STORMWATER INGRESS IN SOUTH AFRICAN SEWER SYSTEMS: UNDERSTANDING THE PROBLEM AND DEALING WITH IT

with particular reference to the Msunduzi Municipality, KwaZulu-Natal

Report to the
Water Research Commission

by

Su Erskine, Andrew Booth and David Still
on behalf of
The Duzi-uMngeni Conservation Trust

WRC Report No. 1731/1/11
ISBN 978-1-4312-0119-8

May 2011

Executive Summary

During a moderate to heavy rainfall event, it is not unusual for the sewer infrastructure in cities to become completely overloaded. The excessive flow within the sewer pipes results in surcharging sewer manholes which subsequently overflow, pump stations that cannot manage the extra flow and ultimately the overburdening of the Waste Water Treatment Works (WWTW). When this occurs, untreated sewage finds its way onto streets, into stormwater drains and into streams and rivers.

The primary reason for the overloading of sewerage infrastructure during rainfall events is the large quantity of stormwater that finds its way into the sewer reticulation network. This ingress of stormwater into the waste water collection system is termed infiltration/inflow (I/I for short). The need to reduce the quantity of I/I in South African sewer systems is increasingly being recognised as a priority for a number of reasons, including:

- It is unhealthy for both the environment and humans to be exposed to repeated overflows of untreated sewage.
- Holding untreated sewage in stormwater retention dams creates other human and environmental health risks.
- There are cost related implications (the more effluent a works receives, the higher the treatment costs; also bulk sewer lines have to be upsized, which is highly capital intensive).
- Capital expansion programmes may need to be considered at waste water treatment works if they are to be able to deal effectively with storm surges as the works needs capacity to absorb peak flow and not average flows if spillages are to be completely avoided.
- It is illegal in terms of the National Water Act for a municipality or Wastewater Treatment Works to discharge untreated or partially treated sewage into receiving waters.

Infiltration is subsurface flow, or groundwater that seeps into sewers through holes, breaks, joint failures, defective connections and other openings. Infiltration occurs throughout the year, but volumes are greatest following wet periods

Inflow is stormwater that rapidly flows into sewers via roof and foundation drains, downspouts and manhole covers

Earth Teach Team, 2004

This study looks at the different sources of rain water in the sewage system, and shows that the amount of rain water entering the sewer line because of illegal direct connections (mainly through the diversion of roof guttering directly into the sewer) can easily become a significant contributor to the problem. It goes on to discuss what our legislation says about the problem, and compares contrasting approaches to giving effect the legislation. It then reviews how the matter of stormwater ingress is being dealt with in different parts of the world. Finally a community based inspection programme is tried and evaluated, and a public education programme is discussed.

While the international literature and South Africa's local experience suggests that stormwater ingress in sewers is a problem to a greater or lesser degree (usually greater) in all sewered areas, this study has focused more particularly on the situation in the Msunduzi Municipality, KwaZulu-Natal.

Pietermaritzburg, Buffalo City, Cape Town and East Rand Water Municipalities all report peak inflows during the rainy season that exceed the average dry weather flows by as much as 300 to 400 percent. Pietermaritzburg's council ceased to monitor stormwater ingress in 1992 and overloading of the sewer system causes significant pollution of the uMsunduzi River. This is one of the most significant environmental problems the city has. New residential and industrial areas in the Eastern Cape have resulted in a significant escalation of stormwater ingress into the municipal sewers. The allowance built into these sewers' design for inflow and infiltration is quite inadequate with instantaneous ingress pointing to gutter connections or direct inflow through manhole covers as the source.

National legislation regulates the quality of effluent that may be discharged by a WWTW into receiving waters and encourages local municipalities to formulate bylaws to protect their WWTWs. The legislation also provides default regulations for the drainage of properties. Most municipalities have bylaws prohibiting the routing of stormwater into drainage installations as well as to protect drainage installations from the ingress of floodwater. These bylaws typically follow DWA's model Water Services bylaws.

In order to reduce direct inflows, inspection and enforcement is required, and for this to happen effectively political will and a workable enforcement system is needed. In this study it is found that there is unanimity in the prohibition of stormwater to sewer connections in the municipal by-laws and the building regulations in South Africa. However, it was also found that the prosecution of offenders using a formal rights based legal approach is enormously difficult, expensive and time-consuming. For this reason the Msunduzi Municipality, which has a particularly bad stormwater ingress problem, effectively gave up policing this by-law more than ten years ago. A more practical alternative seems to be that previously used by the City of Cape Town, which charged a fee for allowing property owners to connect their stormwater to the sewer. In 2007/2008 this fee was R2.84 per square metre drained into the sewer network for private property, and R7.94 per square metre for commercial property. This fee gave the property owner the incentive to stop using the municipal sewer network to drain away stormwater, and to come up with a more environmentally appropriate solution. The property owner was also incentivised to make the changes without delay, and to not drag the municipality through a lengthy formal process to force them to make the change.

Builders and plumbers who are found to have installed illegal stormwater connections should also be sanctioned. This could involve the payment of fines, or blacklisting.

A reason sometimes used for the lack of enforcement of stormwater by-laws is that municipalities lack sufficient building inspectors. However, a person does not have to be a fully trained building inspector to be able to detect an illegal stormwater connection. In the course of field work carried out for this project it was shown that community-based stormwater inspectors could be relatively easily recruited and trained, and their work, given the short time frame, was very useful. This has proven the cost-effectiveness and value of inspectors with a limited scope of work, in this case specifically that of direct stormwater to sewer connections.

A sewer storm flow monitoring exercise carried out during the course of this study showed that peak flows after heavy rainfall were up to five times normal sewer flow, that the time taken for the sewer flow to go from normal to the storm peak was a matter of minutes, and that the peak flows could be more than accounted for by the incidence of direct connections in the surveyed area. Sewer flow then remained elevated for several days after the rainfall, indicating that groundwater continued to contribute to the flow long after the rain had ceased.

The stormwater ingress problem is therefore due to a combination of both illegal direct stormwater to sewer connections and infiltration through breaks in an ageing sewer network. The nature and characteristics of the flow records indicates that the problem may be fairly evenly divided between inflow and infiltration. In order to reduce infiltration and inflow, flow monitoring and CCTV work is required to determine which sections of the network are most in need of repair and rehabilitation, and thereafter that work must be carried out.

Stormwater ingress can be reduced by upgrading the infrastructure and by reducing the water load at source. Measures to upgrade the infrastructure can range from the less expensive such as replacing missing manhole covers to more expensive such as replacing defective sewers. Upgrading the capacity of the waste water treatment works is the most expensive solution. The cost of the elimination of direct connections at source should be borne by property owners and is therefore the cheapest intervention measure.

It is recommended that any municipality with a serious stormwater ingress problem should set up a dedicated inspection team of purpose trained contract stormwater inspectors. These contract inspectors would work under one fully qualified inspector, who would have the necessary authority to act on any direct connections that are found. Allocating work to inspectors away from their home neighbourhoods may address the risk of bias. In order to gain access to properties this work will mostly have to be done outside of normal working hours and therefore it would be cost effective to outsource the work to NGOs, CBOs or private companies.

Public awareness and community education campaigns can serve to reduce the stormwater load at source and provide an alternative to upgrading infrastructure which is capital intensive and time consuming. Information on stormwater ingress was included in a pamphlet and distributed to a sample of residents for this report, and this was found to increase awareness of stormwater ingress by up to 20% in the targeted areas relative to nearby areas which were not targeted. This was significant given the limited duration and scope of the intervention. For an awareness and education campaign to be really effective, however, it would need to be part of a co-ordinated city wide campaign followed up by extensive inspections and backed up by the political will to deal with transgressors. Education programmes should be focused on a particular community and should involve a visit from a municipal officer who provides instruction on how to rectify direct connections and information on alternative, environmentally friendly stormwater drainage solutions.

Acknowledgements

The team wishes to thank the Water Research commission for the funding of this project and the members of the Reference Group for their valuable contributions.

The Reference Group for the project:

Mr J Harrison	eThekwini Municipality
Mr Abdulla Parker	City of Cape Town
Mr B Sivparsad	Msunduzi Municipality
Mr Pat Reddy	DWA – KZN Regional
Mr Lin Gravelet-Blondin	Water Lily Consulting (ex DWA KZN Regional)
Mr J Pansegrouw	City of Tshwane
Mr D Simpson	ex Umgeni Water
Mr J Pienaar	Aurecon (Africon)
Mr P Gaydon	SSI
Mr M Braune	SRK

Working Smarter: The eThekwini Metropolitan Municipality has been using “smoke detectors” to find illegal stormwater to sewer connections. These devices fit over a sewer manhole and force smoke into the sewer lines. As the smoke builds up in the sewer, it finds its way out of any openings to atmosphere in the sewer system within a radius of a hundred metres or more. This system can be particularly useful for finding openings in the system which might be invisible to the eye. See the addendum to this report for more details.

Table of Contents

List of Tables

List of Figures

Glossary of Terms

Combined Sewer System CSS	Sewer systems designed to convey both sanitary sewage and stormwater in a single pipe are known as combined sewer systems (CSSs) (EPA, 1999). The initial rationale for developing combined sewers was economics; it was cheaper to build a single system (in temperate climates with low intensity rainfall). The system was designed to handle certain size storms and if this capacity was exceeded the excess flow of water would exit the sewer system into the natural drainage system or a relief sewer.
Dry Weather Flow	Refers to the flow of waste water that occurs when there is no rainfall for at least 48 hours.
Infiltration (to sewer)	The inflow of groundwater into a drain or sewer system through defects in pipes, joints or manholes.
Inflow	Stormwater runoff that enters a sewer through direct connections (e.g. rainwater downpipe connections).
Inflow/Infiltration (I/I)	The technical term used to describe the flow of all extraneous water into wastewater collection systems.
Ingress	The common term for inflow/infiltration (see above).
Manhole	A chamber with a removable cover constructed over a drain or sewer to permit entry by personnel.
Receiving waters	Watercourse, river, estuary or coastal water into which the outfall from stormwater drains and wastewater treatment works discharges.
Separate sewer system	In separate systems, wastewater and stormwater do not mix. Stormwater is discharged directly into a river ecosystem at suitable locations.
Stormwater	Water flow resulting from natural precipitation or accumulation and includes rainwater, subsoil water or spring water.
Sewer	Pipeline or other conduit, normally underground, designed to convey wastewater, stormwater or other unwanted liquids.
Sewerage system	System of sewers and ancillary works that conveys wastewater to a treatment works or other disposal point.
Stormwater	Water flow resulting from natural precipitation or accumulation and includes rainwater, subsoil water or spring water.
Surcharge	Wastewater and/or surplus water is held under pressure within a gravity drain or sewer system.
Wastewater	Water discharged as a result of cleansing, culinary or industrial processes to a drain or sewer system.
Water Service Authorities	The local or district municipality that has been mandated to ensure the provision of water to residents.
Water Service Providers	The organisation that has been contracted to by the Water Service Authority to supply water.
Waste Water Treatment Works	A plant designed and built to treat waste water emanating from households and transported via the sewer network to the works.
Wet weather event	Rainfall or another form of precipitation (snow, sleet, etc.).

List of Abbreviations

ADWF	Average dry weather flow (ℓ/s)
CSS	Combined Sewer System
DWF	Dry weather flow
EPA	Environmental Protection Agency
I/I	Inflow and Infiltration
NORIS	No rainwater in sewers
PDWF	Peak dry weather flow (ℓ/s)
POTW	Publicly Owned Treatment Works
PWWF	Peak wet weather flow (ℓ/s)
SSS	Separate Sewer Systems
WRC	Water Research Commission
WSA	Water Service Authority
WSP	Water Service Provider
WWTP	Waste Water Treatment Plant
WWTW	Waste Water Treatment Works

Chapter 1

Stormwater in sewers – the problem

1.1 Introduction

During a moderate to heavy rainfall event, it is not unusual for the sewer infrastructure in cities to become completely overloaded. The excessive flow within the sewer pipes results in surcharging sewer manholes which subsequently overflow (Figure 1), pump stations that cannot manage the extra flow and ultimately the overburdening of the Waste Water Treatment Works (WWTW) (Figure 2). When this occurs, untreated sewage finds its way onto streets, into stormwater drains and into streams and rivers.

Figure 1: Wastewater overflowing (not held under pressure)

Figure 2: Darvill Waste Water Treatment Works overflowing during a storm in Pietermaritzburg
(Steve Terry, 2007)

The primary reason for the overloading of sewerage infrastructure during rainfall events is the large quantity of stormwater that finds its way into the sewer reticulation network. This extraneous flow of water into the waste water collection system is termed infiltration/inflow (I/I for short). The need to reduce the quantity of I/I in South African sewer systems is increasingly being recognised as a priority for a number of reasons, including:

- It is unhealthy for both the environment and humans to be exposed to repeated overflows of untreated sewage.
- Holding untreated sewage in stormwater retention dams at a WWTW creates other human and environmental health risks.
- There are cost related implications (the more effluent a WWTW receives, the higher the treatment costs).
- Capital expansion programmes may need to be considered at WWTWs if they are to be able to deal effectively with storm surges as the WWTW needs capacity to absorb peak flow and not average flows if spillages are to be completely avoided.
- It is illegal in terms of the National Water Act for a municipality or WWTW to discharge untreated or partially treated sewage into receiving waters.

> **Infiltration** is subsurface flow, or groundwater that seeps into sewers through holes, breaks, joint failures, defective connections and other openings. Infiltration occurs throughout the year, but volumes are greatest following wet periods
>
> **Inflow** is stormwater that rapidly flows into sewers via roof and foundation drains, downspouts and manhole covers
>
> *Earth Teach Team, 2004*

This study looks at the different sources of rain water in the sewage system, and shows that the amount of rain water entering the sewer line because of illegal direct connections (mainly through the diversion of roof guttering directly into the sewer) can easily become a significant contributor to the problem. It goes on to discuss what our legislation says about the problem, and compares contrasting approaches to giving effect the legislation. It then reviews how the matter of stormwater ingress is being dealt with in different parts of the world. Finally a community based inspection programme is tried and evaluated, and a public education programme is discussed.

1.2 A review of current literature

1.2.1 Research for the Water Research Commission

In the last six years the Water Research Commission (WRC) has published the following three reports which are relevant to the topic of stormwater ingress:

- **Guidelines on reduction of the impact of water infiltration into sewers** by D. Stephenson and B. Barta (February 2005)
- **A First Order National Audit of Sewerage Reticulation Issues: Report A – Literature Review** by B.W de Swardt and B. Barta (March 2007)
- **Strategic guidance towards prioritising stormwater management research in human settlements** by J. Burke and X. Mayer (March 2007)

The literature review undertaken by De Swardt and Barta (2007) summarises four international studies undertaken between 1985 and 2002. A study by C.J Pratt (1985) explores different techniques being used to reduce stormwater runoff volumes and peak discharges. S. Vatagodakumbura did research in the late 1980s to reduce the incidence of sewer backlogs due to I/I in the City of Edmonton, Canada. This study is of interest as it reviews the implementation of a plan that involves community participation in plot related improvements.

Stephenson and Barta (2005) found that there was very little understanding or awareness of I/I. Subsequently most Water Service Authorities (WSA) and Water Service Providers (WSP) implement reactive maintenance and are unable to control I/I through the implementation of remedial techniques. Their report included guidelines for reducing the impact of water infiltration into sewers.

De Swardt and Barta (2007) conclude that while there are many studies on the ecological impacts of sewer overflows and spillages caused by excessive infiltration and inflow, the team identified the need for further research into practical methods for reducing infiltration and inflow in urban areas, incorporating technical, social, environmental and legal considerations (de Swardt and Barta, 2007).

In 2007 the WRC published Burke and Mayer's report in response to the need for stormwater control and management to be better understood.

The WRC is presently finalising publication of two further relevant reports:

- Guidelines on waterborne sanitation (including the SEWER AID software and guidelines on operation and maintenance of waterborne sanitation)

- Guidelines for determination of vulnerability and risks of water services infrastructure (covering all aspects of infrastructure asset management)

1.2.2 International literature

The international literature on this topic focuses mainly on the challenges faced with converting Combined Sewer Systems (CSS) to separate sewer systems. Combined Sewer Systems are designed to carry both wastewater and rainwater in a single pipe to the WWTW. These were typically built many years ago when the protection of the environment was not uppermost in design and planning considerations, and were more common in cities built on larger waterways than are typically found in South Africa. With environmental standards rising in the world's wealthier countries, there is a move to discontinue the practice of deliberately combining sewage and stormwater flows.

1.3 Understanding stormwater ingress

Stormwater infiltration or ingress refers to those instances where stormwater enters the sewer system. It is primarily a problem for separate sewer systems, i.e. systems that are designed to segregate sewage from stormwater. The sewer lines and WWTW are simply not built large enough to transport or process the swollen flows generated during rainfall, and the excess sewage then spills into the waterways.

Typically rainwater enters the separate sewer system in two ways:

- Direct connections (both legal and illegal) that channel rainwater into the sewer line.
- Infiltration of water from the soil into sewer or other pipes through defective joints, connections, or manhole covers and walls.[1]

Stormwater ingress is a seasonal problem, relating exclusively to rainfall patterns in the catchment area of the WWTW.

Both combined and separate sewer systems are designed with capacity to accommodate flow additional to the peak dry weather flow (PDWF). There are a number of reasons why most cities seem to have outgrown the sewage systems' capacity. Some of the reasons given in the literature and by managers at WWTWs around South Africa include:

- Rapid urbanisation
- Urban infill (densification)
- Increasing land under hard, impervious surfaces, some of which drain (illegally) into the sewers
- Changes on domestic properties including increased paving and home additions (commonly garden cottages), reducing the available area for absorption of stormflows and making the illegal connection of stormwater to sewers more common
- Higher runoff (due to increased paving and roof surface) makes it more difficult to drain stormwater in neighbouring properties
- Increased water usage and corresponding increase in wastewater returned to the system
- Ageing infrastructure resulting in an increase in infiltration from the ground
- Missing manhole covers or covers below the floodline
- An increasing number of illegal direct connections.

1.3.1 Direct connections

Direct connections are most commonly a connection from the roof guttering system into the sewer line. Water draining off hard surfaces (paved areas and driveways) is sometimes also connected directly into the sewer and contributes to the excessive flow of wastewater during wet weather events.

[1] There is anecdotal evidence that older sewers, which are made of baked clay and which have closely spaced joints, are far more prone to ingress than the newer PVC sewer pipes, which have more closely fitting joints at six metre intervals.

The contribution that stormwater makes to the effluent within the sewer lines is significant. One millimeter of rain on one square meter of any hard, impervious surface yields one litre of runoff. Twenty millimetres of rain on 100 m^2 of roof will yield 2 000 litres of runoff, three times more than the expected daily waste water flow from a 100 m^2 house.

1.3.1.1 Combined sewer systems

The older cities in Europe and the United States are served with combined sewer systems (CSSs). The initial rationale for developing combined sewers was to save cost as it was cheaper to build a single drainage system than two separate systems (in temperate climates with low intensity rainfall). The CSS were designed to carry both sewage and rainwater in a single pipe to the WWTW (EPA, 1999). Buildings were accordingly plumbed to ensure that rainwater was directed from the roof guttering system into the sewer line. The system was designed to handle certain size storms and if this capacity was exceeded the excess flow of water would exit the sewer system into a relief sewer. The relief sewer discharged directly into a natural water body (often referred to as receiving waters), as shown in Figure 3 below. This was done to prevent the contents of the sewers from backing-up into basements or surcharging out of manholes onto streets.

This system is more appropriate in temperate climates where rainfall tends to be gentle, rather than in tropical and subtropical climates (such as South Africa's) which experience high intensity rainfall.

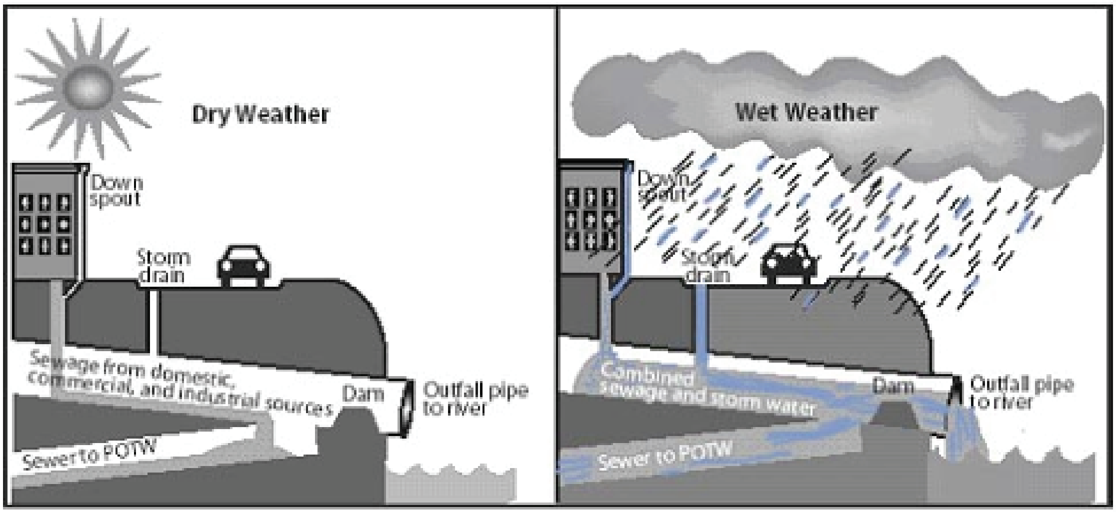


Figure 3: Illustration of combined sewer system (Source: Kentucky Government)

Increasingly combined sewers are unable to cope with the hydraulic loading and therefore the incidence of untreated effluent being spilled directly into the environment is growing, with serious ecological implications and public health risks (EPA, 1999). In addition the economic burden of treating additional effluent means that CSSs are increasingly being replaced by separate lines for sanitary waste and stormwater[2] (Figure 4).

