). The main objectives of this design are to manage water balances, while maintaining and, if possible, enhancing water quality (Beecham, 2003). Further to this, there is an emphasis on encouraging water conservation and maintaining water-related recreational and environmental values (Beecham, 2003).
The linkages between water-sensitive urban design, the built form and the urban water cycle falling within a framework of ecological sustainable development are illustrated in the following Figure, 8. The urban water cycle is linked to an integrated management system in which stormwater management is a sub-component.

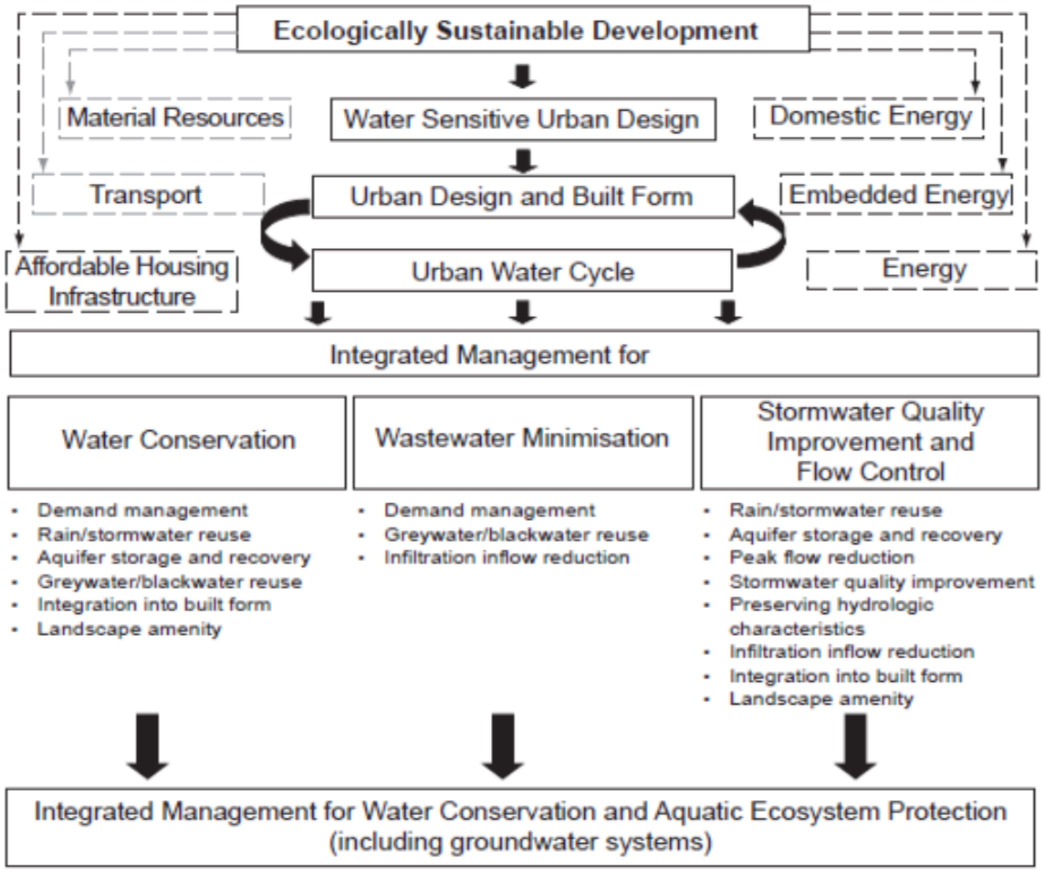


Figure 8: Interactions between ecological sustainable development, water-sensitive urban design and the urban water cycle
Source: Wong (2006)

It is widely agreed that water-sensitive urban design is a model that aims to merge water management with land-use planning (Wong, 2006). Its scope has expanded to include and promote sustainable urban development (Lee & Yigitcanlar, 2010).

The motivation for, perceptions of and impediments to implementation of this model are illustrated in the following figure 9. Figure 9 also clearly illustrates the relevance of this model in a world that needs sustainable solutions.

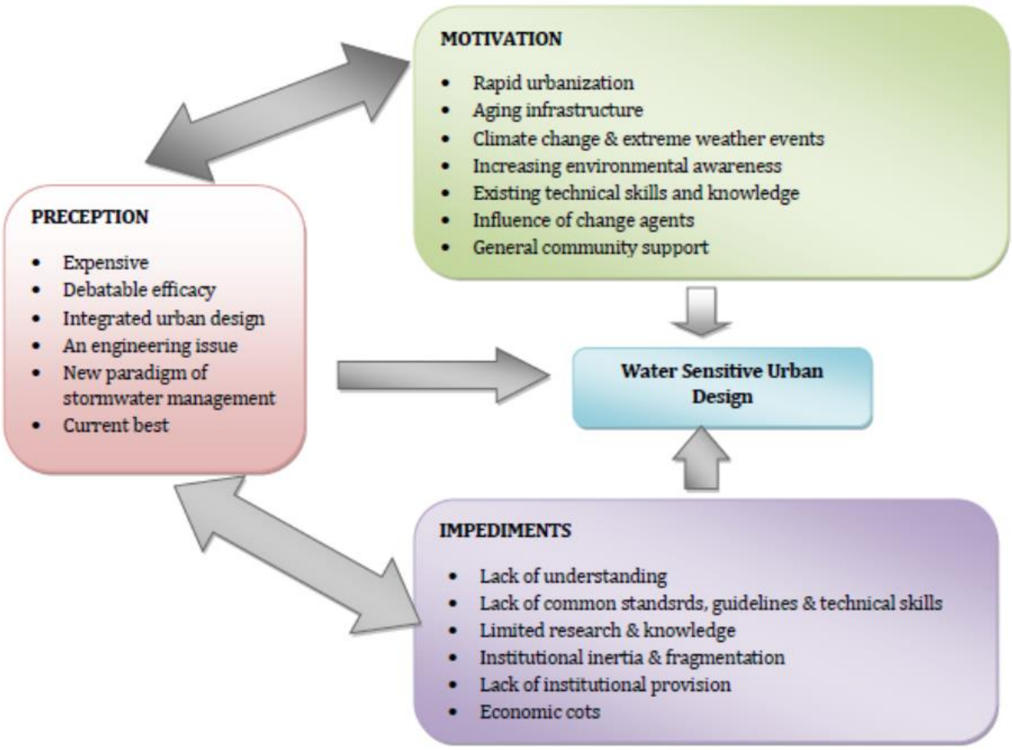


Figure 9: Relationship between the perception, drivers and barriers of water-sensitive urban design
Source: Lee & Yigitcanlar (2010)

The model aims to avoid the ‘out of sight, out of mind’ attitude towards stormwater management (Wong & Eadie, 2000) that conventionally focuses on transporting run-off water and does not view it as a resource or take into account environmental integrity (Lee & Yigitcanlar, 2010). It embraces a consideration of all components of the urban water cycle and their interactions with regards to water management (Hoyer, Dickhaut, Kronawitter & Weber, 2011). Implementation of the model in water-scarce South Africa could produce multiple benefits – a much-needed holistic approach to urban stormwater management and replenishment of the groundwater table, among others.

Water-sensitive urban design is not a new concept, it has been implemented and termed differently in various places, including as ‘low-impact development’ in the United States, ‘low-impact urban design and development’ in New Zealand, ‘sustainable urban drainage systems’ in the United Kingdom, ‘best management practice’ in some European countries and as ‘alternative technologies’ in France (Lee & Yigitcanlar, 2010; Hoyer et al., 2011; Adegun, 2013). The differences in terminology can be confusing, but it is argued that ‘SuDS’ is a stormwater management concept that falls under water-sensitive urban design (Fisher-Jeffes, 2013).

2.5 Bridging the gap: introducing SuDS

The conventional approach to drainage systems is rooted in an anthropocentric mindset in which nature is viewed as external to society and resources can be exploited (Salazar, Espinosa & Walker, 2011). This approach has resulted in ignorance about the effects of such exploitation on the greater environment. An ecocentric approach acknowledges natural and social systems as co-evolving ones (Salazar et al., 2011). *Our Common Future* (1987) described the need to shift from the norms of industrial-era practice to those that protect the earth and its resources. This echoes Frolov’s call (1986 in WCED, 1987) for ‘new ecological concepts’ to be developed. The concept of SuDS was developed at the Rio Summit of 1992 (Button et al., 2010).

Sustainable urban drainage system models fall within an ecocentric approach and this should be apparent throughout the varied stages of planning and implementation (White & How, 2005:28). This model has the potential to remedy landscape disturbance, reduce pollutant emissions, increase biodiversity, replenish the water table, protect against floods and increase environmental aesthetics (Wood-Ballard et al., 2007; Novotny, 2008). In short, the model (Figure 10) aims to ensure the ecological sustainability of the hydrological cycle (Novotny, 2008). In serving to provide basic pollution and flood control, the model (Figure 10) also allows for conservation, recreation and amenity (Ellis 1995 in Butler & Parkinson, 1997:58).

As outlined by Armitage et al. (2013:1) in a report for the University of Cape Town's Water Research Commission, SuDS offers an "alternative approach to conventional drainage practices by attempting to manage surface water drainage systems holistically in line with the ideal of sustainable development." It targets effective management of stormwater quantity and quality, as well as amenity and biodiversity (Armitage et al., 2013). SuDS promote natural drainage through a number of processes that are linked to these aspects – these are described in detail.

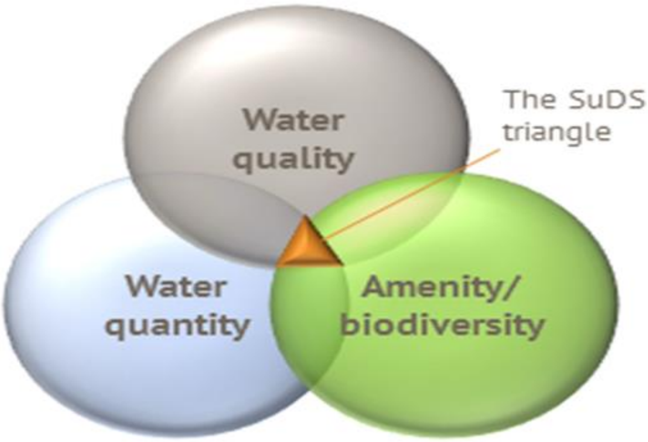


Figure 10: Sustainable urban drainage system triangle
Source: Susdrain (2013)

2.5.1 Explaining SuDS

SuDS encompass a range of interconnected systems that can be managed by various processes from the point of where water falls to where it flows. Water can flow through a series of features that assist in its re-use, treatment and conveyance. This is known as the SuDS treatment or management train. Processes are linked to quality, quantity (flow and volume) and amenity/biodiversity (Woods-Ballard et al., 2007; Vice, 2011; Armitage et al., 2013). Some practitioners separate amenity and biodiversity to create four elements.

Typical processes of SuDS

Processes aim to improve quality, quantity and biodiversity aspects. They can be used in different stages of the treatment train and adapted to the specific context. Typical examples of processes used to maintain or improve quality of runoff water include (Armitage et al., 2013):

- Removing sedimentation in runoff to remove the pollutant load.
- Practising adsorption through chemisorptions (incorporating solute into the structure of the soil), absorption (diffusing the solute into the soil) and cation exchange (capitalising on the attraction between clay material and cations).
- Filtering pollutants conveyed by sediments by trapping them within soil, vegetation and geotextile layers.
- Volatising, which involves transferring compounds from solutions found in water to the soil and into the atmosphere by reducing pressure, chemical reactions or applying heat, or a combination of these.
- Biodegrading, which is "the degradation of organic pollutants in stormwater runoff by microbial factions established within the control structure, using the oxygen nutrients supplied by stormwater runoff inflows" (Vice, 2011).

Processes aiming to control and manage runoff provide a unique opportunity to achieve flood risk management, groundwater recharge, stormwater control and water conversion. Typical examples of processes used to maintain or improve quantity of runoff water include (Armitage et al., 2013):

- Detention, meaning stormwater runoff is slowed down "before subsequent transfers downstream, using storage facilities and controlled outlets" (Vice, 2011:2–10).
- Infiltration to reduce the volume of runoff on the surface by soaking it into the ground.
- Harvesting water by capturing it, typically from rooftops.
- Conveying water through open channels, trenches and pipes from one location to another using controlled outlets and storage facilities.

Processes aiming to maintain or improve amenity and biodiversity focus, among other aspects, on health and safety of people through the use of "safe design practices, alert medical aid teams, and cooperative communities (Vice, 2011:2–11). There is also a focus on assessing and managing ecological risk to ensure longevity as well as creating habitats (Vice, 2011). Recreation and aesthetics form an important part in that emphasis is placed on "protecting, shaping and creating open spaces and enhancing the visual appearances of the specified systems" (Vice, 2011:2–11).

There is an opportunity to also disseminate knowledge about these types of systems and their benefits in the affected community (Vice, 2011).

The SuDS treatment train

The model acts as an interconnected system in which water tends to slowly flow away from where it fell into a soakage or discharge point (Woods-Ballard, 2007; Armitage et al., 2013). (See the techniques in annexure A and a selection matrix in annexure B.) This process unfolds through a series of features that treat, convey, store, re-use and celebrate water; the series is known as the 'treatment train' (Lead Local Flood Authorities of the South East of England [LLFASEE], n.d.). The varied stages remove sediment and other pollutants resulting in lowered maintenance costs and minimised downstream risks, such as clogging and blocking (LLFASEE, n.d; Wood-Ballard et al., 2007; Armitage et al., 2013), as well as minimising the pollutants in the environment, particularly those that can be transported by stormwater (Woods-Ballard et al., 2007; Armitage et al., 2013).

Stages can be combined in a contextual approach for surface water management (LLFASEE, n.d) with control measures implemented at source or on wider local and regional levels. The SuDS treatment train has four primary foci: site management/prevention, source control, site control and regional control (refer to the figure below). Each focus area has certain functions associated with it – good housekeeping and site design are found in site management; managing water close to the source is found within source control, including use of techniques such as filter strips, green roofs and rainwater harvesting; managing runoff sequentially through a series of techniques is found in site control, which allows for enhanced treatment opportunities and the slowing down of water and resultant settlement of sediments using techniques such as gravel filters and vegetation; large-scale management of run-off falls into the regional control focus area, including the use of techniques such as detention ponds.

Figure 11 below illustrates the sequencing of a typical SuDS treatment train.

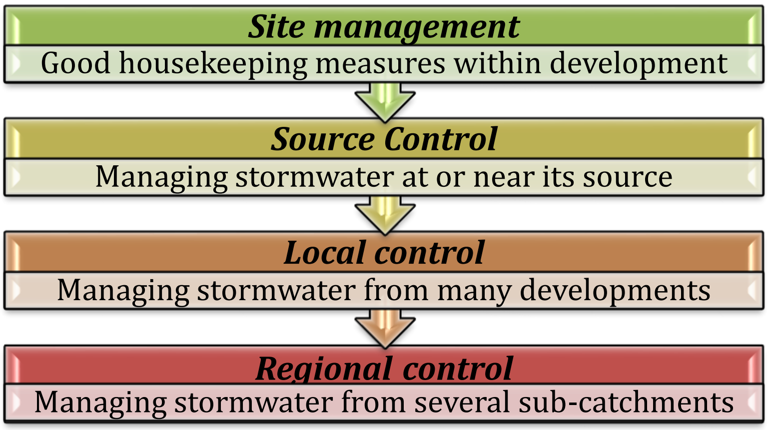


Figure 11: SuDS management hierarchy
Source: Wilson et al., 2004 in Vice, 2011:2–12

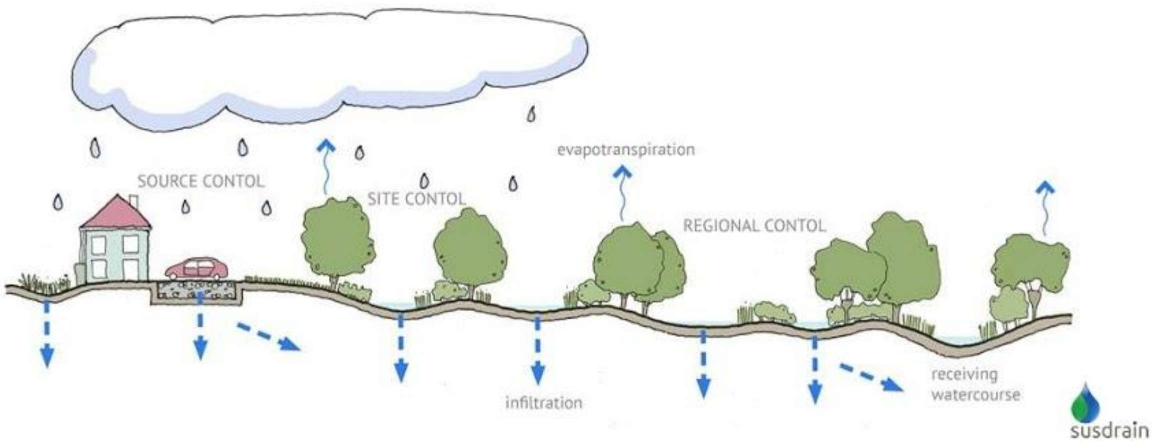


Figure 12: The SuDS management train
Source: Susdrain n.d.

Most of the techniques found under the treatment train are explained in depth in annexure 1. In "…passing water through several stages of treatment, sediment and other pollutants will be removed more effectively, and maintenance costs are reduced as this minimises the risk of downstream SuDS features becoming clogged or blocked" (LLFASEE, n.d:9). It is in the treatment that green corridors and links can be developed. Vice (2011) provides a simplified site development process design beginning with 1) initial project, 2) site investigation, 3) feasibility study, 4) site analysis, 5) concept design, 6) preliminary plan, 7) final plan, and 8) final checks.

Implementation example: SuDS in Century City, Cape Town, South Africa

Given the lack of examples of implementation in informal settlements in South Africa, the example of Century City is provided to give a real-life illustration of different SuDS techniques, despite it not being a community deprived of basic services.