[2] The practise illustrated in Figure 4 above, where stormwater is channelled directly into receiving waters, is regarded as poor stormwater management because of the high flow rate and poor quality of the stormwater.

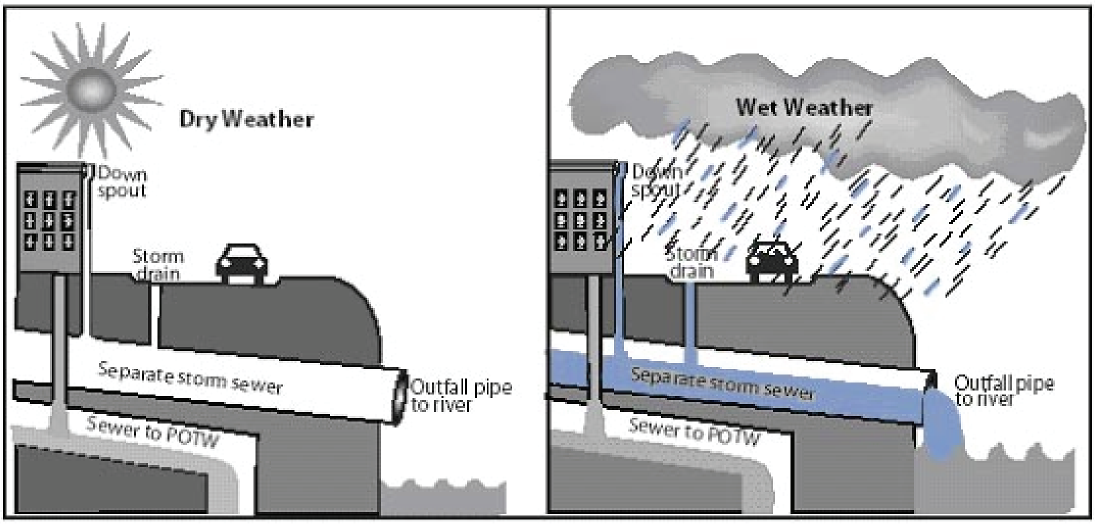


Figure 4: Illustration of separated sewer system (Source: Kentucky Government)

The modifying of CSSs to separate sewage from rainwater is in part being accomplished through the implementation of “Downspout Disconnection Programmes”. Preventing stormwater entering the sewer system via direct connections from guttering is a relatively affordable modification. The alternative, requiring the underground separation of sewer lines into sewer and stormwater pipes, entails extensive construction and is therefore very expensive.

1.3.1.2 Illegal direct gutter connections

Chapter Three of this report deals with the legislation that prohibits the direct connection of gutters to the sewer network in South African cities. Rainwater falling onto a hard surface (i.e. a roof or a paved area) should be either directed into the garden (where it is absorbed into the ground[3]) or onto the street from where it can be channelled into the stormwater system. Rainwater should never be diverted into the sewer system as shown in Figure 5 below, unless it is seriously contaminated.

[3] Directing rainwater runoff onto pervious surfaces, which allow it to be absorbed by the ground, is almost always the best way to deal with excess water.

Figure 5: Roof gutters directed into sewer lines (Source: Pienaar, 2007)

Gutter connections from roof tops contribute significantly to stormwater ingress during rainfall events. Table 1 and Table 2 below show just how significant the proportion of rainwater in the wastewater can be.

Table 1: Yields of rainwater from roof surfaces

House size / **Rainfall event**†	**Small size house (40 m² roof)**	**Medium size house (150 m² roof)**	**Large size house (300 m² roof)**
Low intensity rain event (10 mm/hr)	400 litres/hour	1 500 litres/hour	3 000 litres/hour
Medium intensity (average summer storm) (20 mm/hr)	800 litres/hour	3 000 litres/hour	6 000 litres/hour
High intensity (rare summer storm) (50 mm/hr)	2000 litres/hour	7 500 litres/hour	15 000 litres/hour

(† Source: Stephenson and Barta, 2005)

Table 2: Percentage increase in waste water generated by a house with downpipe connections after a 20 mm rain storm

	Dry weather flow† (ADF ℓ/day/single family dwelling)	**Wet weather volume (litres resulting from 20 mm of rain)**	**% increase in sewage volume due to ingress**
Small house (40 m² roof)	500	800	60
Medium house (150 m² roof)	750	3 000	300
Large house (300 m² roof)	1 000	6 000	500

Direct gutter connections, included in the term “civil disobedience” by Stephenson and Barta (2005) will be more common where there is inadequate inspecting by the authorities. Poor education or intervention by the authorities means that many households are not even aware that linking gutters or swimming pool backwash water into the sewer line is illegal.

1.3.1.3 Manhole covers

Stormwater ingress via manhole covers occurs either because the cover is missing or because the manhole lies below the floodline.

As with the roof gutters connected directly to the sewer line, ingress from a missing sewer manhole cover causes an almost instantaneous increase in flow rates in sewers. A 100 m^2 paved area around a missing or broken manhole cover would result in 5 m^3 of stormwater inflow during a one day rain event of 50 mm.

In areas where water ponds around a manhole a delayed form of ingress may occur as water slowly seeps through the manhole cover or the manhole joints. This is why manhole covers should be designed to sit above the floodline. However in many urban areas flood levels have risen because of increased stormwater run off and a concurrent reduction in the area of open flood plains, with the result that some previously dry manholes are now inundated during heavy storms (Figure 6).

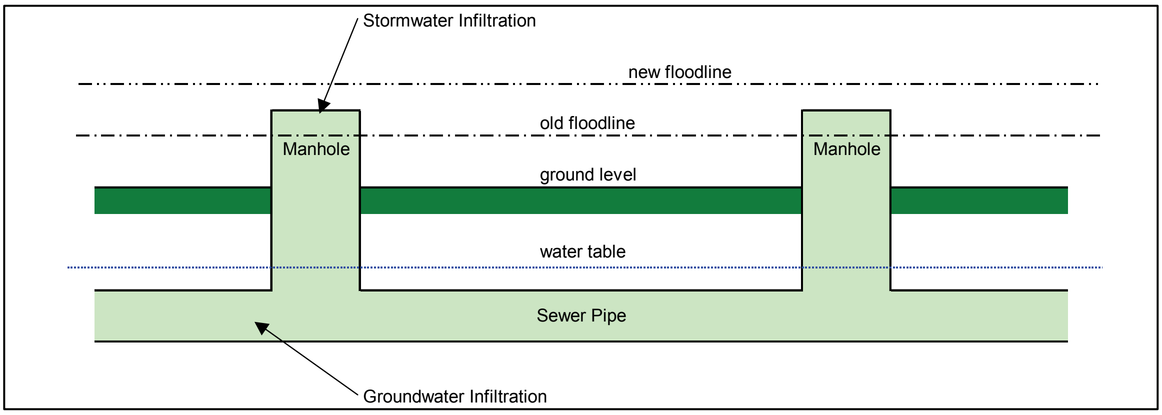


Figure 6: Infiltration of storm-water into manholes (Source: Naude)

1.3.1.4 Stormwater infiltration into sewer pipes and connections

Practically all sewer pipes are laid underground. Except for some pumped sections, they are not pressurised but function as gravity drains. Any break or open joint in the sewer will allow ground water to seep into the pipe. As sewer networks age, particularly if the pipes are brittle, they may crack due to uneven settlement, or due to root damage. Therefore with time, a sewer system can begin to function like a subsoil drainage system. The only way to detect where the problem sections of the network are is to carry out extensive flow monitoring and remote control camera inspection, both of which are expensive operations. Once problem sections of sewer are located, they have to be either relined (if they are large enough to permit this) or replaced.

Chapter 2

Examples of Stormwater Ingress in South African cities

2.1 Determining the source of Inflow and/or Infiltration

As discussed in Chapter One, stormwater ingress can originate from direct connections from gutters or paving, leaking or misaligned sewer lines, missing manhole covers or manhole covers that are too low. Each source will have a different impact on the flow received by the WWTW (Table 3 below).

Table 3: Flow response to rainfall depending on source of infiltration

Response type	Flow characteristics in response to rainfall	Suggested sources
Fast inflow	Sudden increase in flow	**Inflow:** catch basins, roof drains or other direct connections **Infiltration:** sources that respond rapidly to rainfall, such as shallow side sewers
Rapid infiltration	Increase in flow during and/or shortly after rainfall event, with a gradual reduction in flow over a relatively short period after the event	**Infiltration:** shallow sources such as laterals, side sewers, foundation drains; and manholes and mains to a lesser extent
Slow infiltration	Slow increase in flow hours or days after a storm; increased flow may take several days or weeks after a storm to decline	**Infiltration:** deep sources such as manholes and mains; reflects a rising groundwater level

(Source: Naude, no date)

2.1.1. Instantaneous increase of flow

If the flow at a WWTW increases almost simultaneously with rainfall, it suggests that the source of I/I is a direct input of stormwater into the system. While missing manhole covers may contribute to the peak in wet weather flows, it is likely to be small in comparison to direct gutter connections.

2.1.2 Slower, prolonged increase of flow

A less dramatic increase in sewage being received at the WWTW and one in which the heightened flow is prolonged, points to seepage through the sewer lines. This is because the rain takes time to penetrate the ground, filtrate downwards and into the sewer line.

2.1.3 Instantaneous and prolonged increase of flow

If the flow at the works responds rapidly to rainfall, but remains elevated for days after the rain has stopped, then the cause is a combination of inflow and infiltration.

2.2 Stormwater ingress observations from South African cities

The problem of stormwater ingress in sewer systems is widespread and common. Observations of stormwater ingress from Pietermaritzburg, East London, the East Rand and Cape Town are described in this section.

2.2.1 Pietermaritzburg

Pietermaritzburg has a long standing problem with stormwater ingress, with peak inflows at the Darvill sewage works during summer storms regularly exceeding the average dry weather flow by as much as 300 to 400% (Gaydon, 2008)

Figure 7: Darvill WWTW overflowing to the storm dam during a routine wet weather event

The Pietermaritzburg Council used to monitor stormwater ingress into its sewer system at a number of sites in the late 1980s and early 1990s, but this work was discontinued in 1992. In 2011 it is expected that a major new monitoring programme will commence. Figures 8 and 9 below show extracts from the data for one of the monitoring stations.[4] In both cases the data indicates storm related peaks. In the case of the storm which occurred on 20 October 1991 (Figure 8) either the rain continued at a reducing intensity for several days, or the effect of the initial storm was spread out due to groundwater infiltration. In the case of the storm which occurred on 14 November 1991 (Figure 9) the increase in flow depth is limited to approximately six hours.

[4] Note that this data shows sewage depth and not sewage flow. Flow in a circular pipe is a function of depth, increasing exponentially as the sewer fills from empty to a point above half full, whereafter the rate of flow increase with depth reduces. It is not likely that the 0 depth datum in this record is in fact the sewer invert.

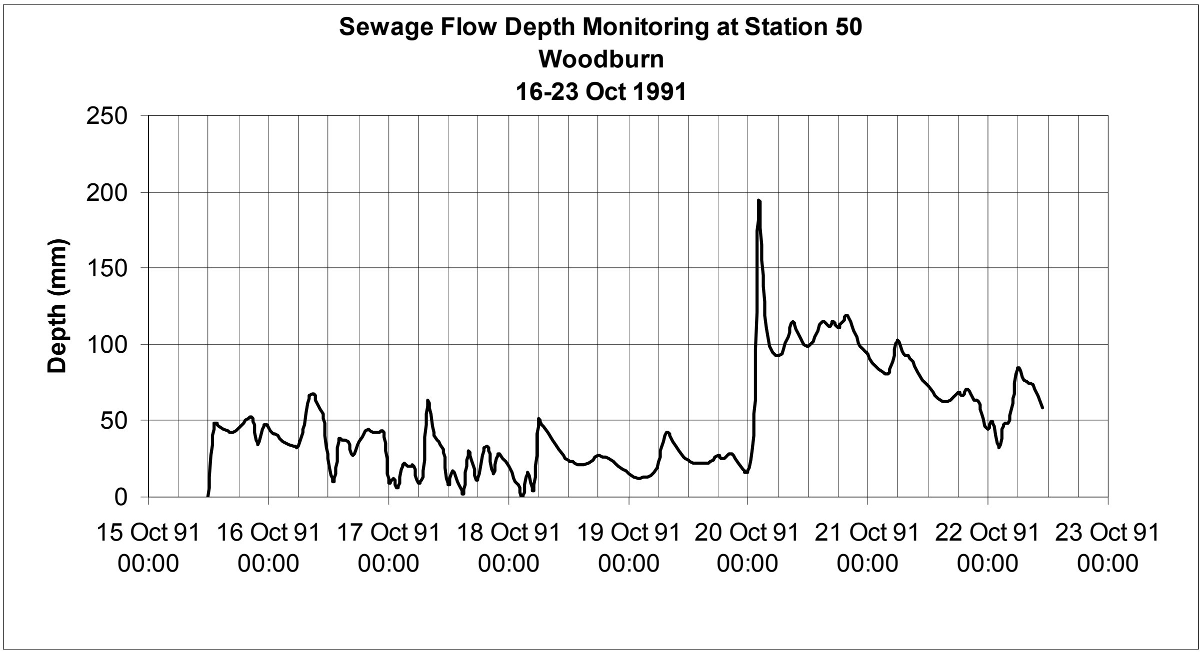


Figure 8: Sewage flow depth response to rainfall commencing on 20 October 1991

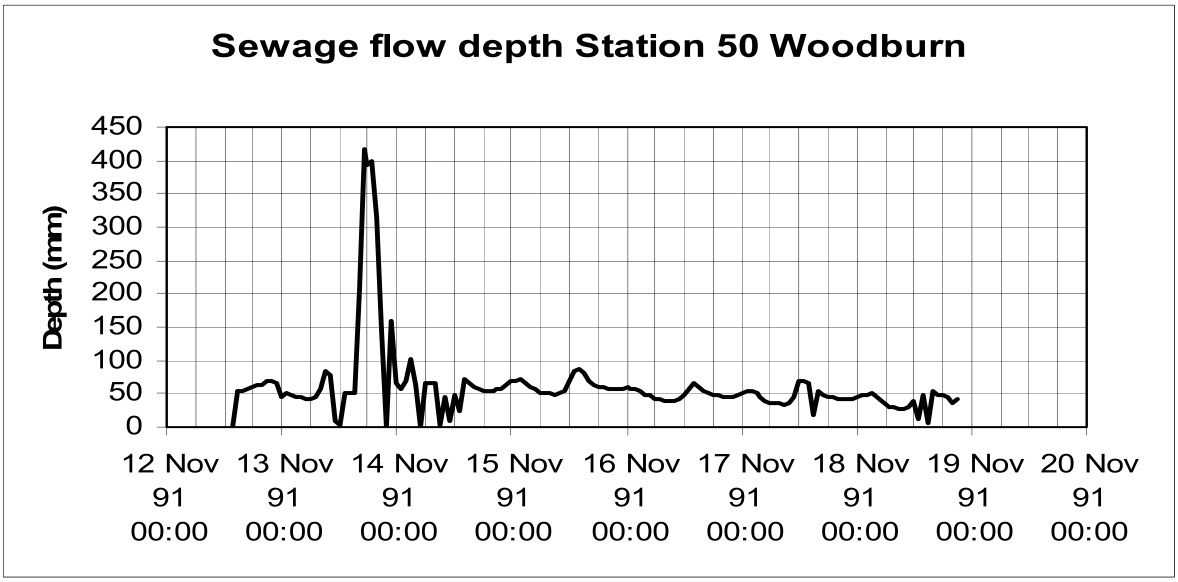


Figure 9: Sewage flow depth response to storm on 14 November 1991

Figure 10 below shows the record of inflow at the Darvill sewage works in Pietermaritzburg over the period November 2005 to June 2007, and also shows the rainfall recorded over the same period (the lower line) in mm per day. Note that the inflows are those that were processed by the works, and do not include excess stormflow diverted to the storm dam (and in very high flows excess flow goes over the storm dam direct to the river). When flow has been pumped out of the storm dam in the wake of high flows, that is recorded as inflow on the days on which it is pumped. Another complication is that sometimes some of the normal flow has been diverted to the storm dam to enable essential maintenance to take place (this explains the occasional unusually low readings). For all these reasons the comparison between sewage flow and rainfall is complex, but even with the uncertainties one can see a direct correlation between the higher rainfall events and the more significant sewage flow spikes.

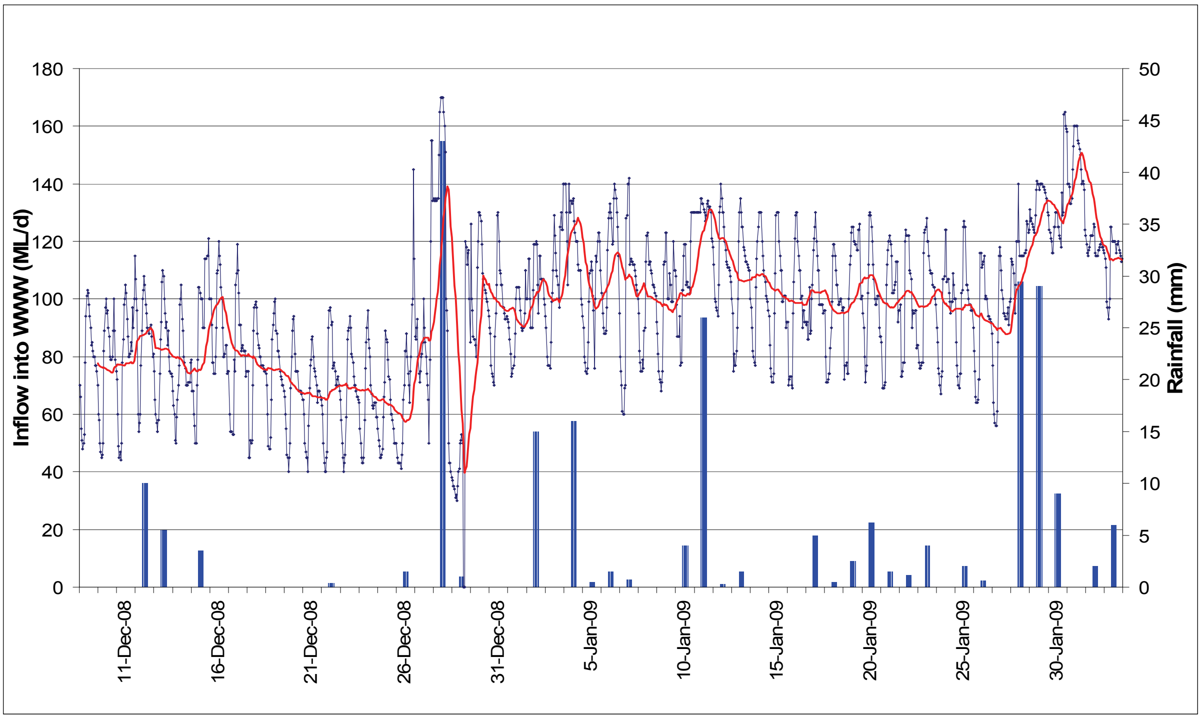


Figure 10: Sewage processed at the Darvill sewage works (excluding inflow peaks diverted to the storm dam) over the period 8th December 2008 to 2nd February 2009 with rainfall for the same period

The overloading of the sewer system does cause significant pollution of the uMsunduzi River, which is one of the most significant environmental problems the city has to deal with. Apart from the need to protect the natural environment from pollution, rowing and canoeing are significant aspects of the city's recreational and tourist activity, and the continuation of these activities is threatened by poor water quality. Figure 11 below shows the results of weekly water quality tests carried out by Umgeni Water at Campsdrift, the 2.5 km stretch of water behind the Ernie Pearce Weir, which is the focus of rowing and canoeing training in the city. The international standard for secondary contact water sports (i.e. not swimming) such as canoeing is 2000 E-coli per 100 ml. Figure 12, which shows the same data as Figure 11 on a different scale, shows that this standard is frequently exceeded. To put this data in perspective, it must be mentioned that Campsdrift, due to the attenuating affect of the large volume (approx 150 000 m^3 above the sampling point) of the impoundment on E-coli levels, is in fact on average the sampling point with the lowest E-coli levels amongst the 17 that are routinely monitored by Umgeni Water.

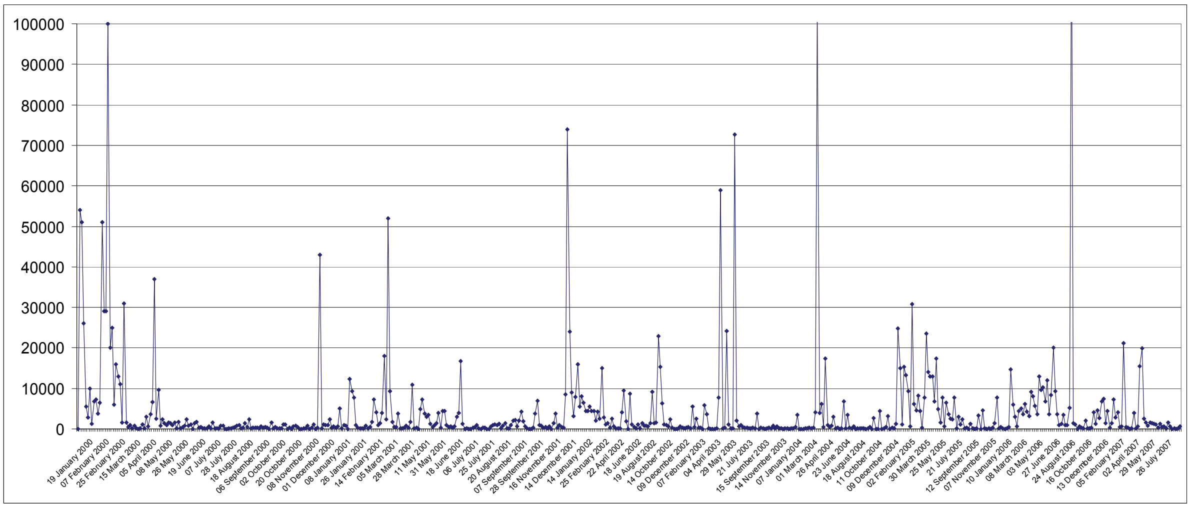


Figure 11: E-coli levels at Campsdrift, Pietermaritzburg, November 2006 to June 2007

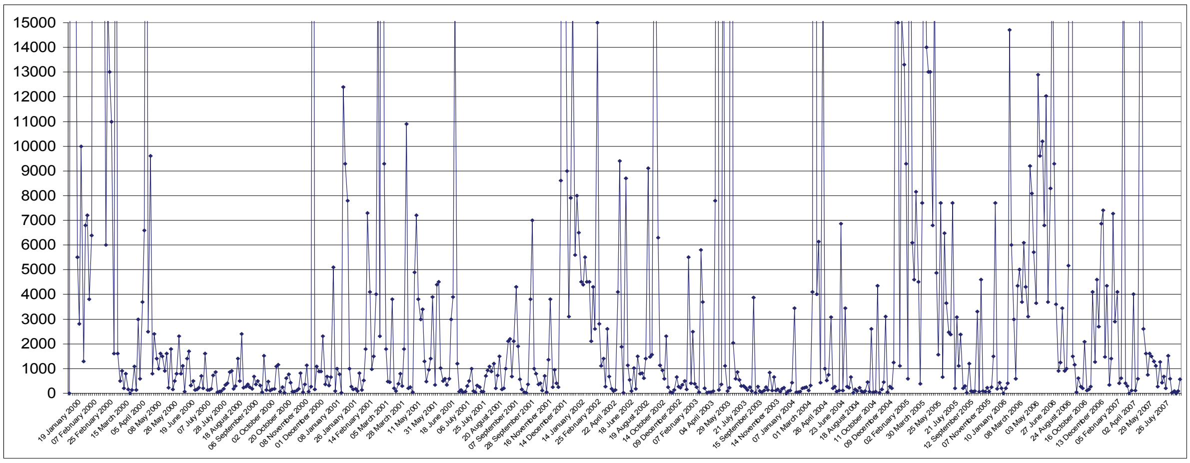


Figure 12: E-coli levels at Campsdrift, Pietermaritzburg with expanded Y axis

2.2.2 Results from Buffalo City

According to Andrew Lucas, stormwater ingress into the sewer system is a significant problem in the Eastern Cape, and is escalating. Lucas attributes the increasing quantity of I/I to rapid urban development over the last ten years, opening up of new residential and industrial areas as well as urban infill. On many plots, homeowners are paving areas (for lower maintenance), extending their homes, adding garages or building garden cottages, all of which increases the surface for run-off. Paving outside areas is increasing in popularity as a low maintenance option. Under these conditions, the allowance built into sewer design for I/I is grossly inadequate (personal communication Lucas, 2007 and Westenberg, 2008).

Ingress Snapshot (Eastbank WWTW)

ADWF: 33 Mℓ per day
WWTW design capacity: 40 Mℓ per day
Peak WWF: 56 Mℓ per day

The ingress into the Buffalo City WWTW is almost instantaneous. This points to the sources being gutter diversions or direct inflow through manhole covers rather than infiltration through leaking pipes. The municipality is currently assessing the average dry weather flow (ADWF) and the peak wet weather flow (PWWF). Preliminary results indicate that the inflow into the WWTW in East London peaks in wet weather at twice the ADWF (Westenberg, 2008).

There is currently one inspector who specifically visits properties to assess how stormwater is managed. This inspector is responsible for over 30 000 properties.

In 2005, the Buffalo City Municipality completed a State of the Environment Report and a summary report on the state of sanitation. Both reports found the state of sewage and sanitation services in the municipality to be of grave concern. The State of the Environment Report identified

> "… the state of sewage and sanitation services in [the municipality] is probably the most serious environmental issue facing [the municipality]. The environmental and associated health risk effects of the existing problems associated with sewage and sanitation services in [the municipality] are profound and pose a serious threat to the health of the broader population." (Integrated Environmental Management Unit, 2005).

In order to try to combat the problems associated with stormwater ingress, the municipality's water services development plan identified the need to (amongst others):

- Implement an effective maintenance, refurbishment and upgrading programme to support development within the City and to progressively ensure that all discharges from the wastewater treatment works are in compliance with their permits
- Implement a community outreach programme to release capacity and prolong the life of existing sanitation infrastructure, by addressing issues such as stormwater ingress, vandalism, spillage, etc.

The community outreach programme was implemented and based largely on the model and materials used by eThekwini Metro in a similar programme. In terms of having an impact, the programme did reduce the number of blockages within the sewer but has had almost no effect on stormwater ingress (Westenberg, 2008).

2.2.3 Results from East Rand Water (ERWAT)

Naude (no date) reports that between the JP Marais, Vlakplaats and Waterval works, 44 Mℓ/day infiltration takes place (see Table 4). This ongoing infiltration is proving to be costly, both for the environment and ERWAT. Surcharging sewers lead to local flooding and pollution, unnecessary pumping and deterioration of the sewer pipes. The cost of treating the extra effluent adds R350 000 per annum onto the chemical costs of the three plants. It is estimated that the cost of building extra treatment capacity to cope with the additional flow is around R110 million (Naude, no date).

Table 4: Infiltration rates at ERWAT WWTP works

Plant	Design Flow (Mℓ/day)	Current Flow (Mℓ/day)	Infiltration (Mℓ/day)
JP Marais	14	27	13
Vlakplaats	83	99	16
Waterval	105	120	15

(Source: Naude, no date)

2.2.4 Results from Cape Town

The City of Cape Town operates 17 waste water treatment plants which jointly process over 20 000 Mℓ of sewage per month. Between 1 July 2000 and 30 June 2001 the single highest single day flow was recorded at several of the works, and this was compared with the average dry weather flow. The results are shown in Table 5 below. The highest single day peak relative to ADWF occurred at the Kraaifontein works, where the maximum flow was 3.8 times the ADWF. The average peak flow for all the works, weighted for flow, is 2.25 times the ADWF. In assessing these figures, it should also be remembered that the peaks shown are day peaks, and do not reflect the instantaneous storm flow peaks, which will be substantially higher.

The City of Cape Town has also summarised its total sewage flow on a monthly basis for all its works and compared the results over the period July 2001 to June 2007. The results are shown in Figure 13 below. The data shows that the average monthly sewage flow during the rain season in the Cape winter is nearly 50% larger than the average monthly sewage flow during the dry summer months.

2.2.5 Conclusion

Although this is not a comprehensive study of stormwater ingress in all South African cities, it is clear that the problem is common and serious. Average wet weather flows are typically 50% more than dry weather flows, and peak wet weather flows are between two and four times average dry weather flows.

Table 5: Peak Wet Weather Flows Recorded between 1/7/00 and 30/6/01 at the City of Cape Town's Waste Water Treatment Works

TREATMENT WORKS	AVERAGE DRY WEATHER FLOW	HIGHEST SINGLE DAY FLOW	
	Ml/d	Ml/d	% of ADWF
Athlone	65.42	153	**234**
Bellville	46.19	136	**294**
Borchards Quarry	23.47	no data	
Cape Flats	165.38	362	**219**
Gordons Bay	2.03	no data	
Kraaifontein	5.11	19.6	**383**
Llandudno	0.16	no data	
Macassar	34.21	70.4	**206**
Melkbosstrand	1.46	no data	
Mitchell's Plain	28.06	no data	
Parow	1.59	2.4	**150**
Potsdam	27.91	53.0	**190**
Scottsdene	2.87	no data	
Simonstown	1.44	5.1	**356**
Wesfleur	10.16	14.2	**140**
Wildevoëlvlei	7.00	17.6	**251**
Zandvliet	48.43	94.3	**195**

(Source: Abdulla Parker, Catchment Planning, City of Cape Town)

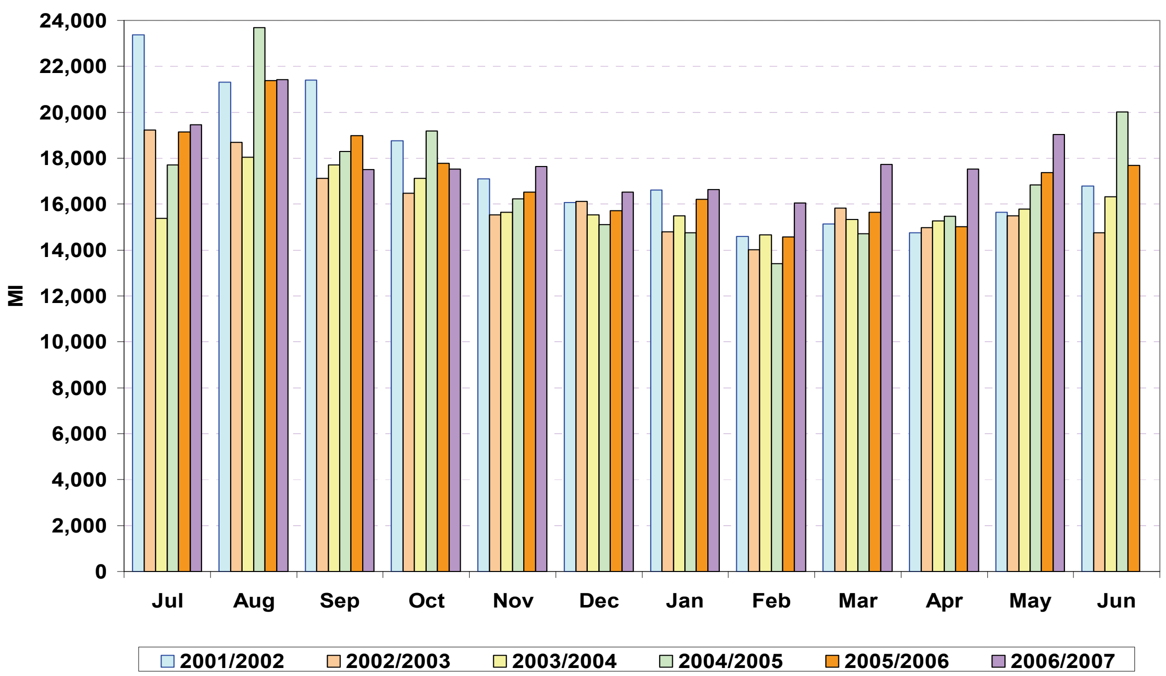


Figure 13: Combined Monthly flow for all of City of Cape Town's Waste Water Treatment Works over the period July 2001 to June 2007

Chapter 3

Stormwater in sewers – what does our legislation say?

In this chapter South African legislation relating to stormwater ingress is reviewed. It also includes both national sample bylaws and a selection of municipal bylaws. It is found that while the practice of diverting stormwater to sewers is in most cases illegal in South Africa, the legislation is unevenly applied.

3.1 National legislation

There are two main pieces of legislation dealing with water in South Africa, the Water Services Act of 1997 and the National Water Act of 1998.

The Water Services Act (No. 108 of 1997): Chapter II, Section 9(2) states that a Water Services Institution must take measures to prevent stormwater from entering its sewage system.

The National Water Act (No. 36 of 1998) is relevant because it provides for the regulation of the quality of effluent that may be discharged by a WWTW into receiving waters. When a WWTW receives more sewage than the works has the capacity to treat or store temporarily, partially treated or untreated sewage is released directly into receiving waters, which is technically illegal. So while the Water Act does not contain clauses prohibiting the diversion of rainwater into the sewer system, it provides an incentive for municipalities to formulate their own bylaws to protect the WWTW and themselves from the liability associated with overflows.

The National Building Act (1977) Section P deals specifically with drainage of properties (see box). Most municipalities do not have specific building regulations and bylaws that deal with drainage and in these cases the building regulations are the default regulations:

National Building Regulations, Section P: Drainage

- Section P2 (1)(d) : all components in drainage installations to be watertight
- **Section P3(2) : prohibits any person from allowing stormwater to enter any drainage installation on site**
- Section P(3)(3) : Municipalities may give notice to the owner of any site to execute precautionary measures to prevent stormwater entering drainage installations on site
- P6(1)(b) : prohibits any person from breaking into or interfering with any drainage installation for purpose other than repair or maintenance
- P6(2) : makes it an offence to contravene the above regulation

(Source: National Buildings Regulations and Standards Act No. 103 of 1977).

The National Building Act and the Municipal Services Act both make provision for the appointment of building inspectors. This is discussed as part of the implementation of the legislation in section 3.4 below.

The Municipal Services Act dictates that municipalities are to prepare an Integrated Development Plan (IDP) which covers all facets of development. These plans should, theoretically, deal with stormwater management. However the focus of these documents tends to be on the provision of services (rather than maintenance and management) (Burke and Mayer, 2007).

3.2 Municipal bylaws

Within South Africa's governance structure, municipalities are able to make and administer local bylaws to oversee matters under their jurisdiction. It is worth noting that municipal bylaws are always superseded by National Legislation should there be a conflict. In this case there is limited national legislation and no conflicts are foreseen.

In a municipality legislation prohibiting the ingress of stormwater into the sewer system is covered by Water Services Bylaws or Water Supply and Sanitation Bylaws and/or the Building Bylaws. Table 6 below highlights under which bylaw stormwater ingress is dealt with for a number of municipalities throughout South Africa.

Table 6: A selection of municipal bylaws governing stormwater ingress

Municipality	Bylaw	Regulations
Amajuba (Newcastle)		Ingress of stormwater into drainage installation prohibited.
Cape Town	Wastewater	2) No owner of property may allow:— (a) the ingress of groundwater or stormwater into a private sewer installation on his or her premises, or (b) the seepage of wastewater from a private sewer installation on his or her premises, or (c) the ingress of stormwater into a private sewer installation on his or her premises, except with the written consent of the Council and subject to such conditions as it may impose. (3) Every owner of property shall take adequate measures to prevent ingress and seepage referred to in subsection (2).
eThekwini (Durban)	Sanitation Building regulations	• No person shall cause or permit and stormwater to enter the sewage disposal system. • Manhole covers to be above 50 year floodline • If sewer requires repair as a result of something the property owner did, the council can conduct repairs at the owner's expense.
Ekurhuleni (East Rand)	Wastewater	• No person shall cause or permit any stormwater to enter the sewage disposal system. • No part of a drainage installation shall be capable of directing water from any source, not being sewage, to enter the installation without human intervention. • No pipe, channel or other device used for or capable of being used to conduct rainwater from any roof or other surface shall be permitted to discharge into any drainage installation.
Emfuleni (Vereeniging)	Water services	Unauthorised and illegal discharges into the drainage system includes stormwater.

Johannesburg	Water services: Sanitation services	• Ingress of stormwater into drainage installation prohibited. • Protection from ingress of floodwater.
Mbombela (Nelspruit)	Drainage and Sanitation	• No part of a drainage installation shall be capable of directing water from any source, not being soil-water or waste-water, to enter the installation without human intervention. • Every manhole in a drainage installation shall be constructed to prevent the infiltration of water.
Pietermaritzburg (Msunduzi)	Water Services	Ingress of stormwater into drainage installation prohibited: • No part of the drainage installation may be constructed to allow any water other than soiled or waste water to enter. • No person shall cause or permit and stormwater to enter the sewage disposal. • No pipe, channel or other device used for conducting rainwater from any roof or other surface may be permitted to discharge into any gully forming part of a drainage system.
Polokwane	Water and Sanitation (DRAFT)	Certain discharges to disposal system prohibited: • Ingress of stormwater into drainage installation prohibited. • Protection from ingress of floodwater.
Port Elizabeth (Nelson Mandela Bay)	Water Services (Sanitation)	No person may discharge sewage to the sewerage system which: (j) contains stormwater.
uMhlathuze (Richards Bay)	Water Services	Objectionable discharge to sewage disposal system: • No person shall cause or permit any stormwater to enter the sewage disposal system. • Officials may order owners to conduct periodic expert inspections of the premises to ensure compliance with By Laws.
Sol Plaatjie (Kimberley)	Water Services	Objectionable discharge to sewage disposal system prohibits stormwater entering the sewage disposal system. Drainage installations must be protected from ingress of floodwaters.
Tshwane[5] (Pretoria)	Sanitation	Stormwater not to enter sewers: No person may discharge or cause or permit to be discharged any substance other than sewage into a drainage system.

(Source: Bylaws for each municipality[6].)

As can be seen from the table above, most of the legislation regarding dealing with rainwater on properties is covered by two clauses:

- Routing of stormwater into drainage installations is prohibited
- Drainage installations are to be adequately protected from ingress of floodwater.

While the various municipalities differ in the wording and make differing provision for enforcement of the legislation, the legislation contained in the two sections of the bylaws all basically follows that of the Model Water Services Bylaws (see box).

[5] Tshwane Metropolitan Municipality revised its bylaws in August 2003 to ensure that all legislative changes introduced since 1994 were adequately accommodated (Stephenson and Barta, 2005).
[6] Note: wording used in the tables is exactly as it appears in the bylaws.

Text from Dept Water Affairs' Model Water Services Bylaws

159. Unauthorised and Illegal Discharges

(4) No person may discharge or cause or permit the discharge of—

(a) any substance, including stormwater, other than sewage, to be discharged into a drainage installation;

(b) water from any swimming pool directly or indirectly over any road or into a gutter, stormwater drain, watercourse, open ground or private premises other than the premises of the owner of the swimming pool;

(c) water from artificial fountains, reservoirs or swimming pools situated on premises into a drainage installation, without the approval of the municipality and subject to the payment of relevant charges and such conditions as the municipality may impose;

(d) any sewage, industrial effluent or other liquid or substance

(Source: Model Water Services Bylaws: Department of Water Affairs and Forestry (June 2005) accessed via http://www.dwaf.gov.za/Documents/Other/WS/ModelWSBylawJun05.pdf)

In workshop discussions with key stakeholders from 16 municipalities, participants felt that the policies, plans, strategies and regulations (bylaws) developed by municipalities to manage stormwater needed to be updated on a more regular basis (Burke and Mayer, 2007). The groups also thought that:

- Regulations pertaining to stormwater at design stage are inadequate
- Municipalities need to develop a uniform approach to regulating stormwater
- Enforcement of regulations needs attention.

3.3 Provisions for ensuring legal compliance

The above sections shows that there is adequate provision made in municipal bylaws to prohibit stormwater ingress. However, without a system to ensure compliance, bylaws are unlikely to be adhered to. Two acts make provision for giving municipalities the power to enforce their legislation. The National Buildings Regulations and Standards Act No. 103 of 1977 and the Municipal Systems Act of 2000 provide a regulatory framework for the deployment of inspectors. According to Act 103, building control officers must be appropriately qualified and have the following responsibilities:

- Make recommendations on plans submitted for consideration by the municipality.
- Ensure the instructions of the municipality are carried out.
- Inspect buildings and ensure compliance with plans submitted.
- Report non-compliance to the local authority.

(Source: National Buildings Regulations and Standards Act No. 103 of 1977).

Example of the Power to serve and compliance with notices

(1) The Executive Director may by written notice order a person who fails, by act or omission, to comply with the provisions of this bylaw or any condition imposed there under, to remedy such breach within a period specified in the notice.
(2) If a person fails to comply with a written notice served on him by the Executive Director in terms of this bylaw within the specified period, the Executive Director may take such action that is necessary to ensure compliance, including (a) by written notice require the owner or occupier of the premises to do specified work within a specified period at his own expense, or (b) if the situation is a matter of urgency, without prior notice do such work or cause it to be done and recover the cost from the owner;
(c) limiting or discontinuing the provision of services; and
(d) instituting legal proceedings.
(3) A notice in terms of subsection
(1) will – (a) give details of the provision of the bylaw not complied with; (b) give the owner, consumer or other person a reasonable opportunity to make representations and state his or her case, in writing, to the Executive Director within a specified period, unless the owner, consumer or other person was given such an opportunity before the notice was issued;
(c) specify the steps that the owner, consumer of other person must take to rectify the failure to comply; (d) specify the period within which the owner, consumer or other person must take the steps specified to rectify such failure; and
(e) state that the Municipality –
(i) may undertake any work necessary to rectify the failure to comply if the notice is not complied with and that any costs associated with such work may be recovered from the owner, consumer or other person; and
(ii) may take any other action it deems necessary to ensure compliance.
(4) The costs recoverable by the Municipality in terms of subsections (2)(a) and (2)(b) is the full cost associated with that work…"

Under the Municipal Systems Act (2000), Building Control Officers or Building Inspectors are empowered to ensure compliance because they have:

- Power of entry into any property.
- The right to inspect the property.
- Are able to give notice to rectify any aspects that are found to be non-compliant.
- Can enforce compliance through the imposition of a penalty.

The National Buildings Regulations and Standards Act makes provision for temporary building inspectors who may be trained and equipped for a specific purpose (e.g. the detection of illegal stormwater connections).

3.3.1 Penalties for non-compliance

Typically bylaws include clauses on the steps to be taken should someone be found to be contravening the bylaws. The first step is usually to give the offender written notice of the offence and a time period in which to rectify. Should the property owner not act on the notice, most municipalities can then rectify the problem (at the owner's expense) or can impose a fine or imprisonment (see Table 7 below). Fines often reflect the date the bylaws were last revised rather than highlighting the seriousness of the offence. In many cases the fines are not high enough to act as a deterrent.