Century City, on the outskirts of Cape Town city centre, was conceived of in 1995 and the land on which it is located was rezoned to allow for "…medium-high density residential, medium-high density commercial, public transport interchanges, educational facilities, internal private open spaces, as well as Africa's largest shopping mall, a theme park and a multi-purpose constructed wetland" (Vice & Armitage, 2011:2). Development of the 250 hectares of low-lying land has been characterised by invasion of the natural wetlands and the alien vegetation which was attained through the combination of SuDS applications (Vice & Armitage, 2011). The property owners' association coined the slogan 'Live, Work, Play' to describe the desired atmosphere of a self-sufficient Century City (A new model of urban management, n.d.; Vice & Armitage, 2011). The property is home to Intaka Island (meaning 'bird' in isiXhosa) and 16 hectares of wetland home to 177 indigenous plant species and 120 bird species within seven-level natural habitats (Vice & Armitage, 2011). Wetlands are the 'lungs' of urban drainage systems.

The figure below depicts a combination of SuDS techniques used on the property. The area illustrated below is a combination of vegetated area, in which gravel and layers are used to fence the vegetation. The stone hedges assist in filtering the water before it reaches the permeable paving to continue on to the nearest watercourse and into the wetland. The technique of bio-retention settles sediment further away from the wetlands.

Figure 13: Combined techniques in Century City used for drainage prior to conveyance to the wetlands
Source: A new model of urban management (n.d.)

Swales and infiltration trenches seem to be the preferred source of SuDS techniques used in the watercourses leading to the wetlands (see figure below). Swales provide temporary storage for stormwater (LLFASEE, n.d.), which helps reduce peak flows and filtering of pollutants (Environmental Agency, n.d.; Vice, 2011). The water seeps directly into the ground and microbial decomposition is encouraged (Environmental Agency, n.d.).

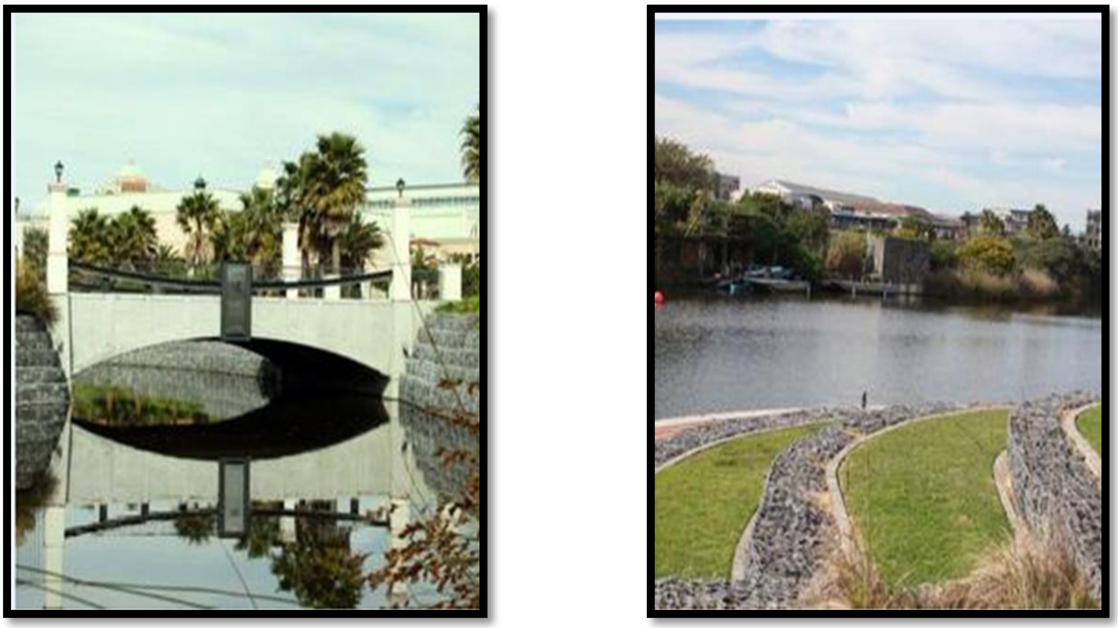


Figure 14: A combination of infiltration trenches and swales (infiltration trenches)
Source: A new model of urban management (n.d.)

The configuration of the drainage system is complex and characterised by three drainage principles that work together for maximum optimisation.

These three principles are conventional drainage practices, individual SuDS options and SuDS options in the treatment train (Vice, 2011; Vice & Armitage, 2011).

The drainage system collects its runoff from the surrounding areas, such as the Tygerhof development triangle and Summer Greens in Cape Town (Weathering the storm (water) in Cape Town, 2010; Vice, 2011). The wetland comprises four main treatment cells, of which two are large seasonal salt pans, and are connected to the canal network. This is shown in the figure alongside, which provides a panoramic view of the property.

Figure 15: Panoramic view of the constructed wetland's four treatment cells
Source: Vice, 2011

Cells 1 and 2 have reed beds that slow down runoff water while encouraging the settlement of particles. They also serve to remove phosphates from the stormwater. Cell 3 has a deep, open body of water that is aerated by the wind, which allows for bacterial breakdown and gives the nitrogenous compounds space to flourish. Cell 4 is a shallow body of water, which is well aerated with dense vegetation and it facilitates the removal of residual nitrates and phosphate.

SuDS is a flexible model that can be adapted to different circumstances and through its varied implementation (see following figure) can bring about different results ranging from a single-purpose system to one that results in multiple benefits. Designers need to set the sustainability criteria according to the constraints of the particular context (Ellis et al., 2004).

A cautionary note must be made that these drainage systems do not serve as sewer systems, these need to be tackled as a separate issue (Reed et al. 2001).

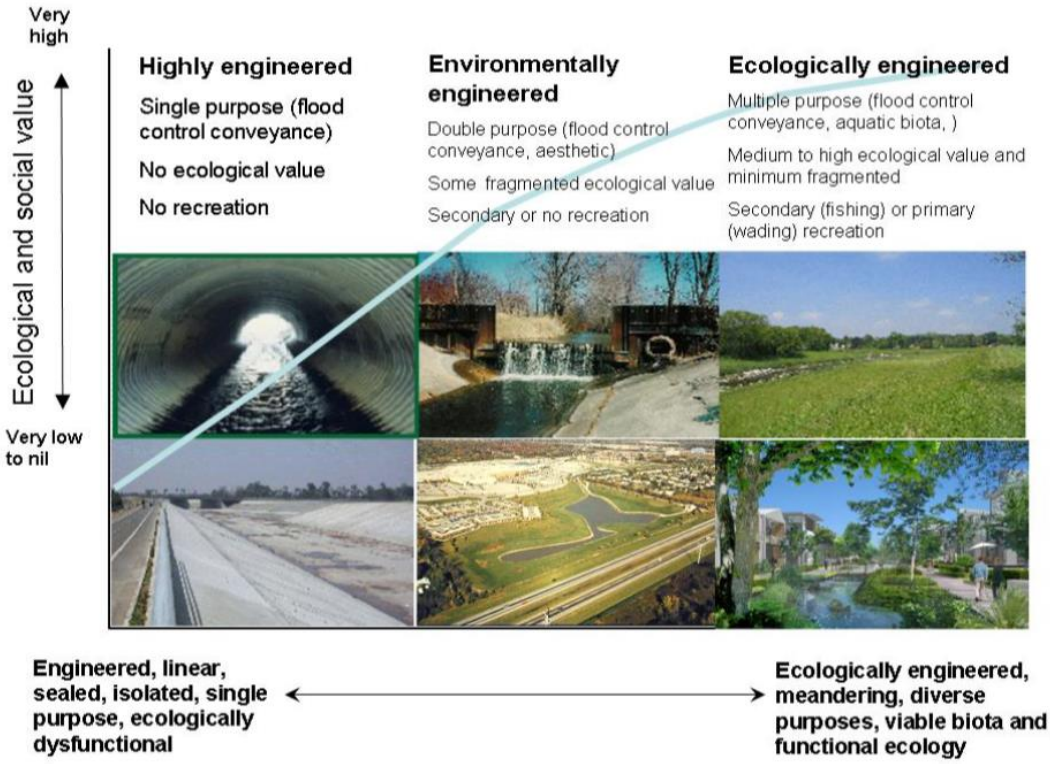


Figure 16: The engineering approaches to urban drainage from traditional to eco-engineering
Source: Adapted from Ahern (2007) in Novotny (2008)

It is still relatively onerous for planners to ensure the technical aspects of this model are satisfied given that they are already hard pressed with development control and they might not be aware of new developments that incorporate the relevant techniques (White & Howe, 2005). However, the conventional singular purpose of drainage has been the norm for a while now, but provides few benefits in a world where a holistic developmental approach is fast becoming the norm as part of the shift towards sustainable development.

African countries, including South Africa, are in a way fortunate to be lagging behind in terms of implementing this approach as they then have the advantage of learning from the experiences of other countries. Abbott (2002:305) notes that South Africa "...as a late entrant [writing about informal settlements upgrading] … has a wealth of experience from elsewhere that it can draw on."

2.5.2 The appropriateness of SuDS for the informal context

The following figure illustrates the exploration of the appropriateness of SuDS in the informal settlement context. It is important to understand that stormwater drainage caters to three functions: controlling soil erosion, controlling flooding, and controlling water quantity flow. Stormwater drainage is separate to a sewerage system, partly because sewer sullage is expensive to treat and combining both systems can reduce the ability and functionality of sewers leading to overflows, stormwater quality and the resource of stormwater value. Stormwater is considered relatively clean compared to sewer water; however, because it often flows from roads to the watercourses, it can pick up residential oils and other chemicals and transmit pollutants. This risk can be minimised through good housekeeping practices, such as ensuring that stormwater drains are kept clean and free of debris (Armitage et al., 2013). However, this is difficult to do in conventional systems.

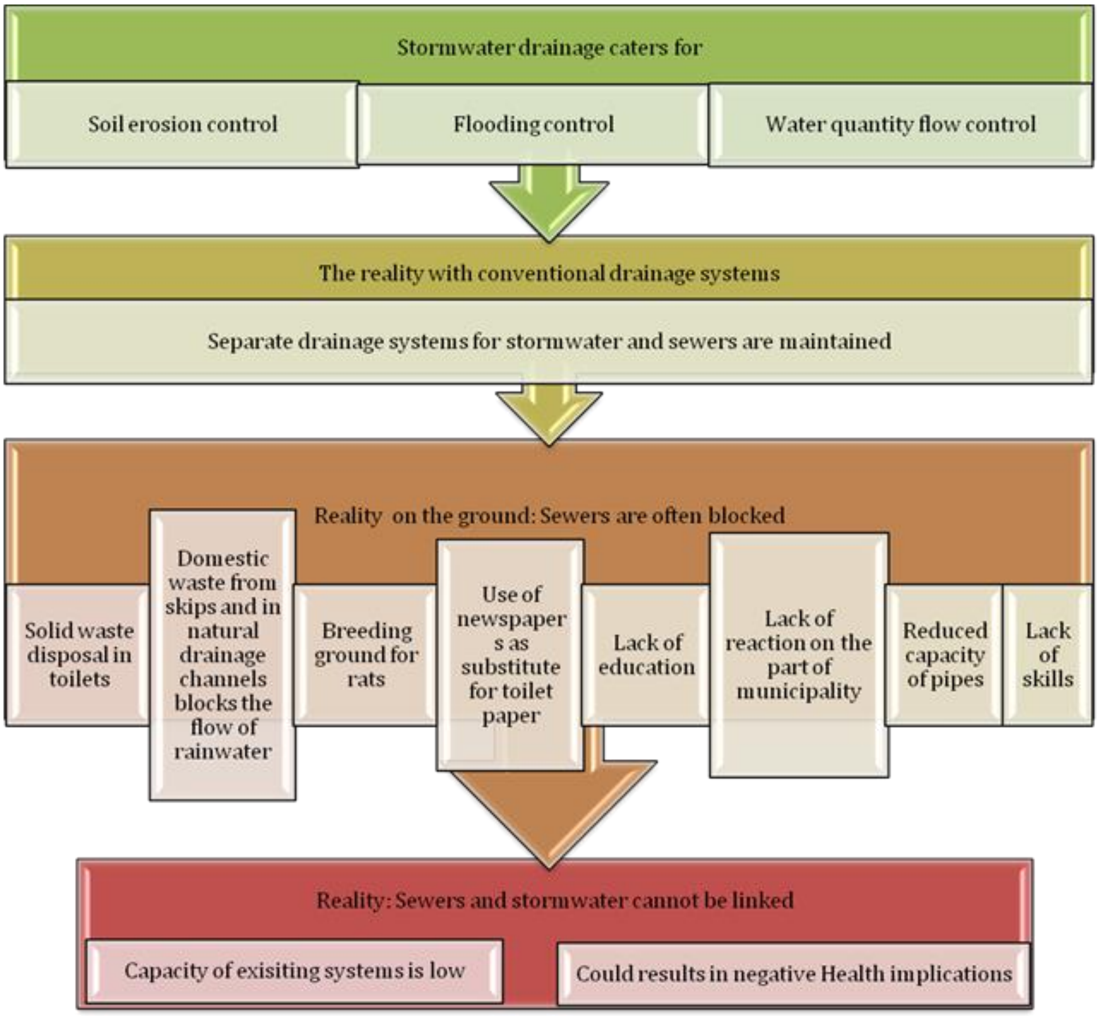


Figure 17: Mind navigation: alternative stormwater management techniques
Source: Author (2013)

2.5.3 The benefits of SuDS

Sustainable drainage systems are cost-effective, easy to manage and resilient in terms of usage and time. These systems offer multiple benefits that extend beyond the urban setting. Benefits include flood risk and water-quality management, enhancing amenity and biodiversity, increasing and improving water resources, opening up community recreational spaces, providing the opportunity for environmental educational awareness and enabling development and the creation of tourism opportunities (Susdrain, 2013).

SUDSs operate at the intersection of quality, quantity and amenity (see the figure below) (Butler & Parkinson, 1997; Wentzel, 2013) and, as one of its goals, aims to connect community members and relevant stakeholders in taking "care of all the stormwater measures" (Button et al., 2010:10). This could provide a starting point for communities to start indicating and identifying the social, economic, institutional, and technical factors that are likely to affect development together with the help of professionals. It is also an adaptive system and so longer lasting (Novotny, 2008) and easy to maintain. The advantage to implementing them in informal settlements thus becomes apparent and the system allows for optimisation of functional (scarcity of space) and relational (social domain) complexity (Fratini et al., 2012). In addition, while mitigating floods, this system encourages the restoration of natural space. The challenge is the lack of skilled implementers (Wentzel, 2013).

There are three other benefits derived from implementation of SuDS that are of particular relevance in the informal settlement context in that these systems cater to relational complexity (looks at the relationships that exist within a system and how they affect a greater phenomenon), functional complexity (Functional complexity looks at the lack of space within a space in which a phenomenon can be addressed) and enhancing ecosystem services.

A system that caters to relational complexity

The system caters to relational complexity – the diverse actors involved in the decisionmaking process (Fratini et al., 2011). The social domain in which they operate encompasses the "collective imagination and the way different interpretations of places interrelate and constrain each other" (Healey in Fratini et al., 2011:3).

The system needs to address these relational complexities, while addressing urban sustainability issues (Fratini et al., 2011), as engaging in individual relational actions is likely to be unproductive, especially in matters pertaining to the planning and managing of drainage, and could lead to "…inefficient, un-scalable and brittle outcomes at the level of the whole system" (Hales & Edmonds, 2003:1). A variety of perspectives need to be incorporated into the decisionmaking process. This requires a multidisciplinary, interdisciplinary or transdisciplinary approach. In addition, the micro-dynamics – the existing uncertainties and characterisation variability present in both the social and physical domains – must be integrated into stormwater management (Fratini et al., 2011).

A system that caters to functional complexity

The lack of available space in informal settlements presents a constraint to infrastructure development and this is often cited as the reason for delays in service delivery provision. Enkanini, like most informal settlements in the country, cannot be equipped with conventional drainage because of the steep gradient of the location and the lack of available space (Wentzel, 2013). In addition, the Stellenbosch Municipality lacks the financial capacity to install this kind of infrastructure. Furthermore, the lack of explicit spatial data need for planning is compounded by the lack of a methodological linkage between social and natural data (Veldkamp & Lambin, 2001).

The "greater experience with flooding events may cause a shift concerns from property values to environmental impacts of development" (Acevedo et al., 2007 in Parker, Hessl & Davis, 2008:792). Furthermore, Parker et al. (2008) argue that perceived value of the environment will likely vary among those who are spatially removed from the natural systems and not affected by them and those who live in informal settlements or work for the municipality, who are more likely in the coming decades to want a change in their environment and service delivery that is sustainable (Parker et al., 2008). This could open up a space for implementing SuDS in informal settlements.

A system that caters to ecosystem services

The links between the effects of urbanisation on ecosystem services are have been assessed (Elmqvist, 2011). This has led to the understanding around vast quantities of natural resources and amounts of waste production resulting from impacts of urbanisation which have also had a negative effect of ecosystems services.

SuDS contribute to the reduction of negative effects of conventional configurations and contribute to ecological and ecosystems restoration. Stormwater pollution is a major issue for cities as this feeds directly into water courses and water is a scarce resource. A sustainable urban drainage system enables some level of natural treatment to take place. At the local level, cities are likely to have negative impacts on freshwater services (Elmqvist, 2011).

All this can be achieved because the ecosystems approach is a strategic approach to managing water, land and living resources and one that aims to promote conservation and sustainability even though the link between human security and ecosystems functions is not made explicit (Elmqvist, 2011). Moreover, according to the Millennium Ecosystems Assessment (2005), ecosystems are meant to provide four primary services. These are provisioning – food, fresh water and raw materials among other things; supporting – habitats for species; regulating – ground water recharge, flood mitigation, water purification, climate and air quality control, global climate change and greenhouse gas regulation; and cultural aspects – recreation, education and the aesthetics. Mak, James & Scholz (2012) have to date provided the most comprehensive outline of linkages between SuDS and ecosystem services. The indicators for evaluating the linkages are illustrated in the following figure 18.