Table 7: A summary of penalties for contravening local bylaws

Municipality	Penalty for contravention
Cape Town	Liability for a fine mentioned - no amount specified
Durban (eThekwini)	Maximum fine R500 or 6 months prison (first offence) Maximum fine of R1000 or 1 year prison, or both, (subsequent offence)
Ekurhuleni (East Rand)	Fine up to R20 000, or imprisonment up to 6 months
Emfuleni	Fine up to R4000, or imprisonment or community service up to 4 months Further fine of R2000 per day of continuing offence
Hermanus	Fine of up to 50 pounds Fine of 1 pound per day for each day of continuing offence
Johannesburg	No offence created for contravention of bylaws, save for non-payment of fees for use of sewers and sewerage purification plant
Kimberley (Sol Plaatjie)	Fine or up to 1 year imprisonment (first offence) Further fine up to R1000 per day for continuing offence after written notice issued Fine (unspecified amount) or imprisonment up to 2 years (second offence)
Mbombela (Nelspruit)	Fine up to R300 or prison up to 3 months (first offence) Further fine up to R50 per day of continuation of offence after written notice issued by Municipality, Fine of up to R1000, and imprisonment up to 6 months in default of payment (subsequent offence)
Pietermaritzburg (Msunduzi)	Unspecified fine or 6 months prison (first offence) Further fine of up to R50 in event of continuing offence, in or default of payment, up to 1 day's imprisonment for every day of continuance of offence
Polokwane	Fine up to R10 000 or 6 months prison, or both Further fine of R500, or imprisonment not exceeding 10 days, or imprisonment without option of fine, or both, for each day of continuation of offence, or in default of payment, to imprisonment not exceeding one day, for every day during the continuance of such offence after a written notice has been issued by the Council
Port Elizabeth (Nelson Mandela Bay)	Maximum penalty prescribed for an offence by section 189(23) or the Municipal Ordinance, 1974 (Ordinance 20 of 1974)
Richards Bay	Fine (unspecified amount) or up to 6 months prison Further fine up to R50 per day of continuation of offence & after notice to discontinue, or in default of payment imprisonment of 1 day per day of continuation of offence & after notice to discontinue
Tshwane	Fine of up to R5000, or imprisonment up to 4 months Fine of up to R5000 for each day on which offence continues, in event of continued offence

3.4 Making the legislation work – two contrasting approaches

Stormwater in sewers is undesirable, and in most cases illegal. On that the law is clear and there is little variation in the wording from one municipality to another. However, it is one thing to have good law and the intention to enforce it, it is quite another to actually enforce it. Two contrasting approaches to the enforcement of the stormwater ingress prohibition are described below, that practiced by the Msunduzi Municipality and that previously practiced by the City of Cape Town.

3.4.1 The Msunduzi Municipality's approach to controlling illegal connections

3.4.1.1 The bylaws

Stormwater is prohibited from entering the sewer system under the Msunduzi Municipality Water Services Bylaws (17 March 2005). The Msunduzi municipality specifically prohibits the connecting of roof guttering to the sewer system (see point 3 below). The relevant extract from the bylaws is as follows:

Chapter 3: Sanitation services

Ingress of stormwater into drainage installation prohibited

73 (1) No part of a drainage installation may at any time be constructed or designed to allow or be capable of allowing water from any sources, not being soil water or waste water both as defined in the national regulations published in Government Notice R2 378 of 23 October 1990, as amended, to enter the drainage installation.

(2) No person may discharge or cause or permit to be discharged any substance other than sewage into a drainage installation.

(3) No pipe, channel or other device used for conducting or capable of being used to conduct rainwater from any roof or other surface may be permitted to discharge into any gully forming part of a drainage installation.

(4) Should the Council at any time become aware of any installation which does not comply with the provisions of section 76 and Chapter 6, it may carry out such alterations to the installation as it may deem necessary to ensure compliance with the provisions of those sections and recover from the owner the costs or the prescribed fees as determined by the Council.

Where premises are constructed within, or any portion of the property lies within the 1 in 50 year flood plain, the top level of any manhole, inspection chamber and gully shall be above the 1 in 50 year flood level, except in the case of a manhole and inspection chamber the cover of which is secured in place by approved means.

3.4.1.2 Enforcement of the by-laws

The municipality's building inspectorate is responsible for ensuring enforcement of the regulations, and has a water sub-unit to deal directly with complaints. In the past, regular site inspections were done on residential properties; however this is rarely if ever done now. In a recent report in the *Witness* newspaper, the municipal strategic manager for infrastructure services and facilities (the City Engineer) reported that the city had at the time nine building inspectors and is committed to improving their coverage and intends to increase the number of inspectors. The report also notes that the municipality depends to a certain extent on help from the public:

> "On the subject of properties that illegally route stormwater into the sewer system, [the municipal strategic manager] says, 'We need the help of our communities. It is difficult for the municipality to uncover certain activities without the residents' help. We therefore appeal to our residents to report any illegal structures, water and sewer connections to our building inspectorate.' " (Denny-Dimitriou, Witness, February 2008).

The Water sub-unit was contacted, as suggested by the municipal strategic manager in the newspaper article quoted above. The number given proved to be a customer care officer who suggested that the Water and Sanitation section or the Building Inspectorate could help. An official at the Building Inspectorate said that while building inspectors check all new developments, renovations and additions to existing properties, the inspectors do not specifically look for illegal sewer connections. The official suggested that the Water and Sanitation section should be contacted. The senior sewer inspector in the Water and Sanitation section said that they had stopped doing inspections for illegal stormwater connections more than 10 years ago when the number of sewer inspectors employed by the municipality fell to below the number required to do essential maintenance on the sewer network. He did, however, state that they would inspect if specific violations of the law were reported to them.

The manager of the Msunduzi sewer maintenance section was then interviewed in order to gain an understanding of how the illegal stormwater connection inspection process works, and why the city appeared (for all practical purposes) to have given up on enforcement. This interview proved most enlightening. He explained that dealing with an illegal stormwater connection in his municipality is an eight step process, with the detail as follows:

Step 1: Inspect property

The first step is to inspect a property, either as part of a routine sweep through an area or in response to a report that there is an illegal connection there. In order to do so, the inspector has to gain access to the property. In most cases such access can only be gained outside of normal working hours (when the home owner or tenant is at home), which means that the inspectors have to work overtime. In many cases it is clearly obvious that the stormwater is discharged to the garden and not into the sewer. However, in some cases the stormwater disappears into a gully or drain, and then it is not possible without further inspection to tell if it drains into a soakpit or into the sewer. In such cases the inspector has to find the terminal manhole to which the household wastewater is directed. To complicate matters, this may have been illegally paved over, built on or landscaped over, which means the next manhole in the line must be found. Once a suitable manhole is found, dye must be poured into the suspect gully or drain to see if it comes out in the downstream sewer pipe. If it does, then there is an illegal direct connection.

Step 2: If there is a problem, issue notice to rectify

Having established that the property has one or more illegal connections, or any other infringement such as the covering over of a manhole, a notice is issued to the property owner informing them of the infringement. A set form is used for this notice. The notice informs the owner that they have a period of time to remedy the problem at their own expense, and that thereafter the municipality will return to re-inspect. Here a complication might develop, in that the owner might not live on the property, or might not have been present during the inspection, and might require clarification of the notice. Another possible complication is that the property might be occupied by a tenant and the owner might not see the notice. A return visit by the inspector might be required to meet the owner, and possibly to redo the test.

Step 3: Re-inspect property

Several months may pass, as the municipality will tend to allow the owner a significant period of grace to remedy the problem. This is because it is far simpler and more cost-effective (for all parties concerned) for the owner to fix the problem than for the municipality to pursue the rest of the enforcement process. The grace period having passed, the property is re-inspected. It may be found that the problem has been remedied, in which case the owner can be issued with the necessary certificate of compliance. It may, however, be found that the owner has made no attempt to fix the problem. As before, the re-inspection process has to happen at a time when the owner is available, and this may require the inspector to work overtime.

Step 4: If the problem persists, issue a Final Notice

If the property owner has not fixed the problem and this is proven by a re-inspection, then a Final Notice is issued. This notice gives the owner a further period of time to make good, and informs him/her that failure to comply will result in the municipality taking matters into its own hands and doing the repair using its own staff or contractors, with the costs to be charged to the owner.

Step 5: Re-inspect the property

After the new period of grace has expired, the inspector must once again access the property to check if satisfactory remedial action has been taken. Overtime work might be required. If the problem is resolved, a compliance certificate can be issued. If not, the problem is referred to the municipality's legal department.

Step 6: If the problem persists, refer to the municipality's legal department

If the owner has still not remedied the problem, the manager of the sewer maintenance unit refers the matter to the municipality's legal department. Because of the legal implications of violating private property, the legal department has to satisfy itself that due process has been correctly followed up to this point, i.e. that the inspector has done his work correctly and that the homeowner has been properly informed of the implications at each step in the process.

Step 7: Serve Notice of Municipality's Intent to carry out work

If the legal department is happy that due process has been correctly followed, a notice is served on the property owner of the municipality's intent to access the property to make good, with the costs to be charged to the property owner. Proof must be obtained that the property owner has received the notice. The serving of the notice might have to be done outside of normal working hours.

Step 8: Carry out remedial work

The final step is that the municipality's staff or its appointed contractor has to gain access to the property, the remedial work has to be carried out and the costs of the work have to be billed to the property owner. This cost must be recovered, and a follow-up inspection may even be required to check that the property owner does not re-establish the illegal connection once the municipality has left the site.

The process described above is lengthy, laborious, time-consuming and expensive. Much of the work has to be done after-hours, and overtime payment is generally a point of contention in the organization. To pursue one illegal connection through the full eight step process described above can easily take more than 20 professional or skilled man hours, which realistically will cost the municipality at least 5 000 Rands, quite apart from the cost of construction if this is not borne by the property owner. In the last fifteen years the number of sewer inspectors employed by the municipality has halved, even as the length of sewer network for which they are responsible has grown by more than 60%. The frequency of blockages has increased, and it is all the remaining staff can do to try to cope with emergency maintenance and repairs. Given this situation, the pursuit of illegal stormwater connections is not a priority and this work was to all intents and purposes abandoned by the Msunduzi Municipality more than 10 years ago.

3.4.2 The previous Cape Town municipality's approach to controlling illegal connections[7]

3.4.2.1 The by laws

The Cape Town municipality's bylaw for controlling illegal stormwater connections was contained within its Wastewater By-law, which was updated in September 2006. The relevant section of the by-law reads as follows:

(2) No owner of property may allow:—
(a) the ingress of groundwater or stormwater into a private sewer installation on his or her premises, or
(b) the seepage of wastewater from a private sewer installation on his or her premises, or
(c) the ingress of stormwater into a private sewer installation on his or her premises, except with the written consent of the Council and subject to such conditions as it may impose.
(3) Every owner of property shall take adequate measures to prevent ingress and seepage referred to in subsection (2).

3.4.2.2 Enforcement of the bylaws

Clause (2) (c) in the Wastewater By-law was key to their enforcement approach, because the clause in fact made stormwater ingress legal *with the written consent of the Council and subject to such conditions as it may impose.*

What this means is that the municipality would inspect a property to establish whether there were any direct connections. As in the case of the Msunduzi Municipality, this could only be done when there was someone there to open up and so this work sometimes had to be carried out outside of standard working hours. If there were any direct connections of stormwater to the sewer (either from paved

[7] The information in this section regarding the Cape Town approach to dealing with direct stormwater connections was provided by Nigel Ireland, who is one of the city's drainage engineers.

surfaces or the roof) the contributing catchment area was measured. The owner was notified of the situation, and was notified that the council would bill him for the service (drainage of stormwater) at the applicable tariff. The owner was further advised that if he changed the situation, he should notify council who would re-inspect the property at a time of their choosing. If the inspector was satisfied that the alterations were satisfactory, the municipality would cancel the stormwater drainage charge forthwith. This put the onus on the owner to make the changes, and to be available at a time convenient for an inspection to confirm that the changes had been made.

In 2007/2008 the charges for providing a stormwater drainage service were R7.94/m^2 for commercial properties and R2.84/m^2 for domestic properties.

3.4.3 Discussion of the contrasting enforcement approaches

The old Cape Town enforcement approach differs from the current Msunduzi enforcement approach in two important ways:

i) After only one inspection the responsibility for correction of an illegal connection was placed in the hands of the property owner, and the owner was charged for the stormwater drainage service. From this point on the owner would either pay for the drainage service, or would make every effort to remedy the situation and to meet with the council inspectors at a time of their choosing.

ii) The income derived from property owners paying for direct connections covered the cost of the inspectors required to detect and control these connections. The inspection service was therefore potentially self-financing and not a burden on the city's budget.

The Msunduzi approach is unworkable and as a result the municipality has long since given up its attempts at enforcement. The previous Cape Town approach appears to have been more practical and self-sustaining.

A criticism of the old Cape Town approach would no doubt be that it will allow rich people, who can afford the cost, to choose to burden the sewer system with their stormwater. However, if the tariff is appropriately set it will cover not only the inspectorate but also the full cost of conveying and treating that stormwater at the wastewater treatment plant. It can also be argued that it is better to have a practical if inequitable control system than an idealized rights based control system that is so complicated that it exists only in theory and is therefore quite useless.

It must be noted, however, that the seemingly more practical approach previously practiced by Cape Town has been discontinued in the new unified City of Cape Town. The city has reverted to an approach more similar to that described for Msunduzi, and is applying this in targeted areas where it is believed to have a significant inflow problem. Provided sufficient resources are allocated to inspection and enforcement, this approach may have a quicker and more significant impact.

Chapter 4

Stormwater in sewers – dealing with it

Stormwater ingress is an inevitable part of a separate sewer system because perfect separation of wastewater and stormwater is almost impossible to achieve. For this reason, WWTWs are designed and built with some additional capacity. The CSIR's engineering design guidelines (the "Red Book") recommends an additional 15% for "extraneous" flows (above the Peak dry Weather Flow, which is up to 3.5 times the Average Dry Weather Flow) and up to a further 50% to accommodate the extra effluent expected from future developments. However, the rate of inflow and infiltration from many South African cities has surpassed this safety allowance and strategies to reduce and manage stormwater ingress need to be implemented timeously.

4.1 Dealing with stormwater ingress

There are a number of options for dealing with stormwater ingress. These can be split into two broad categories:

- upgrading the infrastructure to keep up with the additional loading or
- reducing the loading at the source.

Both are discussed below in terms of their merits and potential shortfalls.

4.1.1 Infrastructure upgrades to keep pace with the peak wet weather flow

One of the cheaper methods for reducing stormwater ingress is to replace missing manhole covers. Replacing broken or missing manhole covers has other advantages for the sewer lines because it helps prevent blockages caused by objects finding their way into the sewer and subsequent sewer damage. The success of a campaign to replace manhole covers is partially dependant on public participation because it requires that the new covers are not broken or stolen. However, it has limited capacity to reduce overall ingress. A pilot study conducted in Kings County, Washington found that at two sites where manhole rehabilitation and replacement formed the focus of the intervention, there was very little or no reduction in I/I (Earth Tech Team, 2004).

Table 8: Impact of a project designed to reduce I/I by rehabilitating manholes

Area	Percentage of manholes rehabilitated	Impact on I/I
Coal Creek	52%	No I/I reduction
North Shore	64% (and one direct inflow source eliminated)	23%
Val Vue	45%	No I/I reduction

(Source: Earth Tech Team, 2004). Note: impact on I/I is estimated from modelled results and is measured against a predetermined 20 year peak I/I.

Following a major sewer spill in Pietermaritzburg which turned out to have been caused by a log which had became lodged in a bulk sewer, the Msunduzi Municipality made the decision to replace the manhole covers in the problem area and brick them in. These concrete covers cannot (easily) be stolen. However should the sanitation department require access to those particular manholes, the supporting structure would have to be partially broken (Figure 14).

Figure 14: "Vandal proof" manhole covers

A number of municipalities, realising that stormwater ingress is a major problem, have embarked on programmes to upgrade and fix aging sewer lines. This usually involves the use of remotely operated CCTV cameras to inspect the sewer lines, which enables the sewer inspectors to determine which sections of the sewer line are in poor condition and to replace only those sections that are malfunctioning. Fixing only those sections of sewer that are broken is a cost-efficient strategy, although the CCTV technology is expensive (the current budget for the Msunduzi Municipality to inspect approximately 500 km of sewers is R10 million, or R20 000 per kilometre). However, in terms of reducing stormwater ingress, this measure is potentially significant. Even so, repairing sewer lines can be costly and disruptive, especially if these sewers are found in the busier parts of town under surfaced roads (de Swardt and Barta, 2007).

Some sewer systems can be modified to cope with stormwater ingress through increasing the storage capacity within the system (Wisumperuma and Vercruyssen, 2006). Peak storm overflow facilities (often referred to as stormwater retention dams) can be constructed alongside the WWTW. Excessive flows can be temporarily stored for treatment at a later stage. While this might reduce the frequency of spillage into receiving waters, it does not address the additional costs associated with processing excessive amounts of wastewater. Flow control devices can also be used to solve flooding problems. These devices would typically be installed at the on-line or off-line detention tanks. The detention tanks are constructed at various places along the sewer line and in combination with flow control devices are used to control the onward and downstream flow of wastewater throughout the system (Stephenson and Barta, 2005).

Figure 15: Construction of the Browns Bay on line storage tunnel
(Source: Wisumperuma and Vercruyssen, 2006)

Following a study on the Mullumbimby Sewerage System in Australia as part of a project implemented by the Byron Shire Council in 2007, the project steering committee made the following recommendations in terms of reducing and preventing stormwater ingress:

- permanent sealing of boundary traps;
- the security sealing of boundary traps;
- the permanent sealing of gully traps;
- the security sealing of gully traps.

These measures would make it virtually impossible for private land owners to divert stormwater into the sewer system.

The most capital expensive option is to upgrade the WWTW. This has rarely been done because of stormwater ingress. Consensus within the industry is that it is far cheaper to delay capital expenditure and reduce the hydraulic loading at point of source.

4.1.2 Reducing the quantity of stormwater at point of source

Any strategy that aims to reduce stormwater in the system by managing ingress at its source is most likely to be effective if it involves the general public. This is because much ingress is a result of their actions. The literature seems to suggest that a combination of education, appealing to people's sense of community, inspections and legal enforcement have the most impact. In other parts of the world, financial incentives to comply have also had success.

4.1.2.1 Public education to prevent sewer abuse

eThekwini's Water and Sanitation Unit community education programme[8] was introduced to address misuse and abuse of the sewer system. The programme targeted communities that had previously had no or poor services and therefore had limited knowledge about proper use and maintenance.

The project, which ran in the form of a road show and schools outreach programme, recorded much success. Attitudinal and behavioural shifts helped reduce the number of sewer blockages by over one third in a 12 month period.

Based on the eThekwini project, Buffalo City implemented a similar community involvement and education programme. The programme was effective in reducing blockages and general sewer abuse, but had no impact on reducing stormwater ingress (Personal Communication, Buffalo City Municipality).

Evidence from other pilot studies to reduce I/I indicate that cooperation from private property owners is essential to the success of the interventions (Earth Tech Team 2004). Education and public awareness around stormwater ingress is most likely to be successful when done in conjunction with an inspection and the provision of alternative drainage solutions (Byron Shire Council, 2007).

[8] For more information about the project visit
http://www.durban.gov.za/durban/services/services/water_and_sanitation/education/sewage_education

Figure 16: Sample of education material used in the classroom

(Source: eThekwini Municipality Education Material, accessed via http://www.ethekwini.net/durban/services/services/water_and_sanitation/education/sewage_education/teachers_resource_guide/educationimagefiles/blockages)

4.1.2.2 Financial incentives to encourage homeowners to manage stormwater

Financial incentives are often used by authorities trying to encourage private individuals to comply with legislation. Sweden, Denmark, Germany and the Netherlands have all made use of levies and incentives to encourage private land owners to reduce their stormwater run-off and ingress (see Table 9 below). Each programme is accompanied by public education and information campaigns (Chouli et al, 2007).

Table 9: Summary of incentives to manage stormwater

Country	Source control technique and incentive
Sweden	Stormwater fee charged per m^2 of impervious surface. If source control techniques are implemented, fee is reduced.
Denmark	Property owners who manage their stormwater get lower drainage fees and 40% rebate on drainage connection fees).
The Netherlands	Downpipe disconnection and rebates per m^2 if disconnected.
Germany (Dresden)	Impervious surfaces taxed per m^2 per year.

(Source: After Chouli et al, 2007)

Burke and Mayer (2007) suggest that while local government could implement a system of stormwater levies (through stormwater by laws) this has not yet been done and may have limited success locally, especially in lower income areas where settlement patterns are denser and households have limited disposable income to make the changes that would allow them to benefit.

4.1.3 The US Downspout disconnection programmes

Across the US and Canada a number of “Downspout Disconnection” programmes have been implemented. In many states, even though the original sewer system was designed as a combined sewer system (CSS), it is now illegal to discharge stormwater via downpipes (called downspouts in North America) into the sewer system. In addition to ensuring legal compliance, the purpose of the programmes is to:

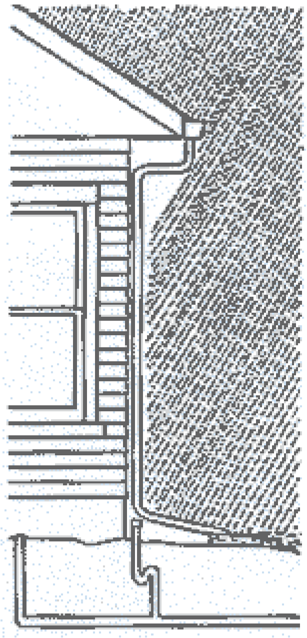
- Reduce the amount of wastewater flowing in the CSS and subsequently reduce the number of incidents where sewer overflow occurs into receiving waters.
- Reduce the quantity of wastewater received by WWTW and therefore the costs associated of processing wastewater. This financial saving is passed onto the customers.
- Defer the need for costly upgrades at WWTW.
- Reduce basement and street flooding (and associated human health risks).

Figure 17: Logo for a downspout (i.e. downpipe) disconnection programme
(Source: City of Toronto: Toronto Water)

The various downpipe disconnection programmes seem to rely largely on appealing to home owners' sense of community responsibility (see box). The City provides a grace period, during which the downpipe is disconnected free of charge by the city authority.

> **Toronto Water – community appeal**
> **The City has a plan - but we need your help!**
> The City has many projects to improve water quality in Toronto as outlined in Toronto's Water Pollution Solution, but we need residents' help. While we're building tanks, tunnels and stormwater management ponds, we need residents to disconnect downspouts wherever possible (Source: www.toronto.ca)

Some programmes offer instructions to home owners on how to disconnect their downpipes themselves and in The City of Portland homeowners are paid US$53 for each downpipe they have disconnected and are subsequently given rebates on stormwater management fees. Similarly the City of Vancouver provides residents with a subsidy of $100 towards the cost of the disconnections. The City of Vancouver's website also provides information to residents on how to disconnect their downpipe from the CSS (see Figures 18 and 19). Figure 18 shows the simpler of the two options and provides instructions on how to cut the downpipe just above where it runs into the ground, how to extend the gutter away from the house where the water is made to flow onto a concrete or plastic splash block to prevent erosion. This permits the water to flow directly onto the ground to be absorbed by the soil. This is the preferred option and the best method in most situations. However, on properties where releasing the water onto the ground is not feasible an alternative method making use of a covered gravel trench is detailed (figure on the right).



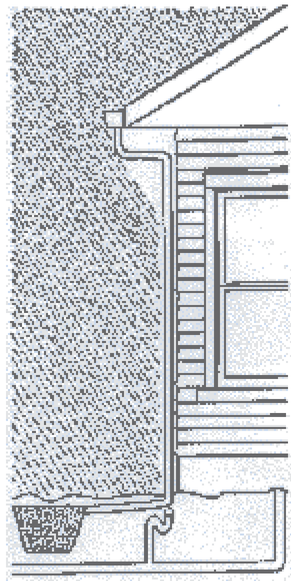


Figure 18: Splash back disconnection **Figure 19: Disconnection with gravel pit**

(Source: The City of Vancouver)

In some areas (e.g. dense urban settlements) where the likelihood of having a garden which can absorb the rainwater is less likely, alternative routing for the stormwater is suggested. The more common suggestions made are:

- Storage in a rainwater tank
- Diversion into the grey water recycling unit
- Systems to re-route water to discharge points.

Less common alternatives include green roofs (pictured right) and the construction of on-site wetlands or water features into which stormwater is channelled.

Figure 20: An example of a green roof, which reduces stormwater runoff by absorption and evapotranspiration

The community based awareness and education literature for the various programmes is similar and includes:

- What the programme is about.
- Motivation for why households need to disconnect their downspouts. Most literature details an environmental benefit and a positive spin-off for the homeowner.
- The cost of the disconnection, available subsidies or incentives
- How to go about getting the disconnection done.
- Timeframes and deadlines.
- Most of the literature also answers the question “How does the authority know if my downpipe is connected?” in order to deal with compliance
- Statement thanking residents for their cooperation.

4.1.4 European solutions to stormwater ingress

A number of European cities have started to tackle stormwater ingress. Chouli et al (2007) report on cases where financial incentives or levies are used to encourage private land owners to manage their stormwater. Table 10 below summarise the various approaches being used by various cities. It is interesting to note that all cities implemented a pilot programme to test the feasibility and effectiveness of the intervention before going to scale and that public information campaigns and the enforcement of regulations and restrictions are common to all programmes.

Table 10: A summary of approaches used internationally to encourage stormwater management on individual properties

	Pilot project	Regulations/ restrictions	Discharge control	Discharge fees	Stormwater fees	Incentives/ rebates	Info campaigns
Sweden	√	√	√		√	√	√
Denmark	√	√	√		√	√	√
Netherlands	√	√	√	√	√	√	√
Germany	√	√	√	√	√	√	√
England	√	√	√	√	√	√	√
France	√	√	√	√		√	√

(Source: Chouli et al, 2007).

In Sweden and Germany stormwater fees are charged per m^2 of impervious surface found on the property. Rebates or incentives are offered on these charges should land owners implement some form of source control. In the Netherlands the incentive is in the form of a financial contribution for each m^2 of impervious surface that is disconnected from the sewer system.

Many of the interventions have required adjustments in the way different departments within municipalities function and have forced closer collaboration between departments. Information campaigns were not limited to public education, and in many cases included specialised technical assistance. Chouli et al (2007) suggest that a key factor in the success is the political will to enforce regulations as well as using innovative strategies to encourage home owners to be compliant. As with most things, a combination of approaches is likely to have the greatest success.

4.1.5 Water Sensitive Urban Drainage

Over the last decade there has been a strong shift in urban drainage thinking from “how big a pipe do we need to get all the stormwater away as quickly as possible?” to “what can we do to slow down and retain the stormwater so as to reduce urban flooding and improve stormwater quality?”. This is a completely new paradigm. Known variously as *Water Sensitive Urban Drainage* or *Sustainable Urban Drainage Systems (SUDS)*, a large amount of literature can be found on the internet on this topic. The University of Cape Town presently has an ongoing project under the auspices of the Water Research Commission to develop a unified and comprehensive South African guideline on Water Sensitive Urban Drainage. Meanwhile certain South African municipalities such as Cape Town and Johannesburg have mandated that all new developments be stormwater neutral, i.e. that they do not heighten the intensity of the runoff from the area which they impact.

Chapter 5

Testing a community-based stormwater inspection programme

While the Msunduzi Municipality may inspect a property for an illegal connection if a specific report is made, it discontinued routine inspections more than ten years ago. The reason given for this is that it does not have enough inspectors (building inspectors or sewer inspectors). This raises the question: why does one need to use a relatively highly trained inspector to monitor something as simple as illegal stormwater connections? South Africa has a very high level of unemployment and the technical side of illegal stormwater inspection can be learned by a reasonably intelligent person in a matter of days or even hours. To test this concept, a pilot community-based inspection programme was carried out in the suburb of Northdale, Pietermaritzburg. Anecdotal evidence (Gaydon, 2007) suggests that this area has a fairly high level of direct stormwater to sewer connections.

5.1 The pilot study area in the Northdale suburb of Pietermaritzburg

The Northdale area of Pietermaritzburg is believed to be particularly problematic in terms of stormwater ingress from domestic properties. There are a number of factors which may have potentially contributed to the high level of ingress from this area:

- Some areas in Northdale were allegedly originally serviced by combined sewers
- The stand sizes are small. Most homeowners over the years have added on to the homes and therefore the roof and paved area is a large proportion of the total erf size.
- Many properties are heavily paved and/or tarred (e.g. Figure 21 below)
- Many houses do not have easy access to the stormwater drainage system as they are down slope of the road (and accompanying stormwater drains) and upslope of their neighbours who will object to receiving their stormwater.

A map of the area and the sewer reticulation network were examined and two potential pilot sites were identified. These were:

- the suburb of Suncrest, on steeper ground with somewhat newer housing and larger plot sizes, which is located in the council's Ward 28 (Figure 22) and
- Lotusville/Woodlands, on flatter ground with older housing and smaller plot sizes, which is located in the council's Ward 31 (Figure 23)

Figure 21: A typical yard in the Northdale area, with a large percentage paved and the downpipes disappearing into gullies which may be connected to the sewer network.

Figure 22: Suncrest (in the middle between the river lines) and its associated sewer network

Figure 23: Lotusville and associated sewer network

5.2 Preliminary field visit

Lotusville is of relatively flat aspect, especially when compared to other parts of Northdale. Many of the residents have lived at their residences for up to 30 years; the houses were originally built by the Municipality to accommodate Indian people who were moved out of the city as a result of the group areas act under the apartheid government.

Over the years many of the homes have been extended. This has resulted in gutters being added to homes, an increase in the size of paved areas, house sizes being increased and the construction of additional outbuildings. The properties are generally small with an average size of about 225 m^2 with large proportions of each property being built on. In many cases this leaves little space for stormwater to drain to, especially for properties that are located below the road level.

During a site visit one home was found where the gutters from the roof disappeared into the ground in neatly constructed drains. The owner of the property did not know where the rainwater went and there was no evidence of stormwater drains to which they could have been linked (Figure 24). The yard of the property was extensively surfaced with a stormwater manhole in the centre of the driveway.

Figure 24: A downpipe from a home in Lotusville disappearing into a gully – where does the water go?

The following photograph (Figure 25) of a home in Lotusville that was being constructed shows the builder's apparent intention to connect the roof gutters to the sewer line (with a soakpit in line to absorb some of the flow). The red arrow points to a trench that has been dug and links to the gutter visible in the front of the house as well as one on the other side of the house. The trench makes its way to what appears to be a soak pit (blue arrow). However the size of the soak pit would not be sufficient to cope with an average rain event. The outlet or overflow from the soak pit then joins with the main sewer line (not visible in this figure).

Later in the Suncrest area a building contractor, a Mr Pillay, who was working on the construction of a new church, was interviewed. The area was heavily paved, so there would have been a definite temptation to join the stormwater to the sewer. All was in order, but Mr Pillay said that as a building contractor and general purpose handyman he was frequently asked by people to connect their stormwater to their sewers. He declined to do this, as he knows it is illegal, but he did not doubt that many other builders would oblige. He also stated that the municipality is ineffective in policing its stormwater regulations (the municipality, at least at inspector level, does not deny this assertion).

"Many people have asked me to connect their gutters to the sewer system, but I won't do it – I tell them it is illegal." A private contractor working in the Suncrest area who does building and renovation work.

Figure 25: The red arrow shows a trench designed to route stormwater to the sewer (off camera), while the blue arrow shows what appears to be intended as an inline soakpit.

5.3 Formation of a partnership with the Msunduzi Municipality

With approval from the Msunduzi Municipality the councillors from Ward 28 and Ward 31 were approached to assist in recruiting members of the community to carry out a survey in the pilot areas. The survey was purposely not focussed just on illegal stormwater connections, but was framed as an investigation into stormwater problems in general.

Both councillors were helpful and fully supported the project. They each spent time with the research team pointing out different problems encountered in their wards with regards to stormwater and sewers in the area.

5.4 Training community inspectors

In Ward 28 six individuals were recruited, half of whom were female; in Ward 31 only four individuals were recruited, and again half were female.

Training took place in two sessions. During the first session each team went through the questionnaire that they would be conducting with house owners. The methods they would be using to ascertain where the stormwater of each house was disposed of was also explained. During the second training session actual house visits were made, interviews were conducted and dye tests were done. After asking each home owner questions about their drainage in general, the recruits then carried out a full drainage inspection. Where stormwater drained into a ground pipe, the terminal sewer was opened and water mixed with food colouring was poured down the pipe to determine whether or not the pipe was connected to the sewer system. However this was not necessary when all the stormwater could be accounted for.

The property owner, a relative of the owner or the tenant was also interviewed.

Questions in the survey included the following:

- How is the stormwater on your property disposed of? (Options: stormwater drain, garden, soak pit, sewer)
- What is the size of the property?
- What percentage of the property is built on or paved?
- Has stormwater ever flooded your house?

5.5 Results from the survey

The survey results are summarised in Table 11 below.

In Ward 28, the newer area, where 228 homes were surveyed, 4.9% of the homes were found to have a direct stormwater connection to the sewer. In the older area in Ward 31, where 283 homes were surveyed, this figure was significantly higher at 13.4%. This difference was according to expectations, as anecdotal evidence suggests that direct connections were more common when the older housing stock was built.

The older area has small plots, on average 227 m^2 in extent. On the average plot 76% of the plot is either built on or paved, leaving just 54 m^2 on average to absorb all the stormwater. It is therefore not surprising that 24% of these homes were reported to experience flooding during storms.

The newer area has larger plots, although these are still fairly small with the average stand size of 360 m^2. On the average plot 65% of the plot is either built on or paved, leaving 126 m^2 on average to absorb all the stormwater. This is 130% more absorption area than in the other survey site, so it makes sense that incidence of flooding was lower at 13%. The flooding incidence is still high, however, which is no doubt due to the smallish erf size and the high percentage that is built on or paved.

In Ward 28, the newer area, the total area reported to be draining into the sewer network from the 4.9% of homes with direct connections amounted to 2624 m^2. This worked out at an average of 238 m^2 per house with direct connections.

In Ward 31, the older area with smaller erfs and more direct connections, the total area reported to be draining into the sewer network from the 13.4% of homes with direct connections amounted to 6075 m^2. This worked out at an average of 160 m^2 per house with direct connections.

Table 11: Summary Statistics from Stormwater Inspection Programme

Ward 28 **225 houses surveyed**			
1	% of houses with stormwater to sewer connection	4.9%	
2	% of houses that experience flooding during storms	13.3%	
3	Total area draining into sewer	2 625	m^2
4	Average size of property	360	m^2
5	Average percentage of property built on	65.4%	
6	Average area drained by each direct stormwater to sewer connection	238	m^2

Ward 31 **283 houses surveyed**			
1	% of houses with stormwater to sewer connection	13.4%	
2	% of houses that experience flooding during storms	23.7%	
3	Total area draining into sewer	6 075	m^2
4	Average size of property	227	m^2
5	Average percentage of property built on	76.0%	
6	Average area drained by each direct stormwater to sewer connection	160	m^2

The survey work was audited and thoroughly checked to ensure that the results could be used with confidence.

5.6 Frequent comments from home owners in both wards

In both of the areas surveyed a frequent comment made was that flooding was caused by blocked stormwater drains in the roads. The houses located below these drains are subject to flooding.

In Ward 28 a frequent comment was that the neighbour had blocked the stormwater drain, causing the stormwater to back up. In cases where the drain was servicing several sites, stormwater then takes several days to soak away, resulting in unpleasant conditions. This was expressed as a reason to illegally connect drainage to the sewer system.

In Ward 31 many noted that the sewer overflows during heavy storms.

5.7 Follow-up Questionnaire

Results from the first questionnaire were used to establish which houses in both the wards surveyed had direct stormwater connections into the sewer line. A follow up survey was done, partly to confirm that the original survey work was correct, and partly to enable further questions to be asked.

All 11 of the homes with illegal connections in Ward 28 were revisited, while only 28 of the 38 homes found with such connections in Ward 31 were surveyed (the other 10 were unavailable on the days on which the follow-up survey was conducted).

The follow-up survey included the following questions:

1. Will you consent to answering a few follow-up questions resulting from the original survey? YES/NO
2. Are you aware that the stormwater from your property is disposed of into the sewer? YES/NO
3. What are the reasons you dispose of your stormwater into the sewer?..
4. Are you aware of the bylaws against this? YES/NO
5. Are you prepared to find alternatives for your stormwater disposal? YES/NO
6. Would you pay for such a service? YES/NO
7. Are you aware of the problems that Darvill sewerage works experiences during heavy rainfall? YES/NO

In view of the small number of homes concerned and wanting to ensure accuracy, the DUCT manager conducted this follow-up survey personally. Despite the fact that members of the community were not used to do this further research, almost all those surveyed in the follow-up visits were willing to answer these questions.

5.8 Results from follow-up questionnaire

Figures 26 to 31 below show the results of questions 1, 2, 4, 5, 6 and 7 graphically.

Nearly all the participants agreed to answer the questions, and were able to remember the occasion when the first survey was done (Figure 26). However one participant in Ward 31 chose not to participate, stating that he could not be sure that the information would not be used against him.

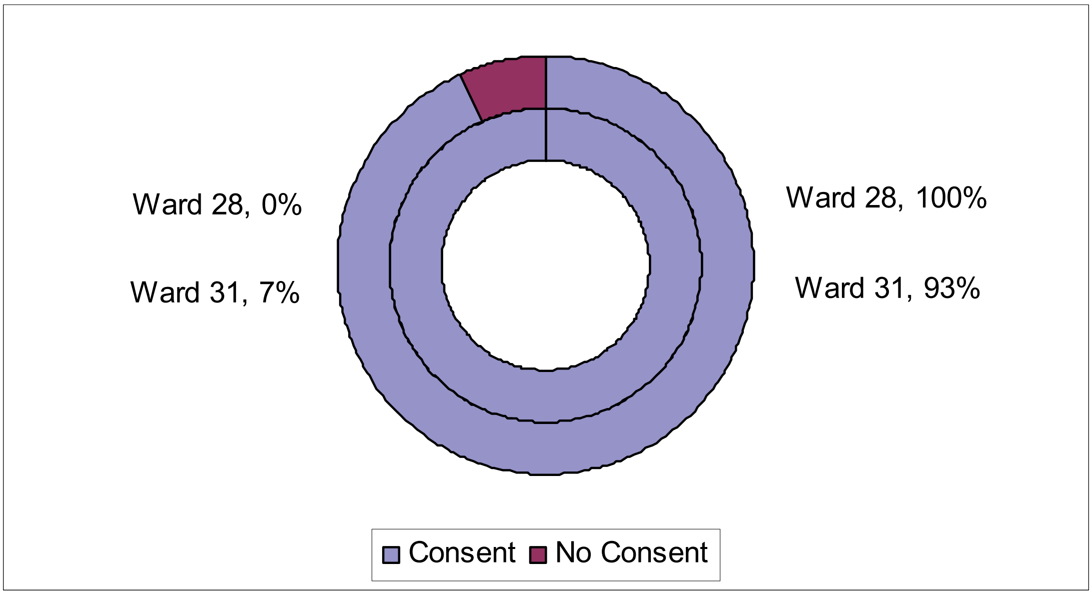


Figure 26: Proportions of participants who gave consent to answer the follow up questions

Approximately half of the respondents in both wards stated that they were unaware that their properties had stormwater connections into the sewer line (Figure 27). There are three possible reasons for this:

- They were afraid to admit that they knew about the illegal connection.
- The pipe containing their stormwater leaves their property before entering the sewer, and they were genuinely unaware of its destination.
- They have never thought about where their stormwater goes.

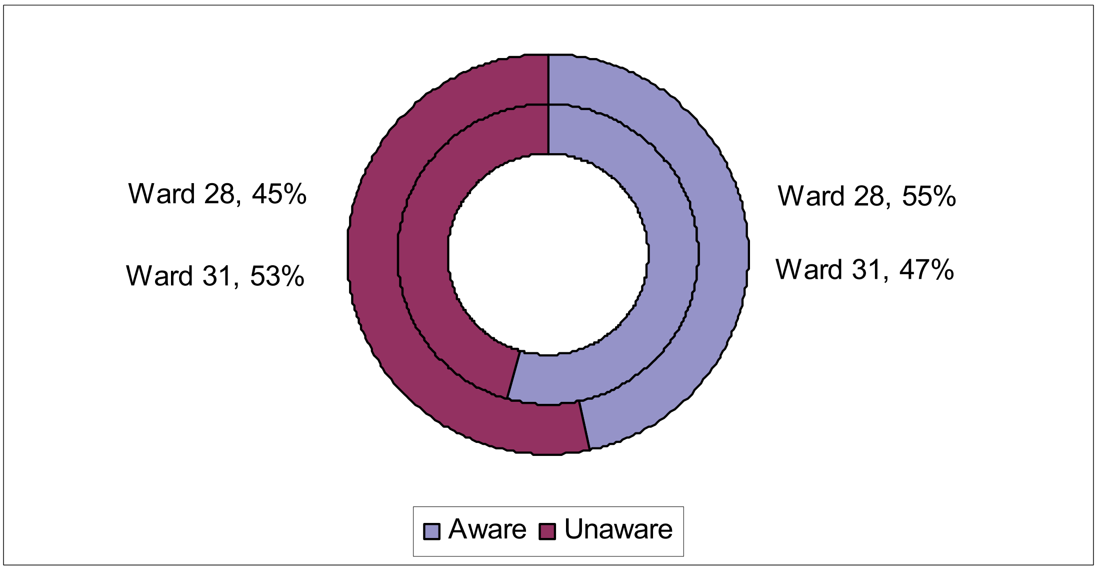


Figure 27: Proportions of participants who were aware that their stormwater was being disposed of in the sewer

The most common reason given for using the sewer to dispose of their stormwater is that the neighbours have blocked the stormwater drain. Other reasons given were that it had always been that way, and that it was done to solve a flooding problem.

A low proportion of participants knew about the bylaws in place in Pietermaritzburg against stormwater connections into the sewer line (Figure 28). A quarter of the Ward 28 respondents claimed to be aware of the bylaw, while only an eighth of the ward 31 respondents said they were aware. Again, the answer to this question might not necessarily have been truthful, as people might have been afraid of incriminating themselves by admitting that they knew there were violating the law.

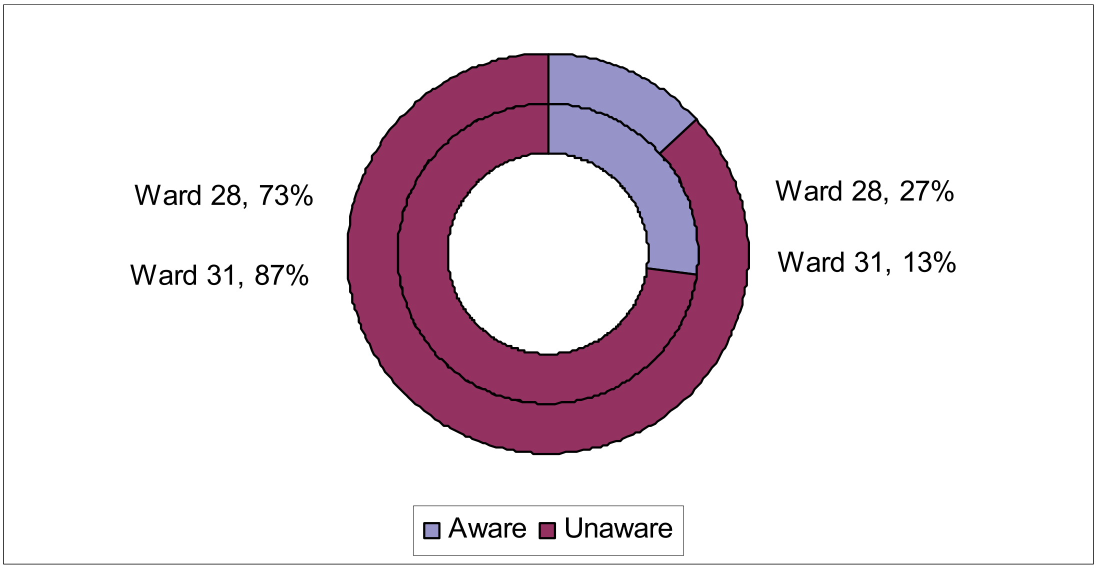


Figure 28: Awareness of bylaws against stormwater disposal.