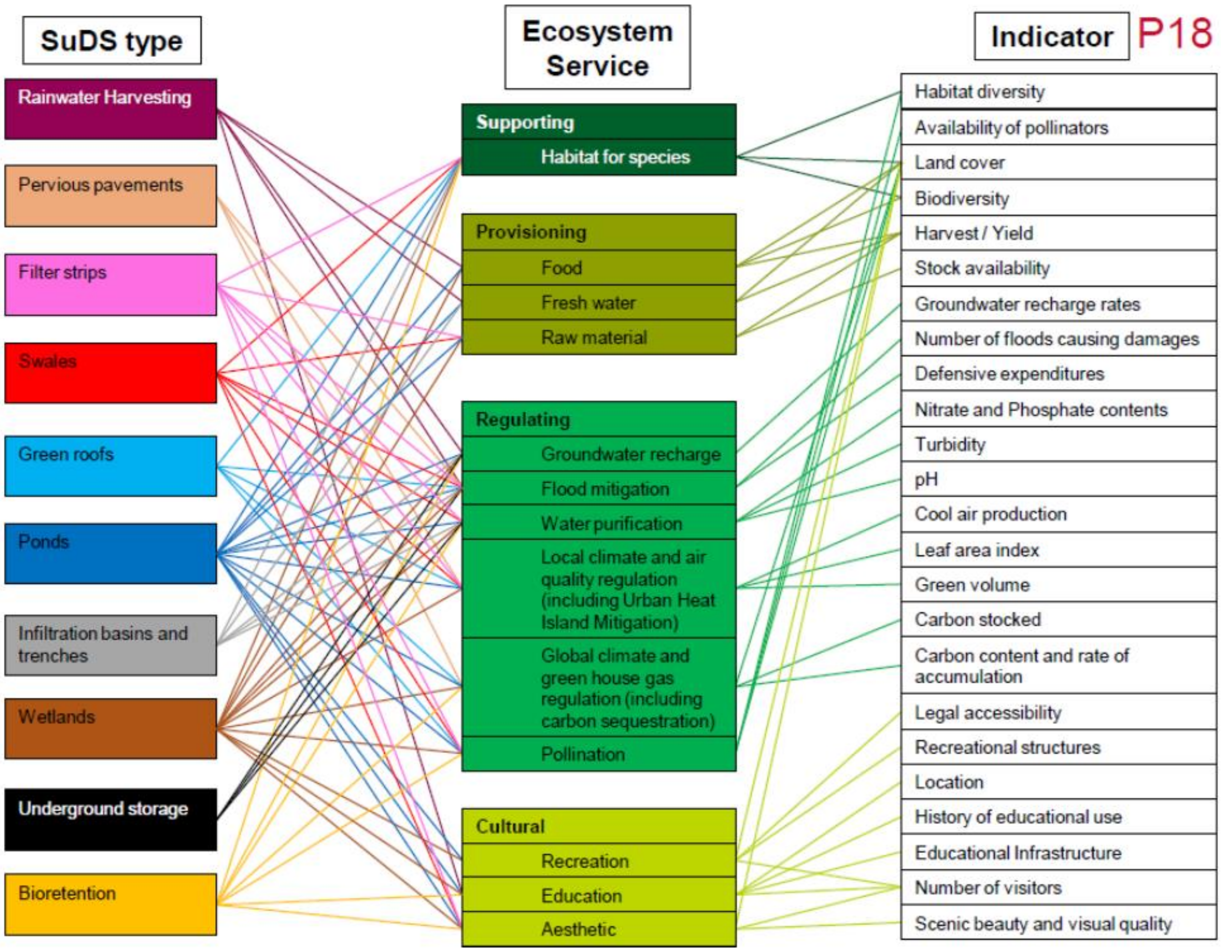


Figure 18: Linkages of SuDS to ecosystem services
Source: Mak et al. (2012)

The provisioning services are the easiest to ascribe with monetary values as the commodities they generate are often already traded in markets. Sustainable stormwater management is located within provisioning and regulation services. Given the limited space in informal settlements and that soil profiles destabilise over time, the vegetative techniques used in SuDS can help reduce the likelihood of mass erosion (Elmqvist, 2011).

While the system does promise diverse benefits when implemented in an informal settlement context, there are specific factors that could hinder or limit the effectiveness of such as system if not addressed prior to implementation. These are expanded on briefly.

2.6 Factors that could limit effectiveness in informal settlements

2.6.1 Access to sustainable drainage assessment tools

It is easier to understand issues of functional and relational complexity and ecosystem services (as explained in the previous section) when they are configured using software packages like Nvivo 10. This is because Nvivo 10 allows for a qualitative analysis, in which a creation of patterns is achieved. The patterns are arrived at through the identification of themes across a set of data called Nodes (e.g. documents, websites, questionnaires etc). The data can thus be displayed in a variety of ways; mind maps word trees etc. This is all arrived at in a time efficient manner. Furthermore, Nvivo 10 can also be used in the collection of themes needed to write the literature review.

However, most of the current packages are limited regarding the types of inputs allowed for analysis (Zhou, 2014); i.e. tools meant to analyse water quality and quantity and spatial planning might not be able to analyse social aspects, which are an important component of informal settlement life. A merger of the different software packages could be attempted; however, the integration of models could result in generating different data at both the associated spatial and temporal scales for the same study (Zhou, 2014). Moreover, most of the software packages tend to be expensive and are technically complex and not user-friendly (Zhou, 2014). These are inhibiting factors in what should essentially be a community-run system. According to Zhou (2014:983):

> *… it is difficult for users to know and choose which models to apply and how to extend/integrate them for a more comprehensive SUDS analysis. Even though some models can be poorly integrated, it is tedious and time-consuming to obtain the huge amount of input data for each sub-model.*

Consequently, although modelling systems might be helpful, they need to be used in conjunction with assessment tools for the system.

The four main categories to consider when implementing SuDS are the economic, health, social and environmental benefits. As indicated in the following figure, each of these has its own aligned assessment methods, which ultimately contribute to the multi-criteria analysis and integrated assessment used to assess the entire system. Given the parameters set for this thesis, these different assessment tools are not presented in detail, but merely outlined to provide a systematic view of the different assessment options.

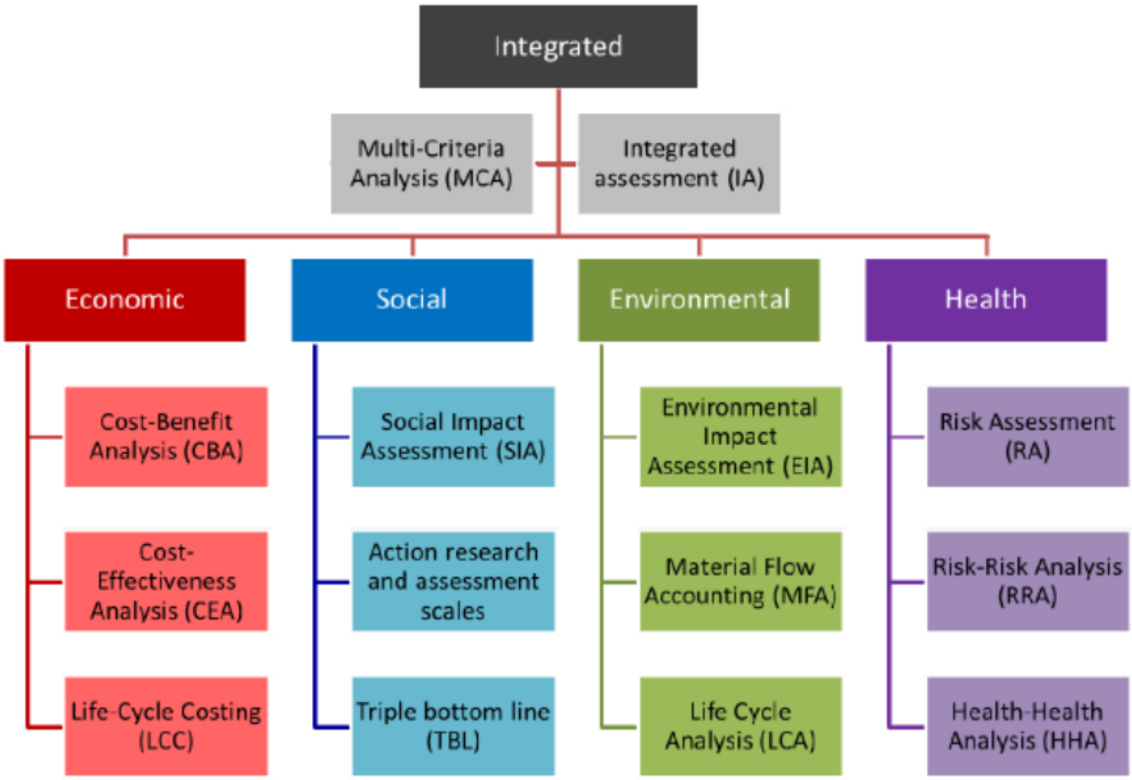


Figure 19: Classification of common decisionmaking tools in sustainable drainage assessment
Source: Zhou (2014)

Even if these tools were readily available to those working in informal settings, their inability to mimic natural processes remains a challenge and potentially could result in an underestimation of the on-the-ground complexities. This could lead to unsatisfactory outcomes following implementation of SuDS (Zhou, 2014). Moreover, the custodianship of SuDS will remain an avenue that will need to be explored in-depth, however, in the initial stages municipality will likely be made custodian.

2.6.2 Solid waste and wastewater dumping

Drainage systems in informal settlements will always be plagued by more problems than those in developed countries. Silveira (2002:31) states this is because "…urban development occurs under more difficult socioeconomic, technological and climatic conditions."

In particular the inappropriate dumping/ illegal dumping of solid waste and wastewater hamper drainage installation and operations. In discussions held at the Genius of Place: Phase 2 in 2013 (Biomimicry, 2013), the aspects of solid waste and wastewater were highlighted as the two most important challenges to tackle prior to implementing SuDS in informal settlements.

Solid waste dumping

Unmanaged waste originating from informal settlements will affect the broader urban environment (Napier & Rubin, 2002). Often waste is dumped in natural drainage paths because this is more convenient for residents living far from municipal skips which are few and poorly maintained (see image below). The consequence of this type of dumping is that the waste acts as a barrier to water flow, which can then result in flash flooding (Sakijege et al., 2012). Garbage collection that only occurs on a weekly basis, for cost reasons nor forgetting poor capacity, poor management, access challenges, or in even longer cycles can result in chemicals from the waste leaching into underground water sources as it decomposes where it is buried by sediments (Armitage, 2007) polluting both underground and surface water (Sakijege et al., 2012). These sediments are likely to become part of runoff water because of the increased water flow (Wentzel, 2013). In addition, sometimes people dispose of their faeces wrapped in plastic bags in these locations as going to the communal toilets at night can be dangerous. Inadequate refuse collection services and lack of a formal practice of using the skips and insufficient skips have been the biggest contributing factors to people dumping their refuse in drainage channels (Daniel et al., 2012).

Figure 20: Waste accumulation in Enkanini's natural drainage path, 2013
Source: Author (2013)

Armitage (2007) classifies debris into plastics, glass, metals, sediments, paper, vegetation and miscellaneous. All of these are found in informal settlement ‘dumps’, including in Enkanini, which means that there is potential for recycling sites in these locations. The debris also poses health risks in terms of rat infestations (Zweig, 2013).

Applying SuDS principles in an environment in which the issues of solid (non-biodegradable) and wet (biodegradable) waste have not been addressed is likely to result in redundant drainage solutions over time.

Wastewater dumping
Potable water is supplied to households in informal settlements, but no provision is made for drainage disposal of wastewater. As a result, wastewater is thrown out indiscriminately resulting in downstream effluent flows (Keraita, Drechel & Amoah, 2003; Armitage, 2011). The discarded water often forms in puddles, which become a place for children to play. Women living in Stellenbosch’s Langrug informal settlement had to approach the municipality for funds in 2011 to construct a wastewater drainage channel as their children were falling ill from playing in contaminated water, according to author’s observation.

In addition, without effective drainage for wastewater, the pollutants present in wastewater can find their way into any stormwater drainage (Silveira, 2002) and increase exposure to health risks. Greywater/stormwater contamination translates into increased costs for the government health sector (Mofokeng, 2008).

As pollution levels increase, naturally occurring freshwater levels will decrease (White, 2002). The expansion of human settlements limits the space for rain water to soak into the soil and provide a base flow for streams and rivers.

Before SuDS can be implemented the issues of wastewater and waste management therefore need to be addressed within a holistic approach to *in situ* upgrading. The aspects presented above are but a few of the complex linkages and interrelationships inherent to drainage systems, which further strengthen the need to address these issues from within a complexity and systems thinking lens.

2.7 Looking to the future

Sustainable development rests on the notion of preserving resources to ensure their availability present and future generations. Water is one of the most sacred of these and essential for human survival. Stormwater drainage is placed in this space. Relevant infrastructure for this purpose has evolved over the centuries encompassing as its rationale flood mitigation with an emphasis on fast conveyance introduced prior to the Industrial Revolution. Runoff water was transported to the nearest watercourse via concrete culverts, thus increasing the velocity flow of stormwater. As cities grew and permeable surfaces diminished so too did the flow and collection of runoff water. As roads were linked to culverts, the level of water pollution increased. Culverts effectively became channels for pollution, wreaking havoc on one of the world's scarce resources. As stormwater is not transported to treatment plants, but to the closest watercourse, pollution is transported straight into freshwater bodies, such as rivers. This has resulted in these bodies becoming polluted and has brought about a paradigm shift in terms of the conventional approach to stormwater drainage.

The SuDS approach is located within the nexus of sustainable development foci – the economic, social and environmental aspects. It attempts to mimic nature's way of dealing with stormwater runoff and it attempts to link stormwater to the urban water cycle. As stormwater passes through the various stages of the 'treatment train' it is cleaned before it passes into water courses. The approach is particularly relevant for informal settlements as it caters to relational and functional complexity, while maintaining and even enhancing ecosystem services. However, there are certain prerequisites that need to be in place prior to implementation. These include plans for solid waste and wastewater management. In addition, the credibility of the technique in terms of its alignment with current stormwater policy needs to be explored. This is done in the following section.

2.8 Legislation and regulations guiding SuDS implementation

Governments will always play a huge part in solving big problems. They set public policy and are uniquely able to provide the resources to make sure *solutions reach everyone who needs them … They are a crucial component of the innovation that improves life for everyone.*

Bill Gates, 2010

Varied legislation and regulations affect the way in which water is managed in South Africa. This section notes the framework legislation and the various strategic and policy documents that are relevant to the issue of stormwater management at all three spheres of government. Water is an essential input for a country's economic success and one of the pillars required for successful development; however, as a renewable resource it is easily polluted and/or overused (NWA, 1998a). South Africa is a water-scarce country and government is not ensuring that stormwater drainage is used to its maximum potential or exploring SuDS for its contribution to providing the social, economic or environmental benefits it could. This is not due to a lack of imagination as the concept of water sensitive urban design, incorporating SuDS techniques, is well known, but rather due to a lack of recognition of the importance of stormwater drainage systems.

The following table provides a slice through the national, provincial and municipal layers of applicable legislation, policy and strategic documents to end-user manuals to illustrate the complexity in which stormwater management is embedded. The Western Cape was chosen at the provincial level and Stellenbosch at the municipal level to link this framework to the on-the-ground realities of Enkanini presented in this study. The documents highlighted in grey represent the strategies falling underneath the legislative and regulatory policies that do not necessarily have an effect on the South African Guidelines for Sustainable Drainage Systems written for the Water Research Commission. SuDS could find a justifiable home in many of the spaces that these documents regulate. The UISP will be analysed in depth in chapter 4.

Table 2: Relevant legislative and regulatory framework affecting SuDS incorporation into UISP

<table>
<tr><td>South African National Constitution of 1996</td><td rowspan="6">Alternative Technology for Stormwater Management
The South African Guidelines for
Sustainable Drainage Systems</td></tr>
<tr><td>Legislation and regulations at national level</td></tr>
<tr><td>
National Water Act (1998)
National Water Resources Strategy (2004)
Catchment Management Strategies
National Environmental Management (1998)
Biodiversity Act (2004)
Alien and Invasive Species Regulations (2014)
Protected Areas Act (2004)
Human Settlement Planning and Design (Red Book)
National Building Regulations & Building Standards Act (1977)
SANS 10400-R: Stormwater Disposal
South African National Road Agency Ltd. Drainage Manual (2006)
Disaster Management Act (2002)
Municipal Systems Act (2000)
Integrated Development Plan (IDP)
Water Services Development Plan (WSDP)
Policy for Provision of Stormwater Services to Informal Areas
National Health Act (2003)
Housing Act (1997)
National Housing Programme: Upgrading of Informal Settlements Programme (UISP).
</td></tr>
<tr><td>Policy and strategies at the provincial level</td></tr>
<tr><td>
Western Cape land Use Planning Act (Act 3 of 2014) which repeals the Land Use Planning Ordinance (Ordinance 15 of 1985; Provincial Administration, 1999) and Western Cape Planning and Development Act (Act 7 of 1999; Provincial Gazette, 1999)
Recreational Water Use Manual
</td></tr>
<tr><td></td></tr>
<tr><td>Proposed strategies for Stellenbosch Municipality</td><td rowspan="2"></td></tr>
<tr><td>
Municipal Systems Act (Act 32 of 2000)
IDP
Water Services Development Plan
Policy for Provision of Stormwater Services to Informal Settlements Areas to be incorporated into the greater UISP
</td></tr>
</table>

Source: Author (2015)

This framework is explored in more detail below.

Legislation and regulation at the national level

The South African Constitution (1996)

South Africa's Constitution (Republic of South Africa, 1996) provides a framework for discussions around stormwater management. Schedule B, part B mandates that stormwater management in built-up areas falls within the responsibilities of municipalities (Republic of South Africa, 1996).

It also states in the enclosed Bill of Rights (Republic of South Africa, 1996:9) that:

> *Everyone has the right— to an environment that is not harmful to their health or wellbeing; and to have the environment protected, for the benefit of present and future generations, through reasonable legislative and other measures that—prevent pollution and ecological degradation; promote conservation; and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.*

These principles form the foundation for SuDS. The legislation and regulations that follow from the constitutional framework regarding stormwater management are discussed below.

The National Water Act (1998)

The National Water Act (1998) defines how water resources are used, including stormwater. The act acknowledges that water is an 'indivisible resource' that should remain under the custodianship of national government (Government Gazette, 1998a). It recognises that maintaining water quality is important and that there is a need for integrated management of all water (Government Gazette, 1998a).

The National Water Resources Strategy (2004)

The strategy aims to help develop national frameworks for managing water resources in line with the National Water Act. It identifies constraints and opportunities that exist regarding water resources that could be linked to catchment management strategies, an intrinsic part of regional source control. The five-year plan will provide much-needed information to educate the general public about water concerns.

The National Environmental Management Act (1998)

The National Environmental Management Act (1998) attempts to anticipate and prevent pollution, degradation, landscape disturbances and negative environmental impacts (Government Gazette, 1998b). It cautions against over-exploitation of renewable resources and ecosystems.

National Environmental Management: Biodiversity Act (2004)

This act provides the framework for conserving, sustainably using and equitably sharing the benefits of the country's biological resources (Government Gazette, 2004b). As part of this, regulations are set regarding alien and invasive species to regulate and monitor particular plant species. Some of these species can be used in conjunction with SuDS techniques.

National Environmental Management: Protected Areas Act (2004)

This act aims to (Government Gazette, 2004c):

> *... provide for the protection and conservation of ecologically viable areas representative of South Africa's biological diversity and its natural landscapes and seascapes; for the establishment of a national register of all national, provincial and local protected areas; for the management of those areas in accordance with national norms and standards; for intergovernmental co-operation and public consultation in matters concerning protected areas; and for matters in connection therewith*.

Human Settlement Planning and Design 'Red Book'

In 2000 the Council of Scientific and Industrial Research released a two-volume series focused on building and construction technology, supported by the Department of Housing. Volume 2 dedicates a chapter to stormwater management in which the effects of development on natural drainage systems are acknowledged. However, the focus remained on implementation of conventional drainage systems. The guide notes stormwater runoff as a 'common enemy' that needs to be conveyed as swiftly as possible from property. The document does not address drainage in a sustainable way.

Disaster Management Act (2002)

This act attempts to focus policy on rehabilitation, while strengthening (Government Gazette, 2003):

> *…reporting on implementation of policy and legislation relating to disaster risk reduction and management … to expand the contents of disaster management plans to include conducting disaster risk assessments for functional areas, mapping of risk, areas and communities vulnerable to disasters; to provide measures to reduce the risk of disaster through adaptation to climate change and developing of early warning mechanism; to provide for regulation on disaster management, education, and training matters; and matters incidental thereto.*

Thus victims of flooding as a result of runoff are supposed to get help and support.

Municipal Systems Act (2000)

The Municipal Systems Act (2000) mandates that municipalities put strategic plans in place to guide local development (Government Gazette, 2000). It also informs budgeting. The plan is developed with national, provincial and community stakeholders and provides the platform for the development of integrated development plans (IDPs). Water services development plans form part of IDPs, as does the spatial development framework and the integrated transport plan (Government Gazette, 2000). These are expanded on in further detail later in this section.

South African National Road Agency Ltd. (SANRAL) Drainage manual

Originally written in 1981, the purpose of this manual was "to combine useful information on road and drainage in a usable format" (SANRAL, 2007:1). SANRAL is under the patronage of the Ministry of Transport. Its mandate is to manage, develop and maintain the national roads. Because this ministry is also responsible under the roads department for stormwater management, the manual caters to design and planning for this function.

The information in the manual applies to conventional methods of catering for stormwater and ignores critical sustainability elements (Vice, 2011).

National Building Regulations and Building Standards Act (1977)

This act aims to "provide for the promotion of uniformity in the law relating to the erection of buildings in the areas of jurisdiction of local authorities; for the prescribing of building standards; and for matters connected therewith." Local authorities are responsible for regulating the erection of buildings, including approving the provision of water supply, drainage, sewerage and stormwater disposal (Department of Trade and Industry, 1997).

SANS 10400-R: Stormwater Disposal (2010)

The South African National Standards aligns with national building regulations and sets the standards for conventional drainage systems (South African Bureau of Standards, 2010). It does not take SuDS into account (Vice, 2011) confirming that stormwater is still not regarded as a valuable resource and disregarding the potential of using the water before it is conveyed to the nearest watercourse.

National Health Act (2003)

This act aims to assess (Government Gazette, 2004a):

> *… overcrowded, dirty or other unsatisfactory health conditions on any residential, commercial, industrial or other occupied premises … ensuring urban and rural land use planning and practices that are conducive to sustainable development conducting sound environmental health impact and other assessments; and ensuring the prevention and abatement of any condition on any premises, which is likely to constitute and health hazard.*

Under this act are the Norms and Standards for Environmental Health (chapter 3, section 2(a)(ii)) that mandates that effective and suitable means of drainage must be provided on all premises in accordance to set standards and the national building regulations (Government Gazette, 2004a). It also expands on issues of environmental pollution control in section 24 related to waste management, blockages and leakages of sewage.

The current situation found in informal settlements in particular of stormwater being polluted through poor or lack of waste and sewage disposal systems needs to be redressed through this act.

National Housing Act (1997) and the UISP

This act aims to provide for the (Government Gazette, 1977):

> … *facilitation of a sustainable housing development process: for this purpose to lay down general principles applicable to housing development in all spheres of government, to define the functions of national, provincial and local government in respect of housing development…*

The act incorporates a guideline for the national housing code, which encompasses incremental interventions and the UISP (Government Gazette, 1977). The UISP was created to "cater for the special development requirements of informal settlements (UISP, 2009:9). It is implemented at the municipal level by the human settlements department, which is responsible for conducting enumerations of settlements to enable planning (Stellenbosch Municipality IDP, 2014). The resultant upgrading is *in situ* to bring about faster provision of basic services, as well as social and economic amenities and secure tenure.

Policy and strategies at provincial level

There is limited guidance given, even at a legislative level, to authorities regarding stormwater management in the Western Cape (Vice, 2011). The following documents provide an indirect influence and potentially open up the space needed for SuDS implementation.

Western Cape Land Use Planning Act (2014)

This act aims to (Provincial Gazette, 2014):

> … *consolidate legislation in the Province pertaining to provincial planning, regional planning and development, urban and rural development, regulation, support and monitoring of municipal planning and regulation of public places and municipal roads arising from subdivisions…*

> *… to make provision for provincial spatial development frameworks; to provide for minimum standards for, and the efficient coordination of, spatial development frameworks; to provide for minimum norms and standards for effective municipal development management; to regulate provincial development management; to regulate the effect of land development on agriculture; to provide for land use planning principles; to repeal certain old-order laws; and to provide for matters incidental thereto*.

This act would influence the UISP, particularly if it integrated SuDS as part of its interim service provision.

Recreational Water Use Manual (2007)

The manual (Department of Water Affairs and Forestry, 2007) outlines the relevant policies and regulations regarding recreational water use, regulation and control, as well as providing guidelines and delegation of authority in this regard. Recreational water encompasses surface water used for sport, tourism or leisure, as well as activities that otherwise contribute to general health and skills development of individuals and society at large.

SuDS techniques, with their potential for creating viable tourism and relaxation spaces or acting as examples of model stormwater management, could find a viable home here.

At the municipal level

A lack of by-laws

Stellenbosch Municipality does not have specific by-laws governing stormwater management; this despite the frequent floods experienced in communities like Enkanini. There also do not appear to be guidelines as how to manage stormwater. Cape Town, said to be at the forefront of stormwater management in South Africa, on the other hand has developed by-laws, partly in response to the number of tourists the city attracts each year. Pollution affecting beaches and other water bodies could impact on the tourist experience and thus revenue for the city.

Stellenbosch Municipality has some regulations regarding stormwater management under street by-laws, which effectively excludes informal settlements as they do not have formal roads. The Manager of Transport, Roads and Stormwater at the municipality, E. Wentzel (2015) notes this lack of formalised stormwater management has a negative effect on the community and environment.

SuDS as a stormwater management system aligns with cluster 2 of the municipality's IDP (2012–2017), which focuses on long-term service delivery goals, dignified living conditions, environmental protection and efficiency of infrastructural services (Stellenbosch Municipality IDP, 2012). Strategic goal 4 of the plan aims to address and protect "environmental planning and management, conservation of nature areas, management of alien vegetation, river rehabilitation and urban greening" (Stellenbosch Municipality IDP, 2012:88) and strategic goal 8 aims to address and develop "…efficient infrastructure and services aimed at integrated, sustainable long term infrastructure planning and resourcing, water and transport" (Stellenbosch Municipality IDP, 2012:105). In addition, the municipality recognises that its rivers are polluted, but has not explored the possibility of pollution being compounded by stormwater run-off. It notes that "water quality is a major problem in all municipal rivers, particularly below settlements" (Stellenbosch Municipality IDP, 2012:27).

There is a clear need for stormwater and water-related service provision to combat pollution at settlement level prior to it reaching downstream water and river courses. Not doing this is in effect neglecting the Western Cape provincial government's strategy to develop "integrated and sustainable human settlements, mainstreaming sustainability and optimising resource-use efficiency and integrating service delivery for maximum impact" (Stellenbosch Municipality IDP, 2012:35). In addition, downstream pollution (emanating from a lack of stormwater management, including drainage) could result in irreversible pollution and prove costly to treat.

Stellenbosch Municipality's IDP (2012), while recognising all other services, ignores the issue of stormwater management despite the obvious need for it. An assessment of the plan in 2010/11 (Stellenbosch Municipality IDP, 2014) recognised that alignment between the water services development plan and the IDP needed to be improved and that issues related to sanitation and water losses needed more intense exploration (Stellenbosch Municipality IDP, 2012).

Unfortunately, water losses in this sense are not extended to include stormwater management and funding for any amendment to the IDP will need to wait for the next cycle that runs from 2018–2022.

Water services development plan

Stellenbosch municipality as a water services authority is mandated under the strategic framework for water services to develop a water services development plan. The objective is to assist the water services authority develop long-term plans that place basic water services provision as a priority promoting economic development that is affordable and sustainable. Plans need to integrate with catchment management strategy and on a technical level integrate with social, institutional, environmental and financial planning.

SuDS' incorporation of social, environmental and economic aspects aligns conceptually with the water services development plan. However, only through its inclusion in UISP would SuDS gain the necessary traction to unlock funding for implementation in informal settlements.

A motivation for inclusion in the UISP

Stormwater management should be regarded as an important element within the greater urban water cycle and environment. As such, it should be formally recognised in policy, legislative and regulatory documents. Given the particular negative effects of this lack in informal settlements, stormwater management should form part of the UISP's interim service provision programme. The issue of drainage must be delinked from its current association with formalisation of settlements (Adegun, 2013) and included in programmes such as UISP specifically created to address the challenges faced by informal settlement residents. Current stormwater management systems do not take into account sustainability principles and are not aligned with systems in developed countries, which increasingly are moving to maximise water usage and mimic natural processes to ensure the integrity of the hydrological cycle. The potential for incorporating SuDS into the UISP is explored further in chapters 4 and 5.

Chapter 3 outlines the methodological approach to the study and the methods used. You need to synthesis the arguments made in your literature review in a concise chapter conclusion. What you have done here is inadequate.

Chapter 3: Research methodology

By employing the intelligence of natural systems we can create industry,
buildings, even regional plans that see nature and commerce
not as mutually exclusive, but mutually coexisting.

Brad Pitt, 2006

3.1 Introduction

The study aims to understand the problems caused by a lack of stormwater drainage in informal settlements in South Africa, and in particular it is a critic of the national polities used to guide the upgrading of informal settlements and stormwater drainage management. It further aims to explore the possibilities of including sustainable stormwater drainage systems in the UISP, which guides infrastructure development in the country's informal settlements.

The study's specific objectives was to show the complex nature of informal settlements and how they require a holistic approach; to understand how implementing SuDS can benefit ecosystem services and the urban water cycle; and to illustrate how inclusion of these types of systems in policy around upgrading of settlements would provide the necessary traction for implementation. To this end, the study aims to answer the following research questions:

1. Is there room to incorporate SuDS in South Africa's UISP?
2. What potential do SuDS have to address drainage issues in informal settlements?
3. What other services can SuDS link to and provide benefits?

In addition, the study is based on a value-driven assumption that any upgrading needs to be sustainable in economic, social and environmental terms. For this reason, it focuses on SuDS within a framework of water-sensitive urban design. This design framework integrates engineering and land-use planning aspects into the functioning of the natural urban water-cycle. Using SuDS can also bring about the necessary social and institutional arrangements that appear lacking in the issue of drainage management because it is currently viewed as merely a technical solution (Armitage, 2007). The context of informal settlements was chosen as the lack of drainage provision has negative consequences for millions of South Africans and it remains marginalised in policy discourse and documentation.

I chose to use complexity theory as the len with which to decomplexify the issues surrounding informality and drainage to support a qualitative approach to this study. The reasons for this decision are outlined in this chapter. The methodological approach had to enable relatively easy extrapolation of data with associated methods that would support the theoretical framework, while assisting in gathering quality data.

3.2 Research design and methodology

Research design illustrates the way in which the research will be approached regarding the proceedings, strategies and methods used for data collection and analysis (Holloway, 1997; Mouton, 2001). The study aimed to investigate the lack of stormwater drainage in informal settlements and whether this issue received enough emphasis in national policy focused on upgrading of these settlements. Policy and programme for critic was chosen on the basis that, the document had to either focused on informal settlements upgrading (space in which settlements upgrading is guided; USIP) or it laid out the stormwater management and its design criteria (*Human Settlements Planning and Design Guide* (the 'Red Book') and the *South African Guidelines for Sustainable Drainage Systems* all though the latter focuses on a holistic approach to stormwater drainage taking into consideration, biodiversity/amenities, water quality and quantity. To this end I needed a theoretical framework through which to analyse the data, which would need to be of a qualitative nature to provide a comprehensive overview of the on-the-ground realities and possible disparities with policy on a local and national level. The design could not be a rigid one as new findings would shape the research process (Holloway, 1997) and eventually allow for the choice of focused methods for data collection and analysis.

Methodology, which refers to "… principles and philosophy on which researchers base their procedures and strategies … consists of the ideas underlying data collection and analysis" (Holloway, 1997:105). Increasingly it is understood that socioecological systems are complex ones (Cilliers, 2008; Audouin et al., 2013) and in a world experiencing a changing climate with non-linear interactions occurring between system elements, connections between human settlements and natural settings are giving rise to 'wicked' problems with no easy solutions.

Informal settlements are but one of the spaces in which connections between human settlements and natural settings occur. However, both are affected by the lack of basic drainage systems, for example, which results in natural disasters such as flooding, which in turn results in displacement of people and economic loss, as well as pollution, which increases health risks and thus the economic burden on the state's health system. This study rests on the belief that these systems are complex ones and so a complexity lens is needed to study the 'wicked' problems that arise (Harris, 2007).

In addition, the study places a great emphasis on the need for drainage systems to be sustainable – cost-effective and socially and environmentally just – to address imbalances in the system and contribute towards a sustainable development agenda. These principles informed the choice of a mixed-method approach to the study.

3.3 A qualitative-methods approach

This study employs a qualitative approach. It does this to ensure validity of the data through triangulation (Creswell, 2009). Triangulation is a qualitative process is used to check and establish validity in a study through the analyses of the research question from the perspective of multiple data sources, in this case policies. Although the process is riddled with inconsistencies, these should not be seen as weakening the evidence, but should be used as an opportunity to uncover deeper meaning in the data and to gain accurate insights into the complexity of the problem. This approach helps to validate qualitative data gathered and provides a more accurate structure to quantitative work. This approach was necessary as the broad topic – the potential for actual implementation of SuDS in the Upgrading of Informal Settlements Programme (UISP) in South Africa – has not been researched before and so would rely on collection of qualitative data (Creswell, 2009; Hilal & Alabri, 2013)., which would come from variables deemed to be important for determining the efficacy of a particular drainage systems.

3.3.1 The qualitative used in the study

Qualitative research enables discovery of the contextual conditions in which people live (Holloway, 1997; Yin, 2010). For this reason, it is a valid tool to explore conditions in informal settlements.

> *… studies the meaning of life under real world conditions, covering a contextual condition in which people live because insights into existing or emerging concepts could help in explaining human behaviour whilst at the same time strive for multiple sources of evidence.*

Qualitative research also allows the collection of data that better explains events "… through existing or emerging concepts" (Yin, 2010:8). Complexity theory is adept at identifying both existing and emerging concepts using systems thinking as the approach for analysis of the rationale. Qualitative research also allows for the exploration of 'how' questions instead of the 'how many' questions usually answered by quantitative research. The concept of SuDS fits into this 'how' space as does the question of 'how' to transition towards sustainable service provision, in this case of drainage, in informal settlements. The 'how' in spaces attempts to show case the possible SuDS approaches that can be fitted and used in a given space area in an informal settlement, whilst, the 'how' in transition focuses on the ways in which a transition into SuDS usages can be adopted as a means of providing sustainable stormwater drainage systems.

Because a social element is attached to the objective, there is a need to realise that the study is embedded in a social context, which gives further credence to the value of using qualitative methods.