Between a third and a half of the respondents were willing to find alternative means for disposal of their stormwater (Figure 29).

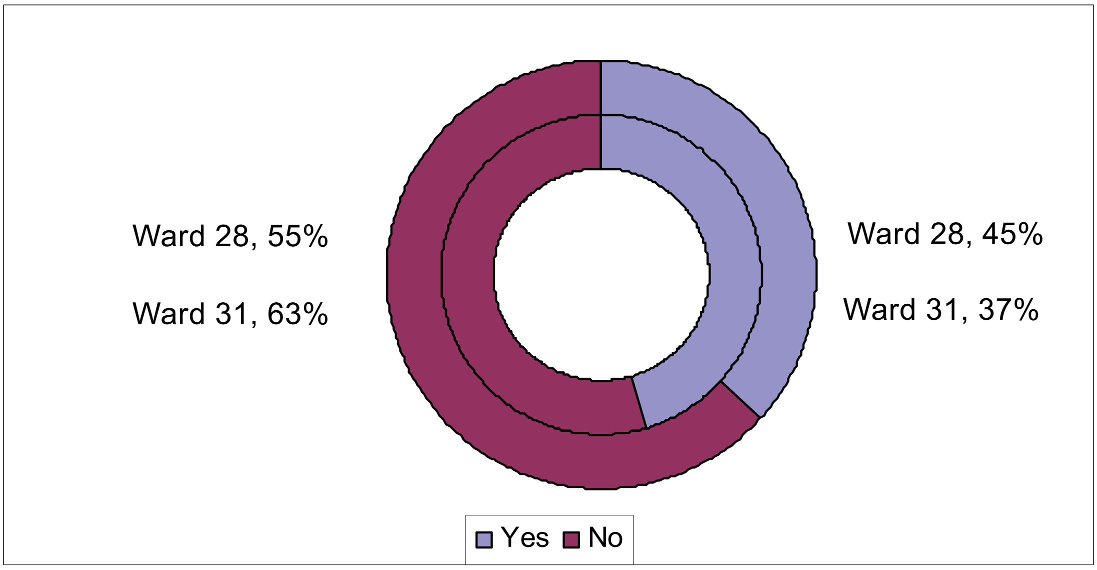


Figure 29: Preparedness to find alternative solution for stormwater disposal

However, when asked if they would be prepared to pay to a monthly levy for using the sewer for disposing of their stormwater, none of the respondents agreed (Figure 30).

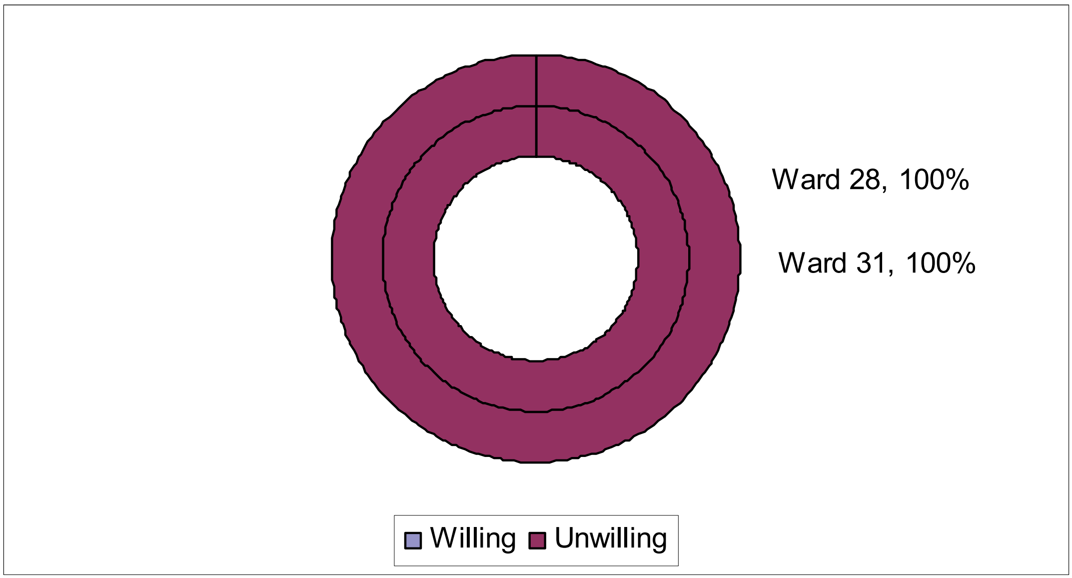


Figure 30: Willingness to pay to continue to use stormwater to sewer connection

Only a quarter of the respondents were aware of the problems experienced with stormwater at the Darvill Sewage Works in Pietermaritzburg (Figure 31).

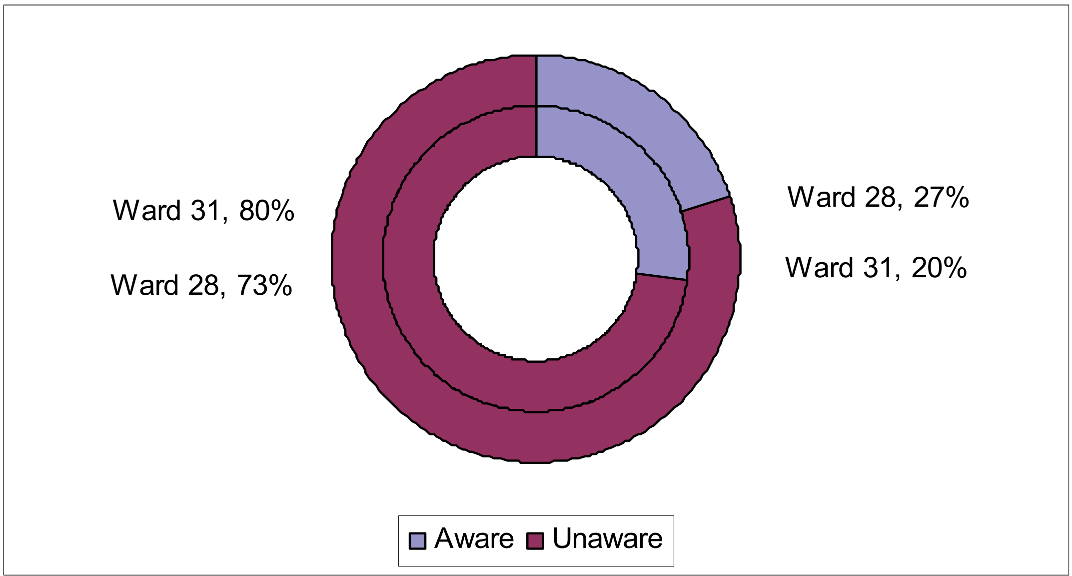


Figure 31: Awareness of problems with stormwater at Darvill sewage works

Several of the respondents commented that they would like to see municipal action to improve the drainage in the area before they would consider playing their part in solving the problem of stormwater ingress (note that in the first survey it was found that between 13% and 24% of the homes surveyed experienced flooding problems during heavy rainfall). This indicates that an educational campaign to encourage the disconnection of illegal stormwater connections is more likely to be successful if it is preceded by municipal action to improve drainage in the area.

5.9 Correlation with ingress measurements

5.9.1 Method and data

The survey discussed in sections 5.4 and 5.5 above was carried out in September 2008. The Msunduzi Municipality then agreed to assist with this research by contracting a specialist company (Flowmetrix) to log the sewer flows in the survey area for a period during the rain season. Two loggers were installed at the Ward 31 site on 10 December 2008 and these were removed on 26 January 2009. The upper measuring station was located in a manhole immediately above the 283 homes included in the survey, while the lower measuring station was located in a manhole below these homes (Figure 32). The exact falls of the sewers above these two manholes were established using a dumpy level, in order that depth measurements in the sewer channels could be converted into flow measurements. A local resident (one of the people used to conduct the original survey) was contracted to record the rainfall during the monitoring period and a rain gauge was set up on his property for the purpose.

Figure 32: Installation of sewer flow logging equipment at Ward 31 site

The number of sites contributing to flow at the upper station was counted from a recent aerial photograph, and this was found to be 800, plus two schools. The number of additional sites between the upper and lower stations was 300 (of which 283 were included in the survey).

Rainfall was recorded at the site from December 15th until January 11th. The measurements are reproduced in Table 12 below. The person entrusted with this duty was asked to record the rainfall on an hourly basis, but appears to have either misunderstood the instruction or been unwilling to carry it out, as only one reading per day was made. For comparative purposes the rainfall records for the city's two weather stations is recorded alongside for the same period. These two stations, one at the Darvill sewage works and one at the Botanical Gardens, are both 5 kilometres from the sewer monitoring site, with the former in a south easterly direction and the latter in a south-westerly direction. The city's rainfall is higher on its western side where there is a 300 metre elevation difference from the city bowl to an escarpment. This effect can be seen in the comparative rain figures for the three sites, with the Botanical gardens site measuring 239 mm over the period, 26% more than the Northdale monitoring site where 189 mm was recorded, which was in turn 67% more than the 113 mm recorded at the Darvill site.

Table 12: Rainfall record for monitoring site, with records from Pietermaritzburg's two weather stations for comparison

Recorded date of rainfall	NORTHDALE - Ward 31	DARVILL WWTW 5 km South East	BOTANICAL GARDENS 5 km South West
15-Dec	14.0	3.5	4.3
16-Dec	8.0		16.5
17-Dec			0.2
18-Dec			
19-Dec			
20-Dec	12.0		
21-Dec			0.4
22-Dec		0.4	0.5
23-Dec	5.0		
24-Dec			
25-Dec	3.0		2.5
26-Dec	24.0	1.5	20.0
27-Dec	30.0		48.0
28-Dec	7.0	43.0	40.0
29-Dec	12.0	1.0	0.2
30-Dec			0.5
31-Dec	4.0		6.0
01-Jan	3.0		15.7
02-Jan	12.0	15.0	0.6
03-Jan	16.0		47.0
04-Jan	4.0	16.0	1.3
05-Jan	3.0	0.5	2.0
06-Jan		1.5	0.8
07-Jan		0.7	
08-Jan			0.2
09-Jan	12.0		8.0
10-Jan	6.0	4.0	22.7
11-Jan	14.0	26.0	1.6
TOTALS	189.0	113.1	239.0

The sewer monitoring equipment was installed on December 10th, but rain recording only commenced on December 15th. During the second week of the monitoring period (17 to 24 December) only 12 mm of rain was recorded, and that on December 20th. During this week at the upstream site the sewer flow[9] varied between 4 litres per second in the middle of the night, to 10 litres per second during the morning peak, which takes place between 06h00 and 09h00 (excluding a very short duration spike in the reading to 15 litres per second on December 22nd – this perhaps correlates with the 5 mm of rain which has been recorded on the morning of December 23rd?). The mean daily flow is 7.3 litres per second (Figure 33). Assuming a mean contribution of 10 kl per day from each of the two schools, the mean contribution for each of the 800 homes above the measuring station is 763 litres per day. In terms of roof area these houses fall approximately into the "medium" category (see Table 1) for which the average expected dry weather flow is 750 litres per day, so the figure of 763 derived above is within expectations.[10]

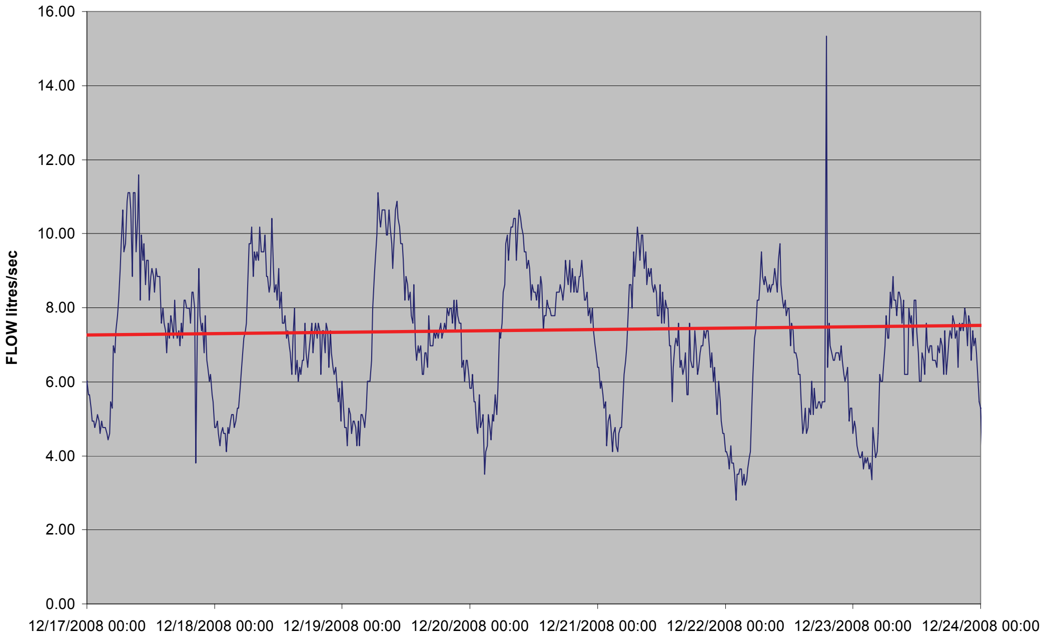


Figure 33: Sewer flow recorded during period 17 to 24 December, upper station, with mean flow trendline indicated.

The flow at the lower of the two logging points is shown in Figure 34 below. Here the daily variation over the same period was found to be between 5 and 16 litres per second, with an average of 10 litres per second. Making the same assumption about the contribution from the two schools, the average contribution for the 1 100 homes above the lower monitoring site is 767 litres per day, which is again within expectations.

On the day that the rainfall was recorded (20 December) there is no significant change in the sewer flows at either the upper or lower monitoring site. It is interesting to note that neither of the two

[9] Note that in this section flow records are referred to, but this is somewhat misleading. The instrumentation measures the depth of sewage in the manhole, and from this flow is calculated. A partial blockage in the line downstream could cause the depth to change, giving a false flow reading.
[10] It is notable that the Peak Dry Weather Flow is only 1.5 times the Average Dry Weather Flow, whereas typical design guideline figures for less than 1 000 homes would use a peak factor of 3.5.

weather stations, whose data is included in Table 12 above for comparative purposes, shows significant rainfall for December 20th, although they do both have a small amount of rain (0.4 mm to 0.5 mm).

During the third week of monitoring (from midnight on 24th December until midnight on 31st December) there was a significant amount of rainfall in the monitored catchment. On the site 80 mm of rain was recorded in the week, with the main falls of 24 mm on December 26th and 30 mm on December 27th. These readings are approximately matched at the other two monitoring sites over that period. Both the upper and lower gauges recorded very marked peaks in the sewer flow during this week (Figures 35 and 36 below – note that the vertical scales have now been adjusted due to the higher readings).

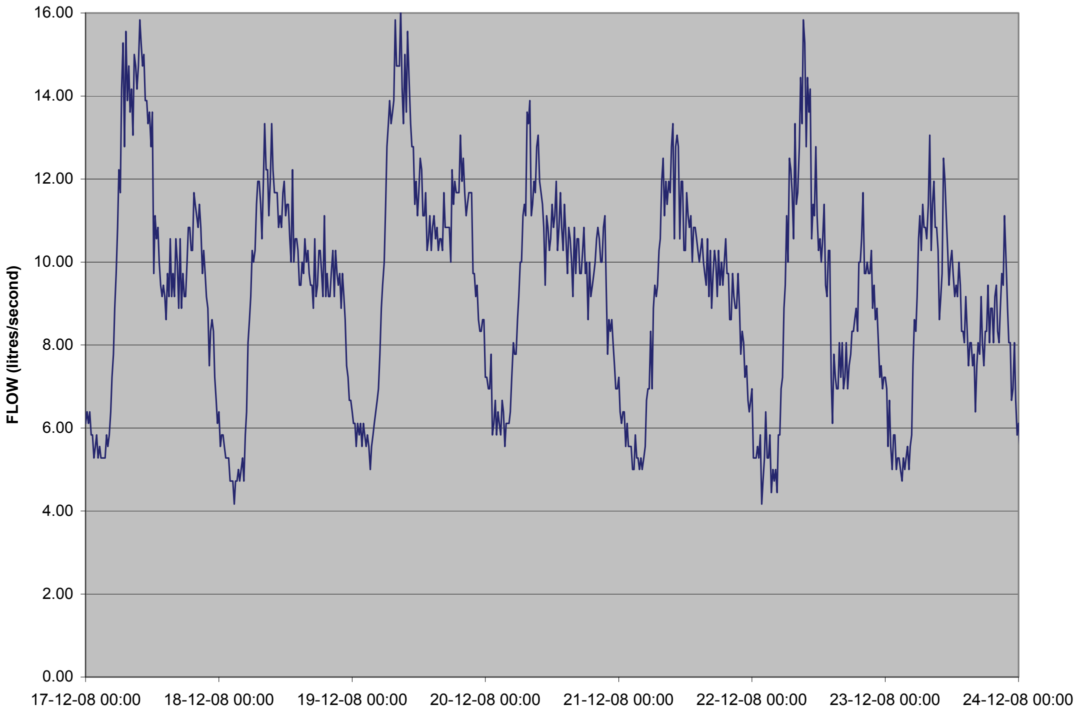


Figure 34: Flow recorded at the lower monitoring site from 17 to 24 December 2008

The flow record at the upper site peaked at 18h30 on December 26th at 36.9 litres per second, remained at that level for another 15 minutes, then dropped back to 8.4 litres per second, after which it peaked again at 35 litres per second at 19h30, only returning to approximately normal flow after another 30 minutes. The flow for the next 24 hours is normal, and then between 19h30 and 22h00 on December 27th the flow once again peaks at over 35 litres per second. After the December 27th storm the recorded flow does not revert to normal, but remains elevated approximately 30% above its previous pattern, with a short spike on December 28th. This flow at the upper site remains elevated for another seven days, with spikes on January 1st and January 3rd, and then shifts lower overnight on January 3rd back to the approximate[11] band that it had followed until December 26th (Figure 37).

[11] The flow from January 4th until January 10th ranges from 3 litres per second to 8 litres per second, which is in fact approx. 20% below the flow range prior to the December 26th storm.

The flows at the lower gauge peaked at the exact same time as those at the upper gauge, i.e. at 18h30 on 26th December. The flows remained elevated until 19h45, and then the gauge became dislodged and effectively useless, with the flows readings going negative. On December 27th the gauge was reinstalled, but the balance of the data from this gauge (see Figures 38 and 40) appears suspect.

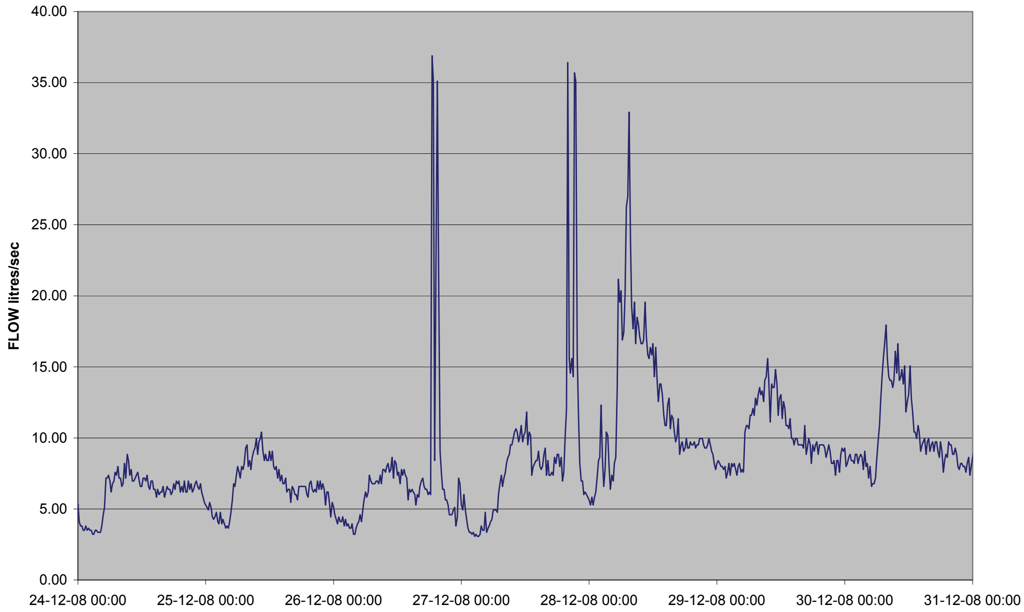


Figure 35: Flow recorded at the upper monitoring site from December 24th to 31st

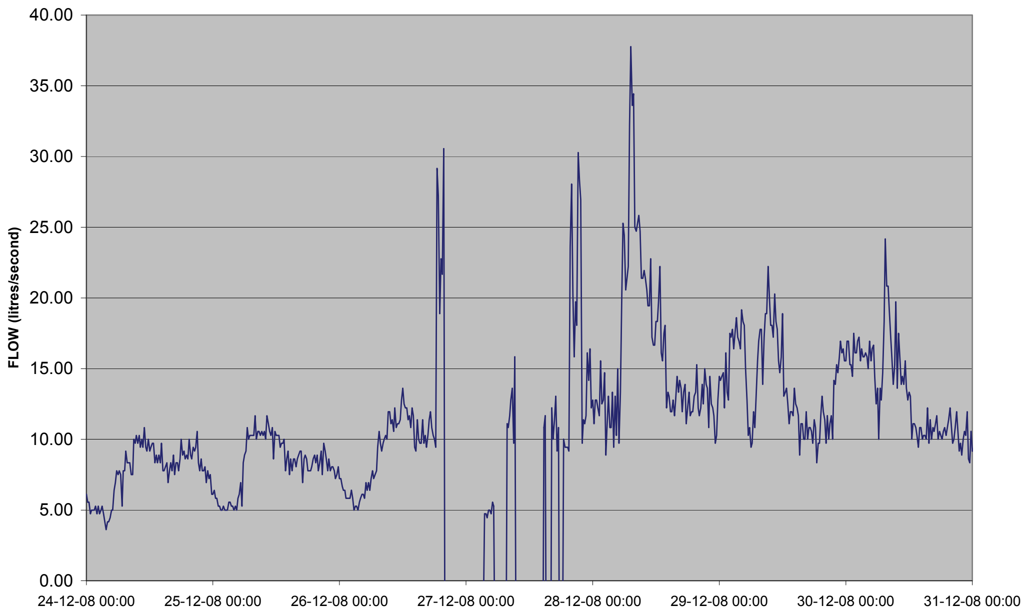


Figure 36: Flow recorded at the lower monitoring site December 24th to 31st

The flow at the upper monitoring site, after returning to approximately the normal range after January 3rd (Figure 37), continues in that range until January 10th and 11th, when the flow again spikes and becomes elevated after rainfall (Figure 39).