Silverman (2010) cautions that the methods chosen for inquiry need to relate to the phenomenon under investigation to yield the best results. Which is why, a critic of the policies and programme was chosen, given the absence of stormwater drainage in UISP, which is meant to guide the upgrading process. Moreover, is in criticising the policies and programme that a realisation is arrived at so the discourse of this issue can be given a platform in which it can be discussed. In effect, he encourages following the data and emergent findings in the pursuit of knowledge (Silverman, 2010).

Given the focus in this study on local informal settlement conditions, there was a need to review and analyse South African-based material that covered SuDS, stormwater management policies and informal settlement upgrading policies and literature in addition to literature focused on drainage systems and paradigms in developed countries. Both primary (interviews) and secondary (review of policy documents and guidelines) data is used to offset the real-world conditions in an informal settlement, with Enkanini acting as a point of reference.

Because the study also focused on policy, a qualitative approach was used to determine the number of times the terms ‘stormwater’ and ‘drainage’ were used in the UISP. It did not go beyond that usage and as such, the data analysis presented in chapter 4 originated mainly from the qualitative research undertaken. The table below provides a detailed description of the distinction between qualitative and quantitative research approaches.

Table 3: Comparing qualitative and quantitative research approaches

	Quantitative	Qualitative
General framework	Seek to confirm hypotheses about phenomena	Seek to explore phenomena
	Instruments use more rigid style of eliciting and categorizing responses to questions	Instruments use more flexible, iterative style of eliciting and categorizing responses to questions
	Use highly structured methods such as questionnaires, surveys, and structured observation	Use semi-structured methods such as in-depth interviews, focus groups, and participant observation
Analytical objectives	To quantify variation	To describe variation
	To predict causal relationships	To describe and explain relationships
	To describe characteristics of a population	To describe individual experiences
		To describe group norms
Question format	Closed-ended	Open-ended
Data format	Numerical (obtained by assigning numerical values to responses)	Textual (obtained from audiotapes, videotapes, and field notes)
Flexibility in study design	Study design is stable from beginning to end	Some aspects of the study are flexible (for example, the addition, exclusion, or wording of particular interview questions)
	Participant responses do not influence or determine how and which questions researchers ask next	Participant responses affect how and which questions researchers ask next
	Study design is subject to statistical assumptions and conditions	Study design is iterative, that is, data collection and research questions are adjusted according to what is learned

Source: Mak et al. (2005)

Additionally, qualitative methodology tends to be underpinned by meta-theory, in this case complexity theory, which aims to concentrate on interweaving aspects relating to the macro-level, which involves institutions and organisations, and the micro-level, which involves individuals within a social domain (Bergin, 2011).

Qualitative research methods also allow for the development of new concepts (Yin, 2010). These concepts can be deduced using the Nvivo 10 software, which allows one to analyse unstructured data in a variety of ways as well as enabling visualisation of analysis. It is possible to develop new concepts as 'nodes' using the software. Nodes are the "...collection of references about a specific theme, place, person or other areas of interest" (Bazeley, 2007 in Bergin 2011:3). Nodes are often created during the literature review to help categorise information by identifying emerging themes found in the literature. Additionally, one begins the coding process with what is termed as a 'free node' (a stand-alone node with no logical connections) that later becomes a parent node.

The more nodes are created the more hierarchical structures begin to emerge and the parent and child nodes become visible. This is illustrated in the figure below where natural environment is depicted as the parent node with child nodes beneath – renewable energy, environmental impacts, etc. The corresponding numbers indicate first the number of sources entered (24 for natural environment) and second the number of references of nodes derived from the sources (325 references to natural environment).

Natural environment	24	325
Renewable Energy	1	16
Environmental impacts	6	27
Ecosystem services	9	13
Landscape	11	38
Water quality	13	146
Environmental change	14	42
Habitat	17	43

Figure 21: Nodes hierarchy
Source: Author (2015)

As with any software, Nvivo 10 has some disadvantages including the time and effort required to learn how to use the programme proficiently. In addition, there is some difficulty associated with changing information categories once they have been developed (Robson, 2002 in Bergin, 2011:3). Furthermore, Odiaka (2008) is of the opinion that relying on computer programmes such as Nvivo can often replace a careful analysis of the materials. The advantage Nvivo offers the researcher is the ability to improve the quality of the research and yield more professional results. It also allows patterns and themes to emerge, which can allow for pre-hypothesising, and reduces the time element required for manual processing of information (Hilal & Alabri, 2013). It also enables teams of people to work together on a single project (Hilal & Alabri, 2013). It is within the nodes generated for this study that gaps in policy began emerging as well as the potential space for implementation of SuDS.

This discovery warrants a review of the current stormwater policies/manuals using Nvivo 10; used in South Africa and the need to incorporate new sustainable drainage approaches, which are gaining traction in developed countries. As Yin (2010) notes, qualitative research allows for the development of new concepts. The process of analysis is simple depicted in the figure below.

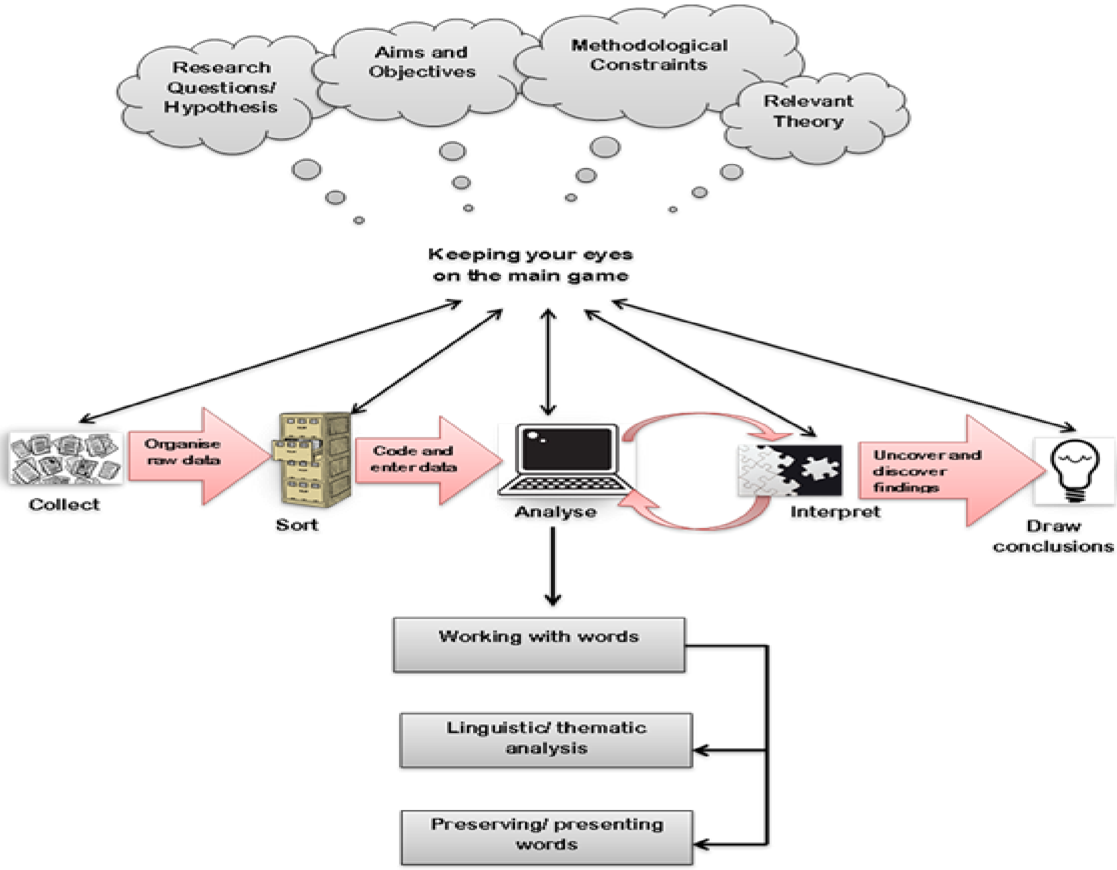


Figure 22: The process of analysis
Source: O'Leary (2005)

These concepts need to subsequently be arranged in theories to help define and explain phenomenon. A "theory consists of plausible relationships produced among concepts and sets of concepts" (Strauss & Corbin, 1994 in Silverman, 2010:109). Complexity theory is used in this study as a framework for analysing data as it can provide a base from which to consider the real world, a place that is "…separate from, yet about that world", which is why it can provide "…both a framework for critically understanding the phenomena and a basis for considering how what is unknown might be organized" (Gubrium, n.d. in Silverman, 2010:110).

3.3.2 A sustainability and complexity thinking framework for analysis

This study was orientated towards sustainability from inception as most of those working in the ISUG were studying through the Sustainability Institute or TSAMA HUB, both of which focus on sustainable development. More importantly, sustainability len was chosen because of its lasting usage for adaptation even by future generation uses, and its availability to recognise the importance of vegetation in water retention and infiltration. Solutions to stormwater drainage challenges in any case need to align to sustainable development principles and be economically, environmentally and socially sustainable. Furthermore, strategic planned stormwater drainage could deliver multiple benefits and synergies required to manage local flood risks and deliver green infrastructure.

The WECD report *Our Common Future* (1987:33) called for the "…need to develop new thinking methods…" given the limited resources, normally financial ones, available to improve the living conditions of the poor. For those living in informal settlements that are located often on land ill-suited for human habitation (steep slopes, high water tables and wetlands) the risk of runoff-related hazards and disasters is increased (Adegun, 2013) and solutions need to be both innovative and sustainable. Efficient water management is vital for the sustainability of urban life (Marlow, Moglia, Cook & Beale, 2013). Current models of water provision are becoming less feasible (Beecham, 2003; Brown, 2005; Goldenfum, 2007; Novotny, 2008) as increased population density, which is expected to escalate exponentially, puts further strain on the water cycle (Bolnick, 2009). This is not just the increased demand for potable water, but as building infrastructure, including roads, covers land, runoff water has nowhere to go and does not contribute to replenishing groundwater reserves. The multiple negative effects that can transpire from this are presented in the following causal loop diagram.

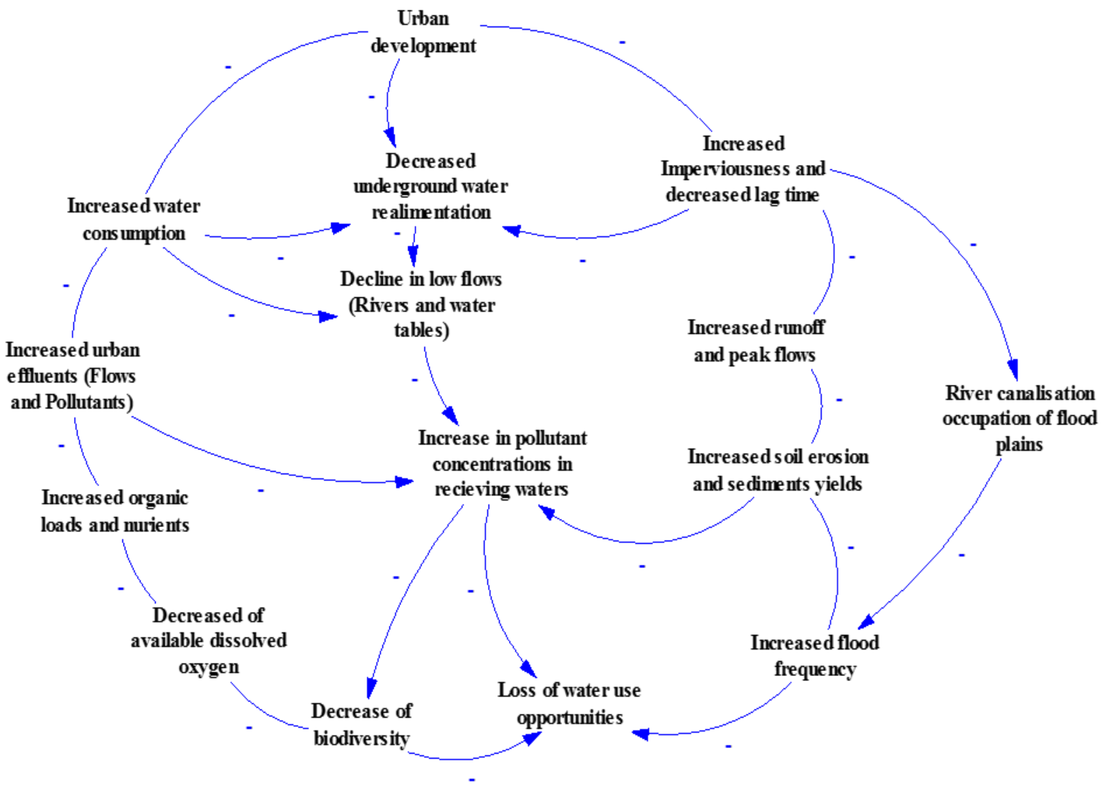


Figure 23: Effects of urbanisation on the urban water cycle
Source: Chocat (2007)

The negative effects linked to an increase in intense human activity in cramped spaces is likely to increase water consumption, soil erosion, urban effluent in terms of pollution and waste water flows, the frequency of flooding and minimise optimal use of water, and decrease biodiversity levels and underground water replenishment cycles. These potential effects necessitate the change to upgrading informal settlements within a sustainable holistic framework.

Unfortunately, problems relating to environmental degradation that result from a lack of drainage infrastructure are not prioritised in poor communities given their immediate focus on reducing poverty and meeting their immediate energy, water and sanitation needs (Simon, 2012). The challenge is thus entangled with many others (such as poverty, energy needs and food security), which are interconnected and so sustainability efforts will need to be embedded in a theory that can help untangle the unintended consequences of not having stormwater drainage.

Complexity theory is required when facing a 'wicked' problem as it enables understanding of the system elements, interactions and potential non-linear interactions (Harris, 2007). An informal settlement is typically a space in which functional (lack of space) and relational (social domain in which different actors meet) complexity are inherent. Relational and functional complexity can destabilise a system that might appear coherent, but in reality be at a tipping point or catastrophic threshold – such as the point at which runoff water turns into a flash flood (Kay et al., 1999). Implementing any sort of drainage system in an informal settlement requires complex systems analysis because of the levels of uncertainty, precaution and resilience that are paramount to ensure the sustainability of complex systems (Harris, 2007).

3.4 Outlining the research methods

The four methods used in this study are a literature review, content analysis, policy document analysis and coding. The limitations to single data collection methods can be mitigated using a qualitative approach (Creswell, 2009). In this study, a variety of methods were used to overcome the limitations of each, which are covered in the following sections.

3.4.1 Literature review

A literature review ensures that the study is not merely a duplication of work done previously while also determining what avenues have been explored and what has been discovered about a phenomenon (Mouton, 2001). In 2012 I studied towards a post-graduate diploma in sustainable development at the Sustainability Institute, Stellenbosch University. One of the modules I attended focused on ecological design, the principles of which are based on the need to design and use methods that "minimize(s) environmentally destructive impacts by integrating itself with the living process" (Van der Ryn & Cown, 1996:18). I had identified stormwater drainage as a pressing issue during my time in Enkanini and during the module I was exposed to literature on SuDS, which aligned with Van der Ryn and Cown's (1996) principled statement. Given that I do not have an engineering background and nor could I access funds to implement a pilot project, I decided to focus on a qualitative study and to conduct a critical and conceptual review of the relevant literature.

Huber (2014) defines a conceptual review as one that synthesises conceptual knowledge to enable a deeper understanding of the issue. A critical review entails careful scrutiny of the methods and the research findings – from both primary and secondary data sources – given the wealth of contextual material (Huber, 2014). The table below outlines the main research findings, which were used to inform the coding of the nodes in Nvivo 10 to better respond to the research questions and objectives. The findings indicate that challenges lie ahead regarding legislation for stormwater management, given that many municipalities have funding issues and do not prioritise drainage in basic service delivery mandates.

Table 4: Key findings from the literature review using Nvivo 10

• There is no national legislation focused on stormwater management. • There is room for policy improvement where stormwater is concerned. • Funding for stormwater infrastructure is often sourced from property rates. • Stormwater management should be placed under the water services development plan and not the roads department.	• Should stormwater drainage in informal settlements continue to be ignored, the spillover effects of time will affect areas in and around these settlements. • But, conventional drainage systems add very little or no social and ecological value.
• Financial constraints are perceived as the limiting factor to implementing any kind of stormwater drainage in informal settlements. • Lack of space for infrastructure is another limiting factor.	• Stormwater drainage should be an inherent component of informal settlement upgrading approaches.
• Sustainable urban design systems appear to more favoured for new developments and the formal urban sector.	• Urbanisation and the resultant population density in informal settlements are responsible for the decreased permeability of most surface areas.
• The lack of institutional capacity is discouraging the implementation of SuDS.	• SuDS offer the potential to replenish underground water tables and to cater for ecosystem services.
• Applying sustainable urban drainage system techniques has never been tested in informal settlements.	• Stormwater drainage challenges in informal settlements will continue with changing climatic conditions.
• Implementing SuDS is likely to be more successful if other service needs are	Stormwater is a valuable resource and should be treated as such.

satisfied.	

Source: Author (2014)

It seems apparent that the placement of stormwater drainage under the Department of Transport does not place the necessary value on water as a scarce resource in South Africa. Its placement in the legislative space effectively curtails the ability of local authorities to ensure that this resource is best used. It should also be noted that while financial constraints might pose real limitations on extending stormwater drainage into informal settlements, the consequences of not having this in place in changing climate conditions could be even costlier.

3.4.2 Content analysis

Content denotes containment and so content analysis "...is the analysis of what is contained in a message" (Prasad, 2008:2). It is a useful technique for drawing inferences from the message and conclusions about specific content (Prasad 2008). This method is the interface between document analysis and literature review (Prasad, 2008). According to Hsieh and Shannon (2005), the lack of definition and procedures has potentially led to the limited application of content analysis, although it can be a useful technique in the allowance of discovery and description.

Content analysis is also valuable for discerning the shift in thinking about the knowledge field (Stemler, 2001), in this case SuDS, by compiling a list of authors and their stance on a particular topic. This helps to build a case to push for increased focus on SuDS and its implementation. Quality content analysis "provide[s] knowledge and understanding of the phenomenon under study" (Downe-Wamboldt, 1992 in Hsieh & Shannon, 2005:1278). Content analysis can also be reduced to specific aspects of interest.

This study used a direct approach to content analysis, which is illustrated in the black-bordered box in following table. As a direct approach, it aims to validate a theoretical framework or theory (Hsieh & Shannon, 2005). Moreover, theory or prior research is often used to guide the discussion of findings. This aligns with the importance of needing to study the "...changing trends in the theoretical content and methodological approaches" by contextually analysing the articles in a given discipline (Loy, 1979 in

Prasad, 2008:6). Consequently, content analysis can be applied based on the problem being studied (Hsieh & Shannon, 2005:1277).

Table 5: Major coding differences among three approaches to content analysis

Type of Content Analysis	***Study Starts With***	***Timing of Defining Codes or Keywords***	***Source of Codes or Keywords***
Conventional content analysis	Observation	Codes are defined during data analysis	Codes are derived from data
Direct content analysis	Theory	Codes are defined before and during data analysis	Codes are derived from theory or relevant research findings
Summative	Keywords	Keywords are identified before and during data analysis	Keywords are derived from interest of researchers or review of literature

Source: Hsieh and Shannon (2015)

The figure below depicts the final coding results from the inputs into the Nvivo 10 software package. It shows the different nodes as they were coded before sorting to find parent nodes.

Nodes

Name	Sources	References	Created On	Created By
Chapter one	5	40	21/05/2015 12:52 AM	ND
Institutional barriers	1	20	24/06/2015 9:13 PM	ND
Conditions for implimentation	4	13	17/04/2015 10:17 AM	ND
Scope in which SuDS can fit	3	10	16/04/2015 11:50 AM	ND
Catch in policy	3	10	16/04/2015 11:57 AM	ND
Chapter 2	2	9	27/05/2015 3:10 PM	ND
Appropriateness of SuDS	3	8	16/04/2015 6:52 AM	ND
Holistics apprach to upgrading	2	7	16/04/2015 6:50 AM	ND
Community empowerment	1	6	16/04/2015 6:46 AM	ND
Funding opportunities	2	6	16/04/2015 6:48 AM	ND
contradiction	1	6	16/04/2015 11:49 AM	ND
Objectives of upgrading	2	6	17/04/2015 10:09 AM	ND
Lack of clarity	1	5	16/04/2015 1:16 PM	ND
Health and safety	2	4	16/04/2015 6:45 AM	ND
Exclusion	1	4	16/04/2015 4:57 PM	ND
community participation	1	4	21/04/2015 9:48 AM	ND
Factors to consider	2	4	19/05/2015 12:26 AM	ND
Community engagement	1	3	16/04/2015 6:51 AM	ND
Rehabilitation of land	1	2	16/04/2015 7:24 AM	ND
institutional arrangement	1	2	16/04/2015 4:16 PM	ND
Effects of urbanisation	1	2	19/05/2015 6:34 PM	ND
Advocacy for the urban water cycle	1	2	24/06/2015 9:13 PM	ND
Contradiction in policy	1	2	24/06/2015 9:13 PM	ND
Ecological services (2)	1	2	24/06/2015 9:13 PM	ND
questions in terms of policy	1	1	16/04/2015 1:23 PM	ND
Operation and maintaintence	1	1	16/04/2015 3:50 PM	ND
Lack of capacity	1	1	16/04/2015 4:52 PM	ND
Issue of ownership	1	1	16/04/2015 4:56 PM	ND
No mention of stormwater	1	1	16/04/2015 4:57 PM	ND
Support to project	1	1	16/04/2015 4:59 PM	ND

Figure 24: Nodes as coded in Nvivo 10
Source: Author (2015)

There are advantages and disadvantages to all research methods. The weakness of content analysis is that it can fail to locate unobtrusive messaging, which could be relevant for the particular research questions chosen for analysis (Berg, 2009:365). However, it is cost-effective and easily accessible. It can also highlight processes that occur over long periods of time (Berg, 2009); for example, the need to rethink the way in which stormwater has been managed. It can illustrate the how the ideology behind conventional stormwater drainage systems has gravitated in approach to align more with water-sensitive urban design principles, ecosystem services and the urban water cycle. Data such as this can be used to advocate for policy change, particularly in a developing country context, and for shifting the responsibility to a more fitting department, such as the Department of Water Affairs.

3.4.3 Policy document analysis

The nature of this study necessitated policy analysis to determine the potential for deploying SuDS techniques in the UISP and greater stormwater management agenda. I chose to blend policy and document analysis as documents, primarily manuals, were able to provide background information while policies, in particular UISP, enabled me to identify gaps in terms of stormwater drainage prioritisation. Documents are able to assist with authenticity, credibility, representativeness and meaning in the type of data handled (Mogalakwe, 2006:223-224), although as many were manuals it does raise questions regarding their credibility when compared to policies. In this sense, meaning becomes important to signify to the reader the direction the study is heading in – in this case, the importance of linking stormwater drainage to the urban water cycle and greater ecosystem services. Policy analysis allows different viewpoints to emerge and enables rigorous debate and discussion on the way forward (Robert & Zeckhauser, 2011).

3.4.4 Data analysis by virtue of coding

Analysis of the methods used in 3.4 will allow for the coding of themes for data analysis. These themes will be based on the main benefits that can be deduced for sustainable urban drainage system techniques. The collection of themes was arrived at by using the Nvivo 10 software for content analysis.

Nvivo software is able to code faster by means of different source pulls and it is better equipped to "discover tendencies, recognize themes and derive conclusions" (Bazeley, 2007 in Hilal & Alabri, 2013:183). Furthermore, the use of nodes in coding allowed for similarity of themes to form and emerge from the data. It does take time to learn how to use the software proficiently and there are concerns around data bias as the researcher effectively distances her/himself from the data virtue of programming (Bergin, 2011).

3.5 Summary

In conclusion, Chapter 3 provides an overview of the research design, approach, aims and objectives, as well as the research questions. It also explains the rationale behind a mixed-methods approach and describes the methods used, along with their main advantages and limitations. The foundations for analysis were laid in chapter two through a comprehensive review of the relevant literature and the resultant findings collated from the methods described in chapter 3 are discussed in chapter 4.

Chapter 4: Data results and analysis

Building sustainable cities – and a sustainable future – will need open dialogue among all branches of national, regional and local government. And it will need the engagement of all stakeholders – including the private sector and civil society, and especially the poor and marginalized.

Ban Ki-Moon, 2012

4.1 Introduction

This chapter identifies the gaps, contradictions and exclusions regarding stormwater management in relevant South African policy documents. While the complete legislative and regulatory framework was discussed in chapter 2, the documents particularly relevant to this study are the UISP, chapter 6 of the *Human Settlements Planning and Design Guide* (the 'Red Book') and the *South African Guidelines for Sustainable Drainage Systems*, which provides information on the different drainage options available. The purpose of analysing these documents was to provide a base for advocating a specialised focus on stormwater management in informal settlements in the UISP. This chapter details the findings of the study and provides an overview of the UISP's upgrading objectives, the hindrances to implementation of sustainable systems from a policy perspective, the factors to consider when implementing these systems and the potential benefits, as well as the importance of integrating these systems into the urban water cycle and the opportunities they present to optimise the cycle.

4.2 A brief overview of the focus of the primary documents

The UISP primarily focuses on aspects of housing, water, sanitation and electricity. It does acknowledge that upgrading should align with the principles of sustainable development and holistic management. The 'Red Book' focuses primarily on planning within the understanding that there are limits to the environment's carrying capacity, identified as the "maximum persistently supportable load" (Council for Scientific and Industrial Research [CSIR], 2000a: chapter 5:1). It does in chapter 6 give detailed coverage of stormwater management and implicitly acknowledges the need for sustainable drainage and the contribution of stormwater to the greater water cycle, but it does not really address the issue of stormwater management in informal settlements.

The concept of alternative stormwater management technologies is introduced in the *South African Guidelines for Sustainable Drainage Systems* (Artmitage et al., 2013) as a means to slow down the flow rate of stormwater, replenish groundwater and enhance biodiversity. However informal settlements are not advocated for in the guidelines as possible implementation sites because of associated concerns, linked to the lack of waste management, waste water disposal and upkeep of the surrounding environment. The exclusion of SuDS from the UISP and thus official recognition of the technique has marginalised the actual implementation of SuDS in informal communities.

4.3 UISP's upgrading objectives

The aim of the UISP is to reach as many households as possible by maximising the programme's impact. The primary focus is on spatial restructuring and integration of informal settlements where the natural and social context poses a threat to the safety of residents.

The objectives mentioned above is the ideal space in which to implement SuDS as part of the upgrading process. And it is necessary – stormwater, in the form of floods, is known according to (Ziervogel & Smit, 2009; Stellenbosch Municipality et al., 2012), to be a key cause of displacement, which affects not only the lives and livelihoods of the individuals and families affected, but also places additional strain on municipalities mandated to find them alternative living spaces (UISP, 2009). The Enkanini (Kayamandi) Household Enumeration Report (Stellenbosch Municipality et al., 2012) indicates that residents prioritise stormwater management as a community concern (Parkinson et al., 2007). This is not to say that implementing SuDS is without challenges. Successful implementation of this technique rests on collaboration between experts and the community – the process cannot bypass the potential end-users of the collective product (Reed, 2004; Brown & Farrel, 2009; Armitage et al., 2013). In addition, land surveying needs to be undertaken to ensure correct placement of the technology (Button et al., 2010). Stormwater management is a complex undertaking in a complex setting and all associated risks need to be considered prior to implementation and mitigated where possible).

4.4 Hindrances from a policy perspective

4.4.1 Lack of capital and capacity

According to *Human Settlements Planning and Design* (CSIR, 2000b), it is the responsibility of provincial or local authorities to thoroughly investigate the environmental effects of stormwater on receiving catchments. This is problematic in South Africa as local municipalities are often financially constrained and often lack the human capacity necessary for such an undertaking (Wentzel, 2013). In addition, finding solutions to problems of this nature is a costly endeavour and one not high on the list of municipal prioritised expenditure. The lack of a user-charge mechanism for stormwater furthers its marginalisation. The UISP notes that upgrading should be carried out on a "priority basis which is in line with international best practices" (UISP, 2009:25), although stormwater drainage should be given priority it is not and moreover, some might argue that the concept of SuDS is not yet an international best practice as it is still a new concept in terms of drainage. There is, however, reluctance from municipalities to involve themselves in projects if their personnel lack the necessary knowledge for building community participation and implementation and ongoing maintenance (Wentzel, 2013). For upgrading processes to be sustainable, they must rest on the ability of the upgraded element to continue working well after the implementing party and funding has been withdrawn (Abrams et al., 1998 in Le Gouais & Wach, 2013:440). This reluctance, although precautionary in measure to avoid wasting money, also cripples the potential for a mass rollout of these types of systems, which in the long-term would save the municipality money.

4.4.2 Lack of funding for informal settlements drainage

UISP projects are often funded based on the number of people who qualify for assistance according to the programme criteria (see appendix C). Although it makes provision for funding those affected by flooding to be re-housed (UISP, 2009), this 'solution' is short-term in nature given the projections of demographic growth in informal settlements. In addition, the programme only provides "funding to informal settlements situated on land suitable for permanent residential development and within an approved IDP of the municipality concerned" (UISP, 2009:14). Although there is consideration that in certain cases marginal land might need to be rehabilitated, the focus on providing funding for rather what will be permanent settlements overlooks the current reality.

Informal settlement dwellers are, however, likely to work on rehabilitating the land they occupy if it reduces their chances of being relocated perhaps to unserviced land and terrain dynamics that they will need to again spend time learning to understand (Satterthwaite, 2009).

Ironically, while UISP programme aims to provide interim services to "… alleviate immediate/emergency need to access potable water, sanitation services and certain preventative measures to curtail the occurrences of disaster" (UISP, 2009:36) there is no mention of stormwater drainage, the lack of which is a leading cause of disaster in informal settlements – both in terms of flooding and pollution levels. It appears from an analysis of the document that financing of interim services applies primarily to those living in stand-alone houses and thus is not applicable to those living in informal settlement because their service is receivable as collective communal services. Furthermore, the physical dwellings are not in its self-upgraded. Although, stormwater management is classified as an interim services it is often excluded from the upgrading agenda and this is, particularly concerning, given that water is a scarce resource in the country. The implications thereafter is a continued ignorance on the importance of stormwater drainage in informal settlements, a loss of reusability of stormwater for naturally beneficial effects (increased infiltration,) and continued challenges of addressing the negative impacts of flooding on a yearly basis.

The lack of priority given to stormwater management in comparison to sanitation and potable water provision is illustrated in the figure below, which is based on a text search of the UISP.

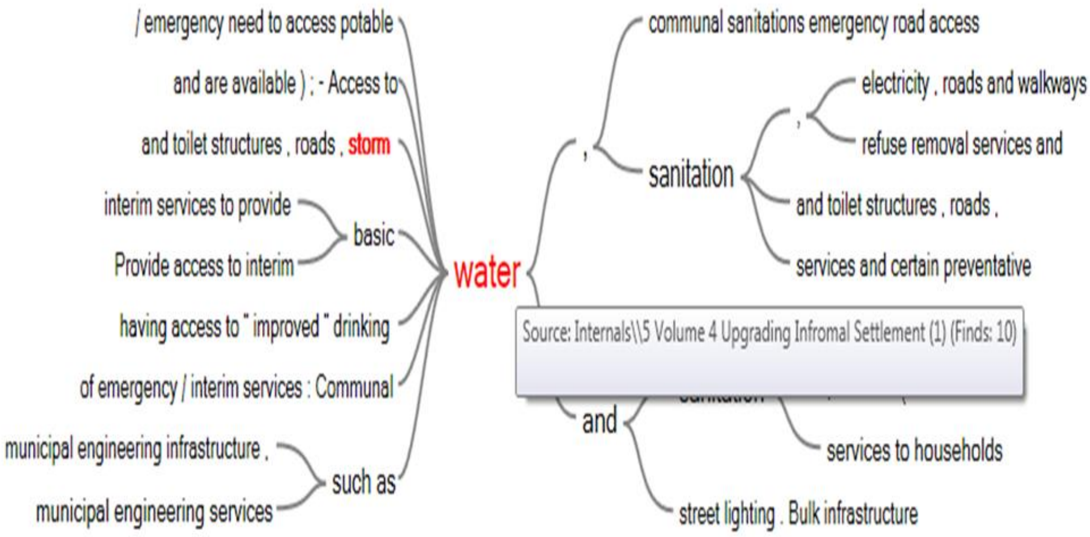


Figure 25: Text search query on the word 'stormwater' in UISP
Source: Author (2015)

Its aim to ensure that a holistic approach is taken in provision of services (both rate and non-rate generating services) implies that that the UISP needs to include stormwater drainage in its ambit.

4.5 Factors to consider before implementing SuDS

4.5.1 Funding opportunities

The UISP first considers those projects that can be initiated *in situ*. This process is facilitated through the National Housing Programme by following a consultative process with local authorities and settlement residents. In this process, the issue of stormwater management can be sidelined, despite the threat of displacement arising from flooding, due to the perceived more urgent need for electrification and its prioritisation by the community. This begs the question as to whether stormwater management will ever supersede or equal the other basic service provisions of housing, electricity, potable water and sanitation. The reality is that, even if funds where availed for stormwater, might not be a welcomed service provision due to the fore-mentioned. Moreover another issue that complicates these type of decision is the trade-off made between capital and maintenance costs in the context of limited funds (CSIR, 2000b).

The notion of 'minimum allowable standards' is invoked, which would imply that even if the capital cost to implement SuDS is high, this would be offset by the low maintenance costs, as SuDS are low-input systems and would fulfil the minimum allowable standard criteria.

4.5.2 Stressing the importance of a holistic approach to upgrading

Life on earth is dependent on water and indirectly on soil, both of which need to prioritised in any upgrading development plan. This necessitates land-evaluation processes that allow for the exploration of environmental considerations that maintain and enhance water and soil capacity in conjunction with that of social and economic determinants; preferably, these processes would also outline projected scenarios dependent on choices made (Armitage, et al., 2013). As responses to climate change cannot rely solely on technological inputs, upgrading processes require collaborative efforts from planning through to implementation and maintenance between the design team, civil experts and the affected community (UISP, 2009). The SuDS techniques facilitate this process.

4.5.3 Health and safety considerations

The primary focus, according to the UISP, should be on implementing upgrades in those areas that pose a threat to safety and health of residents. This can be done by providing "affordable and sustainable basic municipal engineering infrastructure to the residents of informal settlements" (UISP, 2009:13).

SuDS align with the focus on sustainable basic municipal services. While the programme mandates municipalities to be owners of the installed services, communities empowered through the techniques could ensure that services remain functioning – providing monthly reports to municipalities – and through this collaboration minimise safety and health risks. This is done, in the realisation that the lack of Stormwater drainage in informal settlements is a hazard.

The *Guideline for Sustainable Urban Drainage Systems* identifies pathogens and mosquito breeding grounds as an area of great concern when implementing SuDS (Armitage, 2012); measures to mitigate this need to be factored into the design phase.

On-the-ground research and relationship building is a fundamental building block for effective implementation of technically appropriate drainage systems. This requires a level of institutional capacity that is not always present in municipalities.

4.6 Barriers to implementing SuDS

Despite the publication of South Africa's *Guideline for Sustainable Urban Drainage Systems*, there are no demonstration sites of SuDS in South Africa's informal settlements, or those in the rest of Africa. There are some in more serviced areas, such as Century City in Cape Town. On the whole, engineers remain steeped in conservative and traditional approaches to drainage (Reed, 2004). The implementation of SuDS in new or 'green' developments has enhanced the idea that the success of these systems rests on the existence of a certain level of services. There are also concerns that as these systems do not function as sewers, their implementation in informal settlements might be viewed as inappropriate and not serving the most pressing needs (Fisher-Jeffes, 2013).