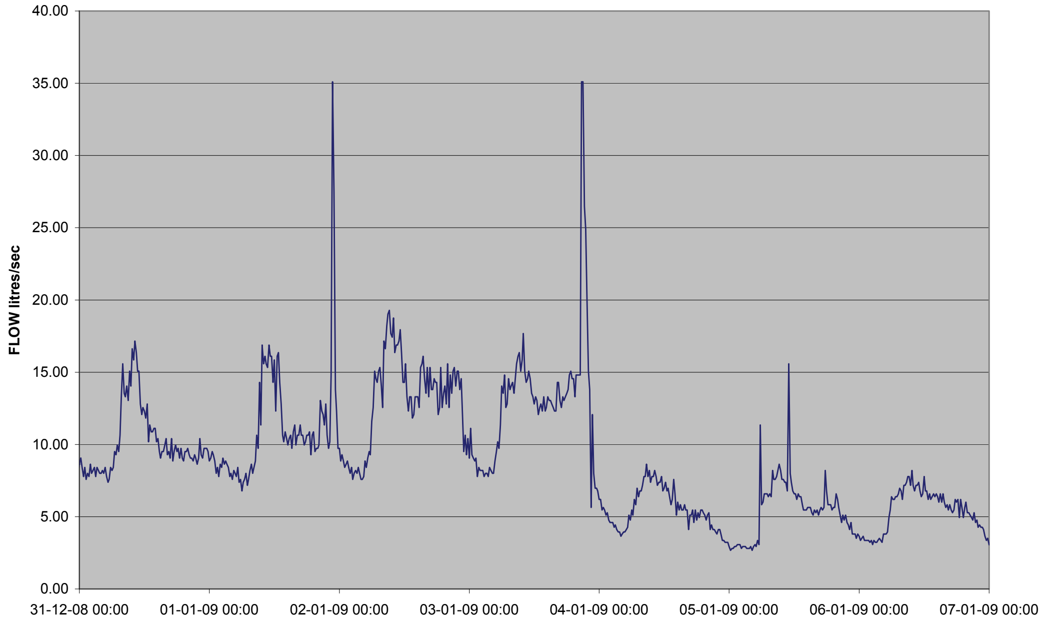


Figure 37: Flow recorded at the upper monitoring site from December 31st to January 7th

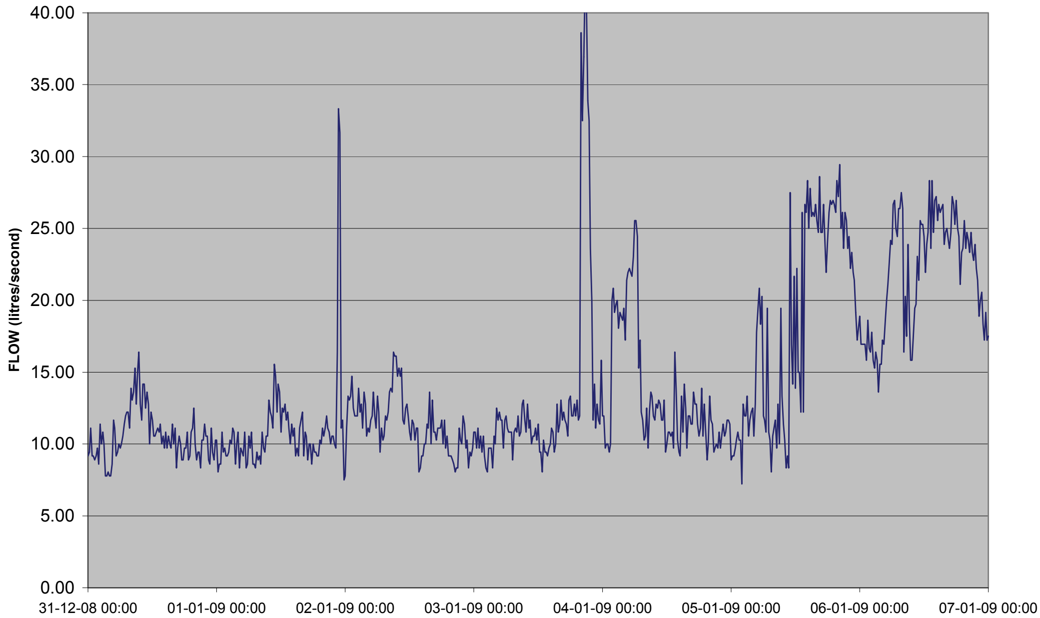


Figure 38: Flow recorded at the lower monitoring site from December 31st to January 7th

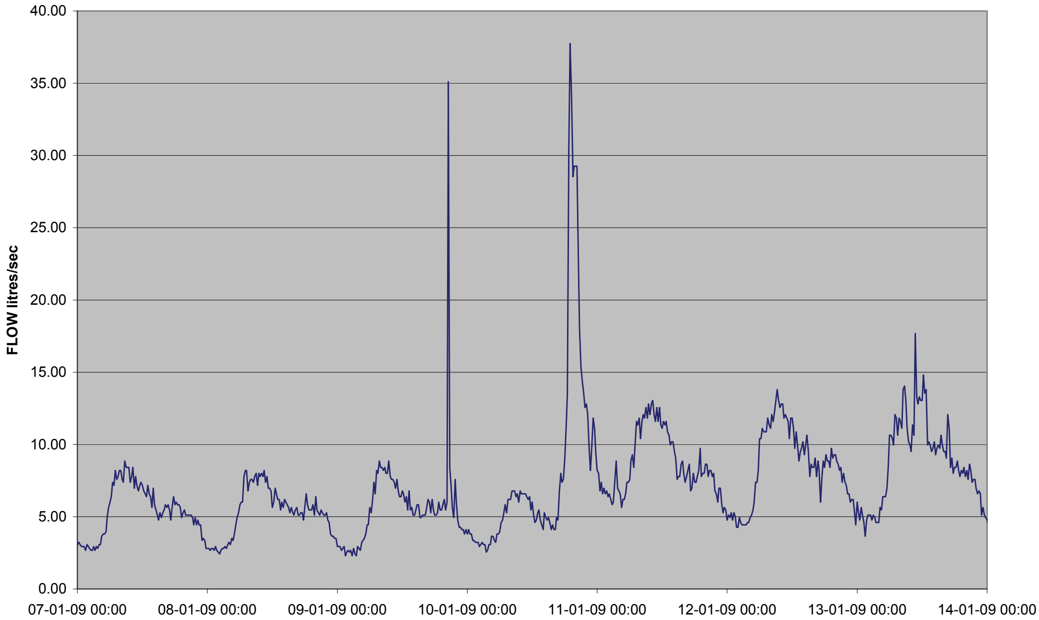


Figure 39: Flow recorded at the upper monitoring site from January 7th to January 14th

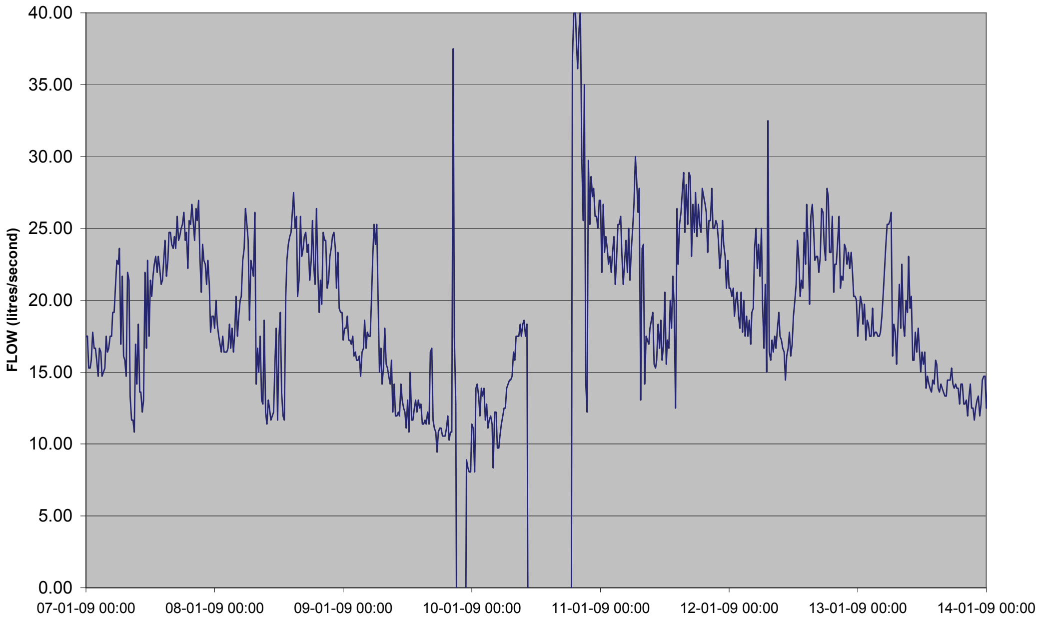


Figure 40: Flow recorded at the lower monitoring site from January 7th to January 14th

In the context of this discussion it should be noted that the data for the Darvill sewage works which is shown in Figure 10 covers the same period as the above monitoring exercise. The daily average inflow to Darvill was trending down to the 60 Ml to 70 Ml per day band until the wet period starting December 26th commenced. Within a day the average daily inflow more than doubled (not allowing for any flow that was diverted to the storm dam), and then continued in the 100 to 120 Ml per day band until heavy rain in late January pushed the inflow up once again.

5.9.2 Discussion of sewer flow monitoring results and correlation with rainfall

With the malfunctioning of the downstream gauge the flow differences between the two gauges cannot be used with confidence after December 26th. The difference between the gauges up until December 26th merely confirms that the difference in flow matches the expected difference due to the increment in the number of houses contributing.

Regarding the upstream gauge, it is noted that the peak readings are all at a similar level – approximately 35 litres per second. This is the capacity of the pipe flowing full. When the flow exceeds this level, the manhole backs up. This shows that the sewer capacity is exceeded whenever there is an appreciable amount of rain. Approximately 25 litres per second in stormwater flow appears to enter the sewer as a result of heavy rainfall.

How does this correlate with the survey findings which were summarized in Table 11? It was found that in Ward 31, 13.4% of the homes had direct connections, and the average area drained by each of these connections was 160 m^2. If this finding can be extrapolated to the 800 homes above the upstream gauge, then 107 direct connections could be expected draining an impervious area of 17 120 m^2. The sewer record indicates a storm duration on 26 December of two hours, during which time 24 mm of rain was recorded. The total volume of water that would have fallen on the 17 120 m^2 would have been 410 880 litres. If this volume drained away in two hours, the average storm flow from just that area for that time would have been 57 litres per second. The recorded peak in the sewer flow data for that period was 37 litres per second. This peak is therefore very likely to be caused by direct stormwater to sewer connections.

The actual flow peak observed is less than the peak that would be expected given the expected incidence of direct connections found in the area. Three possible explanations for this discrepancy are as follows:

- The calculation above is based on an assumption that the 800 homes above the upstream gauge matched the 283 homes below the upstream gauge (which were the homes actually visited) in terms of the frequency and the extent of illegal connections. This assumption is only likely to be approximately correct.
- The extent of the area calculated to be draining into the sewers in the surveyed area was 160 m^2 per site. It is possible that the surveyors incorrectly inferred that all the impervious area on each of these sites was draining to the sewer, when in fact only part of it was.
- It is also possible that some of the stormwater spilled out of the surcharging sewers, with the recorded sewer flow peak being simply the maximum capacity of the sewers.

One thing that can be concluded from the sewer flow monitoring, is that the sewer flow is well correlated with rainfall, and the percentage of storm flow relative to sewer flow observed is in the order of 200 to 300. This correlates with observations of inflow at the Darvill sewage works for the city as a whole, which double, triple and quadruple depending on rainfall intensity and extent.

It is also interesting to note that the sewer flow remains significantly elevated for several days after the original storm. This is evidence that there is ongoing infiltration into the sewer lines from the groundwater, presumably through breaks in the sewer system.

A great deal more sewer flow monitoring work will need to be done to gain a fuller and more accurate picture of the degree and extent of stormwater ingress in the Msunduzi Municipality. It is likely that the monitoring technology will be more accurate as one moves to larger bulk sewers (e.g. 600 mm in diameter rather than the 250 mm in diameter that was monitored here). The Msunduzi Municipality has been fortunate to obtain several million Rands in funding from national government to allow for such an initiative, and this monitoring work is expected to start in 2011.

5.10 Survey Evaluation

The use of community members to carry out the survey was ideal in that they were able to gain access to properties with ease. However difficulties did arise when auditing their work, in some cases their inspection had not been thorough enough and they did fail to report unusual cases. For example, when the research team paid a visit to a house in Ward 31 during the audit it was found that the owner was running a make shift car workshop from the back of the house where it appeared as if oil was being disposed of into the sewerage system. Using people from outside the community may help reduce the number of biased reports; however such people may find it more difficult to gain access to properties.

Part of the purpose of this survey was to gain an understanding of why the local municipality has effectively given up on the inspection of illegal domestic stormwater to sewer connections. One reason which has been offered is that they no longer have the staff to carry out this function. This begs the question, how hard is it to check for illegal connections? One does not require years of training to be able to identify an illegal stormwater to sewer connection.

In this respect the building inspection programme was instructive and a success. Ten local residents, of a variety of ages, were trained in less than one day to carry out the stormwater inspections. They then completed the survey work in less than one month. In some instances there were concerns that some of the surveyors might have worked too fast and there was therefore doubt over the quality of their work. DUCT audited the surveys until it was satisfied that they had indeed carried out the inspections as instructed. Occasionally an illegal connection was missed, for example when the stormwater from one property was disposed onto another property before entering a sewer, but such incidents were rare.

There was no resistance reported from the community to the carrying out of the survey, despite the fact that it required the surveyors to enter private property. This in itself was an encouraging finding. To make the survey less threatening, care was taken to stress that the surveyors were not working for the municipality, and that they were interested in stormwater problems in general, rather than in illegal connections. However, despite the success of this work, it cannot be easy for community-based inspectors in all cases to honestly and accurately report on illegal connections observed at their neighbours' homes. For this reason DUCT believes that if anything this survey methodology probably results in an under-reporting of illegal connections. Hopefully there should not be accuracy problems with other issues such as % paved area and on-site flooding as these are easily estimated and residents were often keen to inform the surveyors of the drainage and sewer problems they were experiencing.

In Section 3.4.1.2 above the Msunduzi Municipality's method for dealing with illegal stormwater connections was described. As the municipality's complement of skilled sewer inspectors has halved in the last fifteen years, even as the total length of sewer for which they are responsible has significantly increased, it is not surprising that the council effectively gave up on the policing of illegal stormwater connections over ten years ago.

This pilot field survey has shown that it is possible to recruit and train stormwater inspectors from the community fairly easily and inexpensively. The 10 community inspectors (working in pairs) were successful in gaining access to 508 private properties, and this was done within the space of one month. This represents 1% of the 50 000 homes connected to the Msunduzi sewer network, so it is not insignificant. During this inspection process 49 illegal connections were found. With more training and supervision, and if the inspectors had been given real authority and were not working in their exact home neighbourhoods, perhaps even more illegal connections would have been found. A team twice this size could cover the entire city within the space of four years (admittedly at a cost of several million Rands, but perhaps this would be well worth it if the stormwater ingress problem was significantly improved). If the city is serious about dealing with its illegal connection problem, it should consider setting up a dedicated inspection team of 20 junior stormwater inspectors, working under one fully qualified inspector. As much of the work will need to be carried out outside of normal working hours (in order to gain access to properties), consideration should be given to contracting this work out and not trying to do it using permanent council staff.

However, as was shown in Section 3.4.1.2, the main reason the Msunduzi Municipality has given up on illegal stormwater inspections is that its enforcement system is unworkable. The eight step process is extremely time consuming, expensive and complicated. By contrast the three step enforcement process previously used by Cape Town (see 3.4.2.2) was more cost-effective and was to an extent self-financing. For example, using the Cape Town domestic tariff of R2.84 per square metre of surface illegally connected to the sewer, the revenue that would have been generated from the 508 sites inspected as part of the pilot project would be R24 708 per month, or R296 496 per annum. This tariff is waived as soon as the property owner corrects the illegal connection, but the owner is given an incentive for doing the work and for not dragging the municipality through a lengthy formal process.

Residents at both pilot sites felt that the Municipality should do more to curb the problem of excess stormwater run-off during heavy storms. Co-operation between communities and their municipalities is essential in addressing the problem. Currently people view the municipality as apathetic towards their needs. This mindset needs to be changed by active participation and improved service delivery from the municipality’s side in conjunction with the education campaign.

Chapter 6

Testing a public education programme

This report identified the need to increase awareness of the legal and environmental aspects of stormwater ingress. This chapter outlines and presents the results of a public education programme and follow up survey undertaken during November 2009. The education programme aimed to create awareness of the following issues associated with illegal stormwater connections:

a. The environmental consequences of stormwater ingress into sewers
b. The nature of direct stormwater to sewer connections
c. The method for identifying direct stormwater to sewer connections
d. The legality of direct stormwater to sewer connections and possible consequences of illegal connections

Section 6.1 describes the education programme design and methodology while section 6.2 outlines the follow up telephonic survey. The survey results are presented in section 6.3.

6.1 Education Programme design and methodology

The survey was designed to test the effectiveness of educating the general public regarding the stormwater issues described above by means of posting an educational pamphlet to homeowners. The effectiveness of the pamphlet was tested by phoning homeowners from streets where the pamphlet was distributed as well as those from streets which hadn't received the pamphlet, and asking them questions about their stormwater. The responses of homeowners from targeted streets were then compared with those of homeowners from streets which were not targeted. Conclusions were drawn on the effectiveness of the pamphlet as an educational means and the post as a means of distribution.

6.1.1 Pamphlet design

The public education campaign was undertaken by means of an educational pamphlet designed to convey the above information in a simple, non-threatening and informative way. The pamphlet is shown in Figure 41 below.

Figure 41: Educational pamphlet on stormwater drainage

6.1.2 Sample Selection

The programme was tested in Pietermaritzburg in three suburbs of differing average household income. The suburbs selected were Prestbury (higher middle income), Northdale (middle income) and Imbali (lower income). Average property value from the city's recently updated property roll was used as a proxy for average household income.

Two streets of reasonable and comparable length were selected from each suburb using a Pietermaritzburg road map. Homeowners on one street selected in each suburb received the educational pamphlet by post, while those on the other street received nothing. One to two weeks later homeowners on all the selected streets were contacted telephonically and asked questions about their stormwater. The results were compared to test the effectiveness of the pamphlet as an educational means. The suburbs and streets selected are shown in Table 13 below:

Table 13: Education Programme Suburbs: Sample and Control Streets

Suburb	Street	Pamphlet/control	Average Property value
Northdale	Balhambra Way	Pamphlet	R660.519
(Middle income)	Bombay Rd	Control	R500.308
Prestbury	Morcom Rd	Pamphlet	R 717,434
(Higher middle income)	Boyd/Stott Rd	Control	R 759,157
Imbali	Manaye Rd	Pamphlet	R 81,738
(Low income)	Mthombothi Rd	Control	R 114,551

6.1.3 Distribution

Once the streets had been selected the Msunduzi Property Roll, which is available on the municipality's website, was consulted. The street address and corresponding name and initials of property owners on each street were extracted to produce a database of residents in each sample road to receive the pamphlet, as well as those in the control streets who would also be contacted during the telephone survey.

The pamphlets were put into envelopes addressed to the property owner and were posted by hand into the corresponding post boxes along each of the selected Roads. 203 pamphlets were posted along Balhambra Rd, 92 along Morcom Rd and 70 along Manaye Road. Some properties listed on the Roll were found empty with no postboxes or found to be a municipal servitude. This accounts for the difference between the total number of properties and the number of pamphlets distributed, seen in Table 14 below.

Table 14: Pamphlet distribution

Street	Total Number of properties	Pamphlets distributed
Balhambra	208	203
Bombay	574	
Morcom	99	92
Boyd/Stott	95	
Manaye	80	70
Mthombothi	165	

Distribution along Manaye Rd was conducted with assistance from residents as the street numbering system was unclear to the surveyors and was non-existent in some cases.

6.2 Follow up Survey

The follow up survey was designed to test the effectiveness of the public education campaign described in Section 6.1 above.

6.2.1 Methodology

The survey was conducted telephonically. A database of residents in the both the pamphlet and control roads was established using the Msunduzi Property Roll accessed via the Msunduzi local government website. The database included a street address and the name of the registered owner. Telephone numbers corresponding to the residents' initials, surname and street address were extracted from the Pietermaritzburg phonebook for 2009/10. The total number of phone numbers obtained for each road is shown in Table 15 below. For the middle income areas typically one third of the property owners had listed telephone numbers. For the lower income areas the percentage of listed numbers in the street chosen for pamphlet distribution was only 10%, while that for the control street (no pamphlets) was higher at 27%.