While SuDS might present an appropriate technical solution, there is a lack of research and piloting of them in informal settings and this is compounded by a lack of human expertise and financial capital, which further enforces the marginalisation of these technologies in policy discourse. As Reed (2004:28) notes "[the] … lack of focus and multidisciplinary nature of drainage systems disperses the motives for applying SuDS" (Reed, 2004:28).

4.7 Institutional issues

Before the notion of SuDS can gain traction as a viable and desirable solution to stormwater drainage issues in informal settlements, the issue of reluctance to pioneer alternative drainage technology due to the lack of institutional capacity will need to be addressed(Vice, 2011). This will include certain institutional aspects, particularly institutional inertia and expertise, will need to be addressed (Brown & Farrelly, 2009). These two aspects are primary contributors to the likely weakness of the complex matrix in which sustainable drainage systems can be placed as the municipal official responsible for drainage may lack the necessary knowledge to implement SuDS (Reed, 2004). As municipalities are responsible for drainage implementation (UISP, 2009) institutional inertia must be addressed at this level.

Continuing with the *status quo* "… only perpetuates the inefficient use of resources and continuing waterway degradation" (Brown & Farrelly, 2009:540); the institutional barriers must be addressed. Institutions are based on historical values that determine and shape current values and decisions – these can arise at managerial, political, social and legal levels. Barriers are therefore also of a socio-institutional nature (Reed, 2004; Brown & Farrelly, 2009). Complexity remains an inherent component of the entire process. Brown and Farrelly (2009) identify the most pressing socio-institutional constraints to implementing sustainable urban drainage solutions as:

- Limited or no coordinating institutional framework for implementation of this type of technology.
- Limited forums or support for community engagement, empowerment and participation.
- A lack of human capacity and financial resources.
- A lack of clarity as to who is responsible for implementation with roles and responsibilities fragmented. This point not only applies to municipalities, but other public and private organisations wanting to involve themselves in a project of this nature.
- A lack of monitoring and evaluation frameworks.
- Low levels of organisational commitment by the municipality.
- A lack of knowledge, information and experience in the application of and adaptive forms of management.
- A reluctance to try alternatives to conventional drainage systems due to technocratic path dependencies.
- A lack of a long-term strategy and vision or sustainable drainage infrastructure.
- Poor communication and low levels of political and public support.
- A limiting regulatory framework.

Brown and Farrelly (2009) note that the topics of institutional inertia and barriers are gaining prominence in urban water literature, but there is still little work done in this regard focused on informal settlements. Brandes and Kriwoken warn against "overlooking the importance of understanding pre-existing and broader barriers that limit the desired programme" (2006 in Brown & Farrelly, 2009:845).

Strong policies and sustainable technical innovation approaches to drainage can improve institutional efficiencies and enhance evaluation processes.

4.8 A note on inclusivity and social sustainability

One of the key intentions of the UISP is to empower communities to bring about social and economic integration. It aims to do this by building social capital through participative processes while addressing greater social needs (UISP, 2009). The programme identifies three stages of involvement: community engagement, community participation and community empowerment (Turkucu, 2008; UISP, 2009). The process works best if the stages set out below are followed sequentially.

4.8.1 Community participation

The programme emphasises that participation needs to be "undertaken within the context of a structured agreement between the municipality and the community" in order to ensure that community members "assume ownership of their [own] development and [the] project" (UISP, 2009:30). Community participation from the outset is crucial in upgrading projects as the community provides the initial primary data drawn from their own local knowledge (Turkucu, 2008). However, participation is often delimited by nepotism and political affiliations with ward councillors and political representatives taking a dominant role in projects of this nature. Those who perhaps have the knowledge and/or aptitude as well as a genuine concern for the community's welfare can be sidelined. The UISP (2009) notes the importance of preserving often fragile community networks to ensure the sustainability of projects and longevity of the settlement.

To ensure community participation, community members need to be assigned duties regarding the provision and maintenance of permanent engineering infrastructure and related services. Arrangements of this nature need to be clearly outlined and agreed to by both parties through detailed written agreements (UISP, 2009). Having clarity around the differing roles and responsibilities is one way in which the possibility of non-linear reactions in a complex system can be mitigated (UISP, 2009).

4.8.2 Community engagement

It is at the stage of community engagement that consultation and education and communication outreaches are initiated to work towards building strong working partnerships. The UISP makes provision for this social process of engagement to be funded, but there is no clarity provided on what the process would entail. At this stage, it would be useful to introduce SuDS and allow for debate about its application and possible benefits or hindrances within the context. Community needs must be balanced with preferences, affordability indicators and sound engineering practices (UISP, 2009). Sustainable urban drainage system techniques could be justified therein as they are both affordable and of proven sound practice (UISP, 2009).

4.8.3 Community empowerment

Empowering a community in this context essentially translates to giving them control over the factors and decisions made in an upgrading process (UISP, 2009). Experts can play a catalytic role in this regard by transferring their knowledge and expertise to community members (World Health Organization, 2015). With reference to SuDS, this would mean that communities would possess the relevant information to make an informed decision around drainage that suited their particular settlement context and topography.

However, unfortunately the UISP (2009) only refers three times to empowerment (see figure below), which seems contradictory to the overall purpose of the policy, which is to address social and economic injustices through implementing viable solutions.

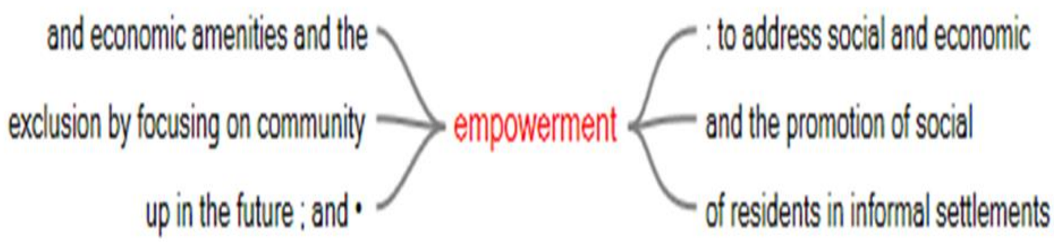


Figure 26: Text search query on the word empowerment in USIP
Source: Author (2015)

The three levels of community involvement are depicted in figure 27. The first level is concerned with the issues and problems pertaining to stormwater drainage and this level could be considered a one-way information flow approach. According to Turkucu (2008), this is the space in which experts could try to come up with the relevant sustainable drainage solutions for implementation in informal settlements; this is done with public feedback. The second and third levels are where the community is given a platform to object to or dispute the proposed techniques as they employ their local knowledge to inform decisions. Levels four and five can be seen as the transition steps between engagement and consultation as this is the highest level of engagement between the experts and community. Level six thus becomes the space in which the public becomes well informed and chooses the techniques they are willing to have implemented in their settlement.

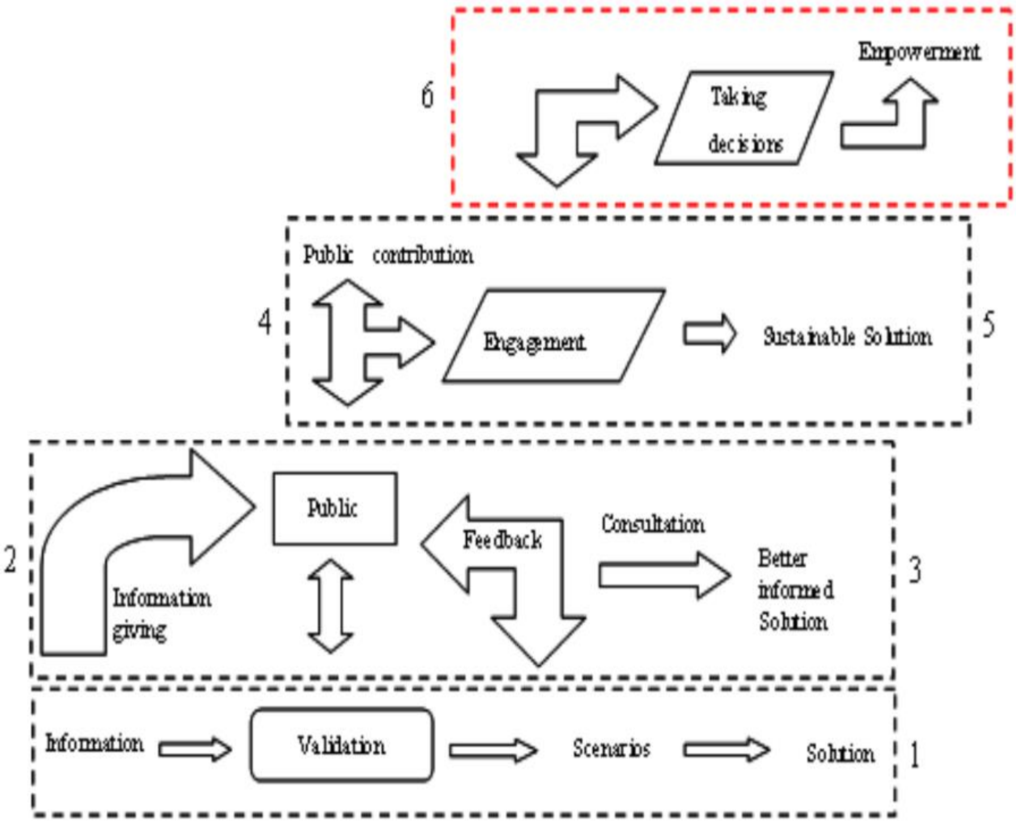


Figure 27: Generic model for community involvement
Source: Turkucu (2008)

Ultimately, community involvement at any given level requires the community to be well informed and this can happen through participation and engagement because in a place with no hydrological or topographical information their local knowledge becomes the primary data with which experts can use to best inform the type of technique to use. This helps with the consolidation of facts for both parties involved.

4.9 Benefits of SuDS

4.9.1 An appropriate solution

The UISP calls for a holistic approach to upgrading that is integrated and locally appropriate. However, the same policy also notes that the national norms and standards that apply to creation of serviced stands need not apply to the programme, although it can act as a guideline (UISP, 2009). This has relevance for the implementation of SuDS as it does not conform to conventional standards, but would need to be implemented in accordance with the *Human Settlement and Planning Design Guideline* (CSIR, 2000b), which acknowledges the need for stormwater drainage systems to mimic nature's flow and processes.

There is some level of contradiction surrounding this as further on in the document the UISP also clearly states that national norms and standards in respect of permanent residential structures "should be adhered to in as far as municipal engineering services are concerned" (UISP, 2009:37). It is unclear as to when the norms and standards can be bypassed and who would motivate for such a decision. However, it would seem that from the community engagement and dialogue happening in the initial stages of implementation, standards and norms cam be set in accordance with municipal engineering and other relevant departments based on their staff capacity and ability to maintain what is being proposed (Wentzel, 2013).

The *Human Settlement and Planning Design Guideline* (CISR, 2000b) calls for use of natural drainage patterns and systems and conveys the need for efficient stormwater drainage to convey the 'common enemy' to the nearest watercourse. The word efficient in this context relates more to cost-efficiency and the need to look for alternative systems as conventional drainage will not cope in the long run given the increasing precipitation due to climate change (Human Settlement and Planning Design Guideline/CSIR, 2000b). The UISP calls for the up-front trade-off with respect to the initial "…capital costs, long-term maintenance and operating costs … the need for environmental sustainability, social acceptability … and safety" (UISP, 2009:37).

The *Human Settlement and Planning Design Guideline* (2000b) encourages multiple uses of stormwater facilities based within floodplains. This also has relevance for implementation of SuDS, which have an orientation towards mixed uses and outputs. The SuDS matrix guides the choice of technique dependent on the context and the desired outcomes. Most techniques can reduce water velocity and help restore permeability through land rehabilitation (Susdrain, 2014). Also, in contrast to conventional drainage systems that have a finite life span, deteriorate over time, are prone to breakages and are costly to expand, SuDS are cost-effective and can be implemented piecemeal while linking into existing conventional systems (Susdrain, 2014). In addition, the process of implementing SuDS is an inclusive one based on community participation, engagement and empowerment.

4.9.2 Environmental rehabilitation

The UISP recognises the importance of rehabilitating land. The programme also exclusively "provides for marginal land to be rehabilitated in certain cases" (USIP, 2009:14). It doesn't, however, specify how land is to be rehabilitated.

SuDS encompassing green infrastructure through the planting of indigenous vegetation (Simon, 2012; SuDS manual, 2013) can provide innovative and cost-effective ways to do this. In addition, these techniques help control soil erosion and mitigate flooding.

The use of scrubs with certain properties could make sure the water is free of nitrates and phosphates while absorbing E-coli into its roots (Habterselassie, Bischoff, Applegate, Reuhs & Turco, 2010).

4.10 Contributing to the urban water cycle

The only mention of the urban water cycle in the analysed policy documents was found in the executive summary of the *South African Guidelines for Sustainable Drainage Systems*. It is described therein as an alternative to stormwater and falls under the water-sensitive urban design strategy of which SuDS are noted as a stormwater management component.

The reality is that the presence of water in urban areas can exist in either natural (wetlands, groundwater and rivers), hybrid (restored rivers) and artificial (sustainable drainage systems and canals) forms and these exist at different scales (Lundy & Wade, 2011). Consequently, to arrive at these forms, the urban water cycle is beset by sustainability challenges, including the need to transition from conventional to sustainable drainage systems (de Haan et al., 2015). Furthermore, the existing complexity in the urban water cycle, which could be a physical aspect, as well as other forms of complexity resulting from possible conflicting social, environmental and economic objectives, poses further challenges. Decision making about drainage systems is therefore employed in a complex setting (Coombes & Kuczera, 2002).

Moreover, the current paradigm has yielded sub-optimal outcomes for the environment and the communities, particularly those in informal settlements with no drainage system in place. The restraints are not a result necessarily of the technology, but rather of "…our perception of system boundaries and constraints that cloud our vision of what is possible" (Coombes & Kuczera, 2002:2).
It is therefore important to formulate the use of alternative practices, such as SuDS, regarding stormwater to better inform the multiple strategies that aim to ensure the long-term sustainability of the urban water cycle (Bettini et al., 2015).
Four major aspects are driving negative aspects of the urban water cycle. The first is an issue of water scarcity, linked to a lack of water resources and freshwater. This is exacerbated by increased extraction of water volumes from rivers to meet urban water supply demands placing considerable stress on the systems within ecosystems (Coombes & Kuczera, 2002). Second is the issue of water quality, linked to a lack of sanitation and inadequate treatment of polluted runoff. There is a need to reduce the pressure on the existing systems in terms of capacity and treatment efficiency, which is increased by the urban diffusion through which the stormwater passes and pollution levels are picked up (Novotny, 2008; Brown & Farrelly, 2009; Armitage et al., 2013). Third is the issue of human health, linked to the effects of a contaminated water supply (Novotny, 2008; Brown & Frelley, 2009; Armitage et al., 2013). Last is the issue of diminishing ecosystem services, linked to the inadequate use of water resources (Novotny, 2008; Brown & Frelley, 2009; Armitage et al., 2013). In addition, water-related challenges are adversely and increasingly affecting the sustainability of human settlements (Van Leeuwen & Marques, 2014).

Water management is driven by scarcity, a pressing problem in South Africa, particularly in the face of a changing climate, which will affect rainfall patterns, flooding and quality (Van Leeuwen & Marques, 2014). There is, however, "persistent policy rhetoric around sustainable urban water management, integrated water cycles, water sensitive cities and the like, as a constant reminder that the drivers on the aspirational side of the continuum are real and must be dealt with" (de Haan et al., 2015:2).

Water-sensitive urban design, which incorporates SuDS, supports the need to achieve and "…incorporate aspects of water into the urban development and planning from the earliest stages" (Lundy & Wade, 2011:654–655). This is especially important in upgrading scenarios in which SuDS techniques will be implemented as their decentralised approach will need to link to an existing, centralised system (Novotny, 2008).

4.11 Opportunities arising from integrated urban water cycle management

Water-sensitive urban design aims to optimise and integrate urban planning into greater management plans for the urban water cycle, while trying to find sustainable ways to manage urban water resources (Coombes & Kuczera, 2002; Lundy & Wade, 2011). There are numerous examples illustrating how urban water is seen as moving well beyond the pre-development phases in the sustainability transition, despite conventional path dependencies and the typically risk-averse culture of most municipalities, particularly those in developing countries. According to de Haan et al. (2015:4), "…urban water provides a comprehensive and representative context for exploring transition processes and dynamics"; these processes and transitions are illustrated in the figure below.

Conventional drainage systems fit into the first three stages (from left to right) with an apparent focus on centralisation of systems and institutions and channelisation and water supply. However, the focus shifts in the last three stages to decentralised systems aimed at attaining flexible institutions and infrastructure.

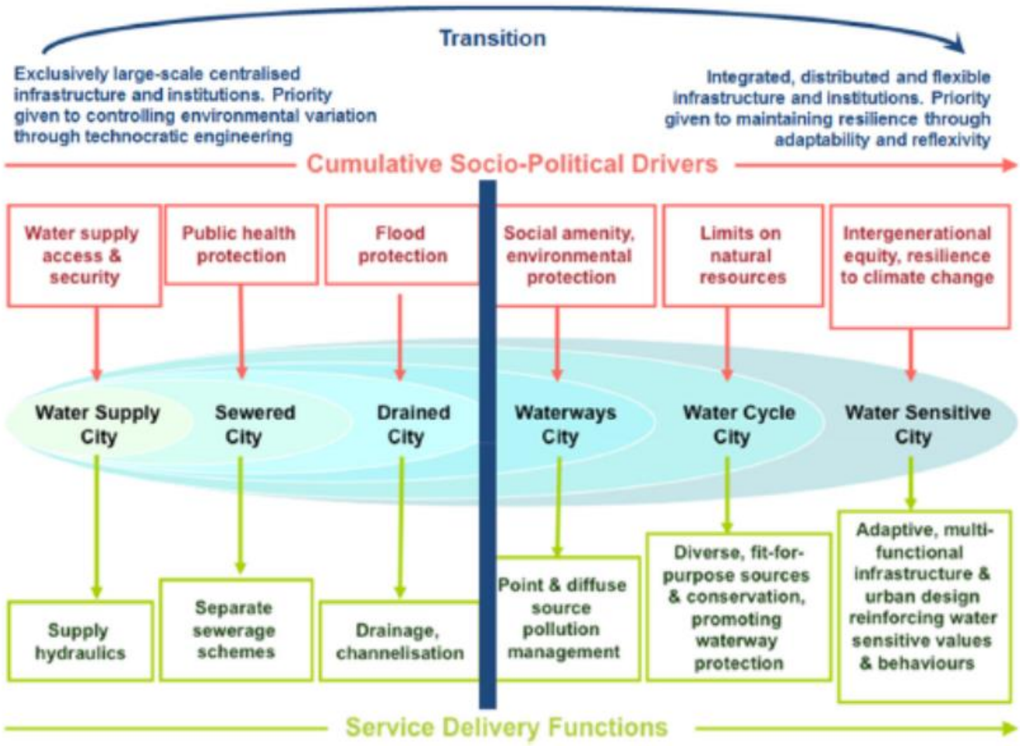


Figure 28: Urban water management and transition continuum: Historical and aspirational states of urban water systems
Adapted from Brown et al. (2009) in Van der Brugge and de Haan (2005:3)

Developed countries have barely reached the aspirational stage, while the potential for the developing world, particularly informal settlements, has barely been explored.

The lack of policy rhetoric around the need for sustainable drainage management is a contributory factor. However, the threats posed by climate change (droughts followed by extreme rainfall events, for example) could incapacitate conventional systems. Using SuDS could also increase the contributions of ecosystem services and itself contribute to creating a water-sensitive city.

4.12 Conclusion

Despite the challenges that arise when using SuDS at the city level, these techniques afford the opportunity to implement decentralised sustainable drainage systems in informal settlements. This process can start from policy inclusion in the UISP and help fulfil the existing empowerment opportunities laid out for *in situ* upgrading in programme implementation. While the positive aspects of SuDS implementation outweigh the negative, the process is not without challenges and the planning process is vitally important to mitigate unintended consequences.

An overview of findings and concluding thoughts, as well as recommendations for further research, are found in chapter 5.

Chapter 5: Conclusion

There can be no settlement of a great cause without discussion, and people will not discuss a cause until their attention is drawn to it.

William Jennings Bryan, 1890

5.1 Introduction

The lack of stormwater drainage systems in informal settlements is increasingly becoming a cause for concern because of the resultant negative consequences. These include flooding, which can lead to a loss of life, as well as displacement with the concurrent effect of loss of livelihood. In addition, these incidents take place in an environment that is prone to high levels of complexity pertaining to provision of basic and interim services. The problems caused by inadequate or no stormwater drainage systems will be exacerbated in coming years if the urbanisation trend continues as expected (Bolnick, 2010), resulting in "escalated overcrowding" (Abbot, 2002:306). Municipalities lack the capacity and often the funding to cater to the increasing demand for housing from low- and no-income groups (Armitage, 2011) and associated basic services; many of those living in or moving to informal settlements could be forced to live in deplorable conditions (Armitage et al., 2010; Butala et al., 2010).

It is disturbing that the guiding document for the upgrading of informal settlements in South Africa, the UISP, does not place much emphasis on drainage systems, retaining its focus on provision of water, sanitation, housing and electricity services.

5.2 Research aims, objectives and questions

The study aimed to understand the problems caused by the lack of stormwater drainage systems in informal settlements in South Africa and to explore sustainable alternatives. These alternatives would need to align with sustainability principles and be implementable in complex socio-environmental locations. The study also aimed to contribute towards the discourse on drainage systems in informal settlements and motivate for the inclusion of SuDS in South Africa's UISP.

The objectives of the research were to analyse the ways in which complexity and informality affect the holistic approach to upgrading of drainage systems in informal settlements; to understand how ecosystem services and the urban water cycle could benefit from SuDS techniques and to illustrate how including these techniques in the relevant guiding policy could provide traction for implementation.

To fulfil these objectives the study attempted to answer the following research questions:

1. Is there room to incorporate SuDS in South Africa's UISP?
2. What potential do SuDS have to address drainage issues in informal settlements?
3. What other services can SuDS link to and provide benefits?

The study is based on a value-drive assumption that upgrading of informal settlements needs to be sustainable. For this reason the study focuses on SuDS within a framework of water-sensitive urban design. The emphasis on informal settlements in the study was motivated by the fact that the lack of drainage systems in this context has negative consequences for millions of South Africans, yet it remains marginalised in policy discourse and documentation.

5.3 Research methodology

The methodology selected for the study was a mixed-methods approach with an emphasis on qualitative research methods – a literature review, personal interviews with municipal stakeholders (Wenzel, 2013), content analysis and policy document analysis. Qualitative coding was used to pull data of which meaning was interpreted according understanding of the researcher. As the problem was a 'wicked' one – with no easy or apparent solution and where a possible solution could effectively exacerbate the problem – and situated within a system exhibiting functional and relational complexity, complexity theory was used as a lens.

Chapter 1 provided a context for the study by illustrating the problems caused by a lack of or inadequate stormwater management systems in informal settlements.

Enkanini, Stellenbosch was used an illustrative example of the negative consequences of this lack. The chapter expanded on the need for using complexity theory to untangle the web of interconnections between urban water cycles, drainage solutions and social behaviour (Audouin et al., 2013) that contributed towards this 'wicked' problem. Chapter 2 presented a comprehensive literature review on the informal settlement context, sustainability and complexity theory and conventional drainage systems and alternatives with a particular focus on SuDS and the benefits it offers. It also outlined the legislative and regulatory framework into which stormwater management, and ultimately SuDS, should fall. Chapter 3 expanded on the research design and methodological approach with a detailed overview of the methods and Chapter 4 presented the data results and analysis. This chapter summarises the research results and provides recommendations for further research.

5.4 Research results

5.4.1 Research question 1: Is there room to incorporate SuDS in South Africa's UISP?

There is room for incorporating SuDS techniques into upgrading policy and programmes. SuDS 'speaks' to the need for sustainable service provision, the need to maximise use of water in South Africa, the need to optimise the benefits arising from basic service provision implementation and the need to ensure the safety of South Africans in their living environments.

The UISP allows for a deviation from conventional set norms and standards. SuDS therefore are allowable in terms of the programme. These systems also allow for multiple other benefits to be realised; this is particularly relevant in the informal settlement context characterised by a degraded environment due to increasing levels of shack sprawl.

SuDS is a cost-effective and sustainable solution that could be implemented at the municipal level and it could contribute to ameliorating some of the challenges this level of government faces in terms of its mandate to deliver basic services and improve the standard of living in informal settlements. However, municipalities face a range of challenges – they generally lack capital and capacity and because drainage systems are not prioritised, funding for drainage is often not considered apart from the initial development stages. These challenges can all be linked to greater institutional issues that need to be addressed. This presents a challenge to incorporating SuDS into the UISP as the entry point is at this institutional level to create a framework for discussion and implementation.

The stated concerns about implementing SuDS revolve around maintenance issues because if techniques are not set up properly and adhered to there is a possibility of natural water in ponds and wetlands becoming contaminated with toxic metals as they could leach from unlined systems into underground water sources or create polluted sediments and soils. The system does require a certain level of knowledge and capacity for regular inspections and activities, such as cutting grass and clogging checks. A poor understanding of SuDS or lack of capacity to implement and monitor these systems could lead to sub-optimal performance.

5.4.2 Research question 2: What potential do SuDS have to address drainage issues in informal settlements?

Drainage systems implemented in informal settlements need to offer something more than draining capacity; they need to add to the concept of *in situ* upgrading, which can be linked to best management practices in the arena of *in situ* upgrading. SuDS respond to this need. It also addresses the problems posed by the functional complexity (lack of space) and relational complexity (diversity of social actors) in the context of the informal settlement. In addition, it responds to the need for future drainage systems to be sustainable.

The issue of providing stormwater drainage in informal settlements in South Africa has not been prioritised in the UISP and the negative consequences of this will be felt increasingly over time. It is unlikely given municipal constraints and the lack of suitable space that conventional drainage systems will be implemented in informal settlements, despite the pressing need for such systems. Therefore SuDS provides a cost and space-effective solution that maximises water use as well as providing a host of other benefits. Informal settlements need to be brought to a certain level of service provision to address existing problems, such as issues around rubbish collection and sewer blockages.

Although *in situ* upgrading is premised on the adoption of best practice management – a sphere in which SuDS can be placed – there is scepticism around its implementation due to the complex-ridden environment of the informal settlement.

SuDS hold out the potential to reduce flooding risks and increase infiltration because it mimics natural drainage flows for stormwater. These types of systems also lend themselves to bolstering the aesthetic environment, having a positive impact on ecosystems and assisting in minimising environmental impacts from pollution, for example. The system can filter pollutants while restoring ground water and preventing overflow from sewers when storm and waste water combine. This reduces downstream flooding. In addition, SuDS techniques are capable of slowing down water velocity while enhancing biodiversity and restoring plant species.

In essence, SuDS are efficient. However, their efficiency is dependent on cost-effective implementation. Even if initial capital costs are high, overall operation and maintenance of these types of systems are lower. This is essential in the South African context, as informal settlement residences do not pay rates, which are conventionally used to pay for these systems.

5.4.3 Research question 3: What other services do SuDS link to and what benefits does it provide?

SuDS embrace the principles of inclusivity and social sustainability and this is exemplified through the stages of community participation, community engagement and community empowerment outlined in the UISP. All three of these stages are crucial to the success of any SuDS implementation in the informal context. These stages allow for co-generation and transfer of knowledge among key stakeholders and the affected community. They are also prerequisites for planning as data is not readily available on these communities and residents are the primary sources of information about local conditions.

Using SuDS techniques provides numerous environmental benefits including rehabilitation. This is crucial in the informal settlement context because shack sprawl results in decreased vegetation, which in turn has accelerated the volume and velocity of stormwater. Vegetation reduces this flow and simultaneously helps in detention.

One of the consequences of a centralised conventional system in which water travels long distances prior to entry into the watercourse has been increased pollutant levels. The SuDS ‘treatment train’ directs water through a series of cleaning methods before entering the watercourse. SuDS also actively contribute to the urban water cycle by replenishing fresh water sources and improving the quality of stormwater prior to it entering the watercourse. This has direct benefits for human health. SuDS also help restore diminishing ecosystem services as it used stormwater as a resource.

5.5 Limitations of the study

This study hoped to contribute to increasing awareness of SuDS techniques as one of the limitations to adoption and implementation is the lack of field evidence for these systems in the informal settlement context. At the onset of the study, an assumption was made that a substantial case study of this nature would be found. This was not the case and so the search began for literature focused on SuDS in the informal settlement context. This was scarce, however, beyond papers focused on planning for mitigation initiatives. This study therefore contributes to filling this gap.

5.6 Recommendations for further research

Given the dearth of information on this subject in the literature, there are several avenues of inquiry that need addressing. Some of these are:

- The implications of implementing SuDS in South Africa’s informal settlements, including the possible limitations of the system and challenges around implementation.
- The institutional implications of SuDS implementation, with a particular focus on costs.
- The lifecycle cost analysis of SuDS.

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Addenda

Appendix A: Sustainable urban drainage systems techniques table

	Description	Setting	Required area
Green roofs	A planted soil layer is constructed on the roof of a building to create a living surface. Water is stored in the soil layer and absorbed by vegetation.	Building	Building integrated.
Rainwater harvesting	Rainwater is collected from the roof of a building or from other paved surfaces and stored in an overground or underground tank for treatment and reuse locally. Water could be used for toilet flushing and irrigation.	Building	Water storage (underground or above ground).
Soakaway	A soakaway is designed to allow water to quickly soak into permeable layers of soil. Constructed like a dry well, an underground pit is dug filled with gravel or rubble. Water can be piped to a soakaway where it will be stored and allowed to gradually seep into the ground.	Open space	Dependant on runoff volumes and soils.
Filter Strip	Filter strips are grassed or planted areas that runoff is allowed to run across to promote infiltration and cleansing.	Open space	Minimum length 5 metres.
Permeable paving	Paving which allows water to soak through. Can be in the form of paving blocks with gaps between solid blocks or porous paving where water filters through the block itself. Water can be stored in the sub-base beneath or allowed to infiltrate into ground below.	Street/open space	Can typically drain double its area.
Bioretention area	A vegetated area with gravel and sand layers below designed to channel, filter and cleanse water vertically. Water can infiltrate into the ground below or drain to a perforated pipe and be conveyed elsewhere. Bioretention systems can be integrated with tree-pits or gardens.	Street/open space	Typically surface area is 5-10% of drained area with storage below.
Swale	Swales are vegetated shallow depressions designed to convey and filter water. These can be 'wet' where water gathers above the surface, or 'dry' where water gathers in a gravel layer beneath. Can be lined or unlined to allow infiltration.	Street/open space	Account for width to allow safe maintenancce typically 2-3 metres wide.
Hardscape storage	Hardscape water features can be used to store run-off above ground within a constructed container. Storage features can be integrated into public realm areas with a more urban character.	Open space	Could be above or below ground and sized to storage need.
Pond / Basin	Ponds can be used to store and treat water. 'Wet' ponds have a constant body of water and run-off is additional, while 'dry' ponds are empty during periods without rainfall. Ponds can be designed to allow infiltration into the ground or to store water for a period of time before discharge.	Open space	Dependant on runoff volumes and soils.
Wetland	Wetlands are shallow vegetated water bodies with a varying water level. Specially selected plant species are used to filter water. Water flows horizontally and is gradually treated before being discharged. Wetlands can be integrated with a natural or hardscape environment.	Open space	Typically 5-15% of drainage area to provide good treatment.
Underground storage	Water can be stored in tanks, gravel or plastic crates beneath the ground to provide attenuation.	Open space	Dependant on runoff volumes and soils.

Source: Lead Local Flood Authorities of the South East of England [LLFASEE], n.d. Water. People. Places. A guide for master planning sustainable drainage into developments. East Sussex: LLFASEE.

Appendix B: Sustainable urban drainage system selection matrix for site conditions

SUDS SELECTION MATRIX FOR SITE CONDITIONS

(empty)	unsuitable
●	suitable

		Green Roof	Rainwater Harvesting	Soakaway	Permeable Paving	Filter Strip	Bioretention Area	Swale	Hardscape Storage	Pond	Wetland	Underground Storage
Flood Plain	Located in the floodplain?	●	●	●	●	●	●	●				
Groundwater	Groundwater less than 3 metres below ground surface?	●	●		● With liner and underdrain (no treatment)	●	● With liner and underdrain	● With liner	● If aboveground	● With liner	●	
Topography	Sited on a flat site (<5% gradient)?	● Source control	● Source control	● Source control	● Source control	● Source control	● With short kerb or rill length	● Careful to provide some gradient	●	● Try to keep flow above ground to	● Try to keep flow above ground to	●
	Sited on a steep slope (5-15% gradient)?	●	●		● If terraced		● If terraced	● If installed along contour	● If terraced		● If terraced	●
	Sited on a very steep slope (>15% gradient)?	●	●									●
Soils and Geology	Impermeable soil type (e.g. clay-based type)?	●	●		● With underdrain (no treatment)	●	●	●	●	●	●	●
Contaminated land	Are there contaminated soils on site?	●	●		● With underdrain (no treatment)	● With liner	● With liner and underdrain	● With liner	● With liner	● With liner	● With liner	● With liner
Existing Infrastructure	Are there underground utilities in the SuDS area?	●	●		● If possible relocated into a marked corridor for future maintenance	●	● Possible with structural grid in soil					●
Space constraints	Limited space for SuDS components?	●	●	●	●		●	Rill or channel more suitable	●		● Micro-wetland	●
Runoff characteristics	Suitable for inclusion in high risk contamination areas?	● Source control	● Source control		● With liner and spill isolation		● With liner and spill isolation	● With liner and spill isolation	● With liner and spill isolation		● If designed for treatment of predicted wastes	● With liner and spill isolation
Protected species or habitat	Proximity to designated sites and priority habitats?	●	●	●	●	●	●	●	●	● If designed and maintained appropriately	● If designed and maintained appropriately	●
Ownership and Maintenance	Can the feature be designed for adoption?	● Dependant on design and local adoption policies										

Source: Lead Local Flood Authorities of the South East of England [LLFASEE], n.d. Water. People. Places. A guide for master planning sustainable drainage into developments. East Sussex: LLFASEE.

Appendix C: UISP assistance criteria

The Programme will benefit households and individuals residing in informal settlements and the following individuals will qualify for assistance under this Programme:

Households that comply with the Housing Subsidy Scheme qualification criteria
Households/persons with a monthly income exceeding the maximum income limit as approved by the Minister from time to time
Households headed by minors, who are not competent to contract in collaboration with the Department of Social Development
Persons without dependants
Persons who are not first-time home owners
Persons who have previously received housing assistance and who previously owned and/or currently own a residential property. Assistance may be considered on condition that access to the benefits of the programme will be considered on a case by case basis to determine the facts and the approval of access in accordance with the provisions of the Implementation Guidelines of the programme; and
Illegal immigrants on the conditions prescribed by the Department of Home Affairs on a case by case basis.
Persons classified as aged: Aged persons who are single without financial dependants may also apply for subsidisation. Aged persons can be classified as male and female persons who have attained the minimum age set to qualify for Government's old age social grant

Searches against property registers, the Population Register of the Department of Home Affairs and the National Housing Subsidy Data Base will be required for beneficiaries to gain access to the programme.

Source: UISP (2009:16–17)