Table 15: Telephonic follow-up survey – residents sampled

	Residents listed on the Property Roll	Residents with listed phone numbers	%
Balhambra Way	203	68	33
Bombay Rd	208	63	30
Morcom Rd	92	37	40
Boyd/Stott Rd	96	28	29
Manaye Rd	70	7	10
Mthombothi Rd	79	21	27

6.2.2 Survey questions

The pamphlet groups and control groups were asked different sets of questions. The questions asked were designed to be as non-threatening as possible in order to get honest responses from the respondents.

The test group was asked:

a. Had they seen the pamphlet?
b. Where they aware of where their stormwater went from their property?
c. Had they used the test described in the pamphlet to determine where their stormwater went?

The control group was asked:

a. Did they know where their stormwater went?

The survey was introduced as follows:

"Good morning /evening Mr/Mrs ________ My name is ________ I'm calling from the Duzi uMngeni Conservation Trust in Pietermaritzburg. We're conducting a public education survey regarding stormwater drainage and dropped off an educational pamphlet in your post box a week ago. Did you see it? Do you know where your stormwater goes? Did you carry out the test described in the pamphlet?"

The telephone survey was conducted over a one week period, beginning 10 days after the pamphlets had been distributed. Homeowners that were not contacted on the first attempt during working hours were then called again between 7.30 and 8.30 am. The survey results are presented in Section 6.3 below.

6.3 Survey results

6.3.1 Number of homeowners contacted

Table 16 below shows the proportion of residents with phone number contacted in each group. In Northdale, 43% of Balhambra Way and 73% of Bombay Rd residents were contacted. In Prestbury 62% of Morcom Rd Residents and 71% percent of Boyd/Stott Rd residents were contacted and in Mbali 86% and 81% of Manaye and Mthombothi residents respectively were contacted.

With regard to the effectiveness of using post boxes to deliver the pamphlet to homeowners, only 41%, 48% and 50% of residents contacted in Balhambra way, Morcom Rd and Manaye Road confirmed they had seen the pamphlet. Residents who had not seen the pamphlet commented that their post boxes were incorrectly situated or that their post was often removed from their post boxes before they collected it. In some cases the homeowner was not resident or was different to the property roll listing.

Table 16: Proportion of homeowners surveyed

	Homeowners with listed phone numbers	Homeowners successfully contacted	%
Balhambra Way	68	29	43%
Bombay Rd	63	46	73%
Morcom Rd	37	23	62%
Boyd/Stott Rd	28	17	71%
Manaye Rd	7	6	86%
Mthombothi Rd	21	17	81%

6.3.2 Stormwater awareness

The results of the telephone survey are presented in Table 17. In response to the question, "Do you know where your stormwater goes", 52% of Northdale residents who received the pamphlet answered "Yes" as opposed to 30% of the control group residents who had not received the pamphlet. In Prestbury 39% of Morcom Rd residents answered "Yes" while only 29% of the control group were aware of where their stormwater was disposed. In Mbali, the statistics were similar for the sample and control groups with 67% and 65% of both reporting they were aware of where the stormwater went from their properties.

Only one resident in Northdale and one in Prestbury used the test described in the pamphlet to determine where their stormwater went.

Table 17: Summary statistics from the Public Education Programme

Northdale

1. Percentage of houses with phone numbers contacted:

   Balhambra Way (pamphlet):
   43%
   Bombay Rd (no pamphlet):
   73%

2. Percentage who saw the pamphlet (Balhambra Way)
   41%

3. Percentage who knew where their stormwater went:

   Balhambra Way
   52%
   Bombay Rd
   30%

4. Residents who tested their gutters using procedure described in the pamphlet
   1

Prestbury

1. Percentage of houses with phone numbers contacted:
   Morcom Rd (pamphlet):
   62%
   Boyd/Stott Rd (no pamphlet):
   71%
2. Percentage who saw the pamphlet (Morcom Rd)
   48%
3. Percentage who knew where their stormwater went:
   Morcom Rd
   39%
   Boyd/Stott Rd
   29%
4. Residents who tested their gutters using procedure described in the pamphlet
   1

Imbali

1. Percentage of houses with phone numbers contacted:
   Manaye Rd (pamphlet):
   86%
   Mthombothi Rd (no pamphlet):
   81%
2. Percentage who saw the pamphlet (Manaye Rd)
   50%
3. Percentage who knew where their stormwater went:
   Manaye Rd
   67%
   Mthombothi Rd
   65%
4. Residents who tested their gutters using procedure described in the pamphlet
   0

6.3.3 Frequent comments from home owners in the three suburbs

Apart from the planned questions, the survey provided an opportunity to listen to residents comments about their stormwater problems. In Northdale many residents commented that their drains had been filled up with concrete or that their stormwater was directed onto their neighbour's property and that they weren't aware of where it went from there. In some cases it was reported that the water flooded downhill onto an adjacent informal settlement. Northdale had the highest proportion of residents reporting problems with their stormwater drainage and many, under the impression that the survey was being conducted by the municipality, requested corrective action.

In Prestbury it seemed that the municipality had spent some time five or six years back attempting to identify and eliminate illegal sewer connections. Six residents reported that there had been an illegal connection on their property which they had paid to correct and now their stormwater now drained into a sump constructed for their property. A handful of Prestbury residents explained that there were two stormwater drainage systems on their property. In these cases the front gutters drained into a sump or gully while stormwater from the back of the house flooded downhill. Many residents who answered that their stormwater went into the gully could not confirm that it did not flow from there to the sewer system.

In Imbali most residents were familiar with their stormwater drainage system from their streets and in most cases residents answered confidently that their water went into the stormwater gully and on to the river.

Homeowners who had received the pamphlet and who had been unaware of how their stormwater was drained expressed appreciation about receiving the pamphlet and the awareness it had generated regarding the stormwater ingress problem. The information was new to almost half of the residents contacted in both the pamphlet and control streets.

6.4 Conclusions and recommendations

Homeowners in areas that received the pamphlet were found to be more aware of how their stormwater was drained than those in streets that didn’t receive the pamphlet (52% of Balhambra Way residents compared with 30% of Bombay Rd homeowners; 39% of Morcom Rd residents compared with 29% in Boyd/Stott Rd; in Imbali no difference was recorded but the sample sizes were small, and perhaps the fact that the pamphlet was not in Zulu might have affected its usefulness).

The means of distribution was only partially effective. Only 41% of the Northdale owners, 48% of the Prestbury owners and 50% of the Imbali owners said that they received the pamphlet addressed to them.

Two homeowners followed the procedure described in the pamphlet to determine where their stormwater went.

While this trial education programme was simple and inexpensive and made a measurable impact, it is not possible for a non government organisation such as DUCT to conduct an effective city wide campaign in the absence of a comprehensive city programme to address stormwater management issues. Such a campaign would need political support, and funds would need to be allocated to establishing a functioning and properly resourced stormwater inspectorate. With the right policy and programme in place, a multi faceted educational campaign could then be launched using a range of media and methods to reach the general public and homeowners in particular.

Chapter 7

Conclusions and Recommendations

7.1 Introduction

Stormwater ingress can result either from groundwater seeping into sewers through holes, breaks, joint failures or defective connections along the sewer reticulation network (infiltration) or from stormwater rapidly flowing into sewers via direct connections to the sewers from roof and foundation drains, downpipes and manhole covers (inflow).

The ingress of stormwater can cause sewer infrastructure to become overloaded during heavy rainfall. This results in overflowing sewer manholes and overburdened wastewater treatment plants. Raw sewage then finds its way onto streets, into stormwater drains and into streams and rivers. This problem is widely experienced in South Africa and the Msunduzi Municipality appears to be on the of the most acutely affected with peak flows tripling or even quadrupling during times of heavy rain.

This study outlined the stormwater ingress problem and reviewed current stormwater ingress literature. It explained the causes of stormwater ingress and reviewed international, national and local legislation pertaining to the problem. The report evaluated potential solutions to the stormwater ingress problem and two pilot studies to test mitigating measures in the form of community based inspection and public education programmes were undertaken.

7.2 Literature review

International literature focuses on the challenge of converting combined sewer and stormwater systems to separated sewer and stormwater systems as historically many European cities were built on large waterways and protection of the environment was not a primary consideration in design and town planning. A review of South African literature revealed that there is very little understanding and awareness of stormwater ingress. Water Service Authorities and Water Service Providers attempt to provide reactive maintenance instead of effectively enforcing the relevant legislation to reduce economic, environmental and health costs associated with overburdened wastewater treatment works. There is thus a need to identify policies for reducing infiltration and inflow in urban areas. Effective strategies should incorporate technical, environmental and legal considerations and require political will and a workable enforcement system.

7.3 Understanding stormwater ingress

Stormwater ingress is a seasonal problem highly correlated with rainfall. According to the Red Book guidelines sewer systems should be designed to accommodate 15% extra flow for ingress (additional to the design peak dry weather flow, which is up to 3.5 times the average dry weather flow) but experience shows that this margin is short of actual ingress. 1 mm of rain on a hard impervious surface results in one litre of runoff. Thus, 20 mm of rainfall on a 100 m^2 roof will introduce 2 000 litres of stormwater into a sewer system through a direct connection of the guttering system into the sewer line. This is more than double the typical daily sewage flow from a middle income family.

Other illegal connections include swimming pool overflows and water draining off paved areas directly into the sewer. Manhole covers that are missing or lie below the flood line are points of entry for stormwater into the sewerage system during rainfall. Direct and other illegal connections result in an instantaneous increase of flow during storm events.

Sewer pipes that are either cracked or have poorly sealed joints cause the sewer system to function like a subsoil drainage system causing a slower, prolonged increase of flow.

Combined sewer systems have historically been used in some countries as an alternative to separate sewer and stormwater systems. If their design capacity is exceeded a relief sewer discharges directly into a natural water body and untreated or partially treated effluent is spilled directly into the environment.

7.4 Stormwater ingress in South African cities

Pietermaritzburg, Buffalo City, Cape Town and East Rand Water Municipalities all report peak inflows during the rainy season that exceed the average dry weather flows by as much as 300 to 400 percent. Pietermaritzburg's council ceased to monitor stormwater ingress in 1992 and overloading of the sewer system causes significant pollution of the uMsunduzi River. This is one of the most significant environmental problems the city has. New residential and industrial areas in the Eastern Cape have resulted in a significant escalation of stormwater ingress into the municipal sewers. The allowance built into these sewers' design for inflow and infiltration is quite inadequate with instantaneous ingress pointing to gutter connections or direct inflow through manhole covers as the source.

7.5 South African legislation

National legislation regulates the quality of effluent that may be discharged by a WWTW into receiving waters and encourages local municipalities to formulate bylaws to protect their WWTWs. The legislation also provides default regulations for the drainage of properties. Most municipalities have bylaws prohibiting the routing of stormwater into drainage installations as well as to protect drainage installations from the ingress of floodwater. These bylaws typically follow DWA's model Water Services bylaws.

Ensuring legal compliance requires building control officers and building inspectors who are equipped to identify illegal connections. Msunduzi Local Municipality's system to enforce compliance is lengthy, laborious and time consuming, requiring a number of site inspections and ultimately legal proceedings if the property owner's co-operation is not forthcoming. Problems with access to properties during working hours severely hamper the municipality's enforcement capacity and the process is largely ineffective.

An alternative approach previously used in the Cape Town municipality made stormwater ingress legal, subject to the conditions the council imposed, which included a square metre based charge to homeowners with a direct stormwater connection to the sewer network. If the property owner was not happy to pay this charge on an ongoing basis, the responsibility lay with him or her to see that the direct connection was removed, and then to arrange for an inspection by a city official at a convenient time to confirm that this disconnection had indeed been done. This approach appeared to be practical and self sustaining.

7.6 Solutions to Stormwater ingress

Stormwater ingress can be reduced by upgrading the infrastructure and by reducing the water load at source. Measures to upgrade the infrastructure can range from less expensive such as replacing missing manhole covers to more expensive such as replacing defective sewers. Upgrading the capacity of the wastewater treatment works the most expensive solution. The elimination of direct connections at source should be borne by property owners and is therefore the cheapest intervention measure.

Reducing stormwater load at the point can be achieved using educational efforts, inspections and legal enforcement or financial incentives. Education and awareness programmes are most effective when conducted together with an inspection and the provision of alternative drainage solutions. Levies and incentives in the form of stormwater drainage fees have had success in addressing stormwater ingress problems in Europe and locally in Cape Town. These measures may have limited success in communities with low average disposable household income.

7.7 Community inspection and public education programmes

This study has found that it is not necessary to employ a highly trained building inspector to detect illegal stormwater connections and that the technical aspects of stormwater inspection are easily learnt. Training community based inspectors would help to create employment and would reduce the cost of paying overtime to city employees to access properties outside of working hours. A pilot community-based inspection programme was undertaken to test its effectiveness as a means of reducing stormwater load at the point of source. Ten local residents were trained in less than a day to carry out inspections and completed a survey of 500 properties in less than a month. It was concluded that community workers carrying out inspections had easier access to properties than municipal workers but that the risk of underreporting illegal connections may be higher. The training was carried out inexpensively.

A flow monitoring exercise also confirmed that sewer flow was well correlated with rainfall in the sample area, and that the instantaneous sewer flow peaks (which were up to five times average sewer flow) could be more than accounted for by the incidence of direct connections in the area. If only 10% of the homes in an area have illegal stormwater connections to the sewer network that is enough to quadruple the sewer flow during a rain storm of moderate intensity. More extensive flow monitoring work over a longer period of time would be needed to provide a fuller and more accurate picture of the stormwater ingress in the area.

The study also identified the need to increase awareness of the legal and environmental aspects of stormwater ingress and the nature and means of identifying illegal stormwater to sewer connections. A survey was conducted to test the effectiveness of educating the general public on the stormwater issues described above by means of posting an educational pamphlet to homeowners. A follow up assessment was conducted telephonically. The pamphlet did make a significant impact, but for such a campaign to be truly effective it would have to be part of a co-ordinated city wide campaign with the intent and the means to do follow up inspections and the will to deal with transgressors.

7.8 Recommendations

7.8.1 Inspection programmes

It is recommended that any municipality with a serious stormwater ingress problem should set up a dedicated inspection team of purpose trained contract stormwater inspectors. These contract inspectors would work under one fully qualified inspector, who would have the necessary authority to act on any direct connections that are found. Allocating work to inspectors away from their home neighbourhoods may address the risk of bias. In order to gain access to properties this work will mostly have to be done outside of normal working hours and therefore it would be cost effective to outsource the work to NGOs, CBOs or private companies.

7.8.2 Public education and community awareness

The study found that communities are receptive to information relating to the stormwater ingress problem. Education programmes should be focused on a particular community and should involve a visit from a municipal officer who provides instruction on how to rectify direct connections and information on alternative, environmentally friendly stormwater drainage solutions.

7.8.3 Practical legal enforcement

It is not enough for a city simply to have a bylaw which states that it is illegal to connect stormwater flow direct to the sewer network. In practice it is found to be extremely time consuming to follow the necessary legal procedures to get such connections removed. A more practical solution is to change the bylaw making stormwater connections to the sewer network legal, but at a high enough charge that there is a strong incentive for the property owner to make the necessary changes. When the direct connection has been appropriately diverted, the property owner will then want to get the city inspector back to confirm the change, and will make himself available for the inspection. Meanwhile the monthly tariff that is charged on stormwater to sewer connections helps to fund the ongoing cost of inspections and education.

Builders and plumbers who are found to have installed illegal stormwater connections should also be sanctioned. This could involve the payment of fines, or blacklisting.

References

Boston Water and Sewer Commission, 2007, website http://www.bwsc.org , accessed March 2007

Burke, J. and Mayer, X., 2007, *Strategic guidance towards prioritising stormwater management research in human settlements: draft final report*. WRC report March 2007.

Byron Shire Council, 2007, *Mullumbimby Sewerage System Inflow and infiltration programme Integrated Strategy*, Accessed via www.byron.nsw.gov.au, January 2008.

Chouli, E., Aftias, E. and Deutsch, JC., 2007, *Applying stormwater management in Greek cities: learning from the European experience*. Desalination 210 (2007) 61 – 68.

City of Toronto: Toronto Water, 2007, Information accessed via the City of Toronto website http://www.toronto.ca

City of Vancouver, 2007, *Downspout Disconnection Pilot Programme* accessed via http://www.cityfarmer.org/downspout96.html

Coorsh, K. 2007: *Works department axes downspout freebie: Disconnecting from sewers mandatory but city-funded program ends on Nov 20*. Town Crier Online accessed via http://www.towncrieronline.ca/main/main.php?direction=viewstory&storyid=6405&rootcatid=8&rootsubcatid=%23rootsubcatid 27th November 2007.

Denny –Dimitriou, J., *A River in Crisis*, The Witness, Friday, February 15, 2008.

De Swardt, BW and Barta, B., 2007*, A First Order National Audit of Sewerage Reticulation Issues Report A: Literature Review*. WRC Report.

Duncan, D., 2007, *Downspouting on the upswing*. Eye Weekly.Com accessed via http://www.eye.net/blogs/cityhall/article/10882 27th November 2007.

Earth Tech Team, 2004, *Pilot Project Report Regional Infiltration and Inflow Control Program*, prepared for King County Department of Natural Resources and Parks Wastewater Treatment Division by Earth Tech Team, Seattle, WSA October 2004. Accessed via http://dnr.metrokc.gov/WTD/i-i/library/PilotProject/report.htm#toc

Naude. L., no date, *The impact of storm-water and groundwater infiltration on wastewater treatment*.

EPA, 1999, *Combined Sewer Overflow Management Fact Sheet: Sewer Separation*. Produced by the Municipal Technology Branch, United States Environmental Protection Agency, Office of Water, Washington, D.C. accessed via http://www.epa.gov/owm/mtb/sepa.pdf 23 November 2007.

Integrated Environmental Management Unit, 2005, *Summary Report: The State of Sanitation,* Report prepared by the Buffalo City Municipality April 2005.

Kentucky Government: Division of Water, no date, *What are combined sewers?* Accessed via http://www.water.ky.gov/permitting/wastewaterpermitting/KPDES/seweroverflows/cso_questions-1.htm 23rd November 2007.

Lucas, A.., 2007, DWAF, Eastern Cape. Personal Communication.

Moloney, P., 2007, *Downspouts to top city agenda.* TheStar.com accessed via http://www.thestar.com/News/article/277664 27th November 2007.

National Buildings Regulations and Standards Act No. 103 of 1977

Personal Communication, 2008, Desmond Lakey, Legal Advisor to Overstrand Municipality February 2008.

Pienaar, J., 2007, *Assessment of Stormwater ingress into Sewers (Phase 1)*. Project Report prepared by Africon Engineering International for the City of Tshwane Metropolitan Municipality 94 May 2007).

Stephenson, D. and Barta, B., 2005, *Guidelines on Reduction of the Impact of Water Infiltration into Sewers*. WRC Report TT239/05.

toronto.ctv.ca, 2007, *Downspout diversion program could cost city $65M* , story published 21 November 2007. Accessed via http://toronto.ctv.ca/servlet/an/local/CTVNews/20071121/downsputs_071121/20071121?hub=TorontoHome on 5 March 2008.

Westenberg, M., 2008. Buffalo City Municipality, Personal Communication 2008.

Wikipedia on-line encyclopaedia accessed via http://en.wikipedia.org

Wisumperuma, K. and Vercruyssen, B. 2006, New Zealand, *Tackling pollution of North Shore City beaches by the use of trenchless technology*. Paper presented at No Dig Down Under 2006, 29th October 2006 to 2nd November 2006*, Brisbane, Australia*. Paper available from http://www.nodig06.im.com.au

ADDENDUM A

THE USE OF A SMOKE GENERATOR TO DETECT STORMWATER TO SEWER CONNECTIONS

In 2009 eThekwini Water Services acquired a smoke generator to assist its efforts to locate direct stormwater to sewer connections. The machine (Figure A1 below), consists of a small petrol engine coupled with a fan, all mounted on a metal plate with a rubber seal that is made to fit on top of a standard manhole. A canister with a diesel and oil mixture is connected to a nozzle which is located above the engine manifold. When the canister is pressurised and the nozzle is opened, the oil drips onto the manifold and smoke is produced. The fan blows this smoke down into the manhole. Once the sewer becomes saturated with smoke, the smoke starts to pour out of any openings in the sewer. Any broken drain pipes or drains that are connected direct to the sewer without water seals (i.e. any connections to the sewer other than toilets) are soon indicated by plumes of smoke.

Figure A1: The smoke generator machine acquired by eThekwini Water Services to assist with the detection of direct stormwater to sewer connections

In June 2009 the smoke generator was demonstrated by the eThekwini team in Northdale, Pietermaritzburg. In Figure A2 below the machine can be seen in place on a manhole. This was not an ideal test site, as the machine is mounted on a round base plate and this particular manhole was square, which meant some of the smoke escaped from the test manhole. However, it would be a relatively simple matter to fabricate a set of base plate adaptors to enable the machine to be fitted to a range of manhole dimensions. Nevertheless, the machine did succeed in blowing enough smoke into the manhole and sewer to reveal a number of direct connections in the vicinity (see Figures A3 and A4).

Figure A2: The smoke machine in place over a manhole and in operation. A base plate adaptor is needed to enable the machine to work more effectively over manhole openings (such as this one) which are not an exact match for the machine's base plate.

Figure A3: Smoke pours out of the ground revealing the location of a broken section of domestic sewer. In this case the home owner may not be aware of the problem with the sewer pipe, but such a section of pipe will function as a subsoil drain, carrying away stormwater when it rains. This kind of sewer break would be hard to find using a routine visual inspection of the yard.

Figure A4: Smoke rises from the ground in a patch of lawn, revealing a broken sewer pipe below the surface. As with the break shown in Figure A3, a problem like this would be hard to find using a routine visual inspection.