

## **State of the Environment Report (SoER)**

# **An analysis of the sustainability of storm and waste water management in the city of Grahamstown**

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### **Abstract**

Grahamstown situated in the Eastern Cape Province of South Africa has a semi-urban environment with its tributaries leading into the Bloukrans River of the Kowie Catchment. The growing population together with the increased development has a major impact on the rivers due to waste water and storm water infrastructure not being able to retain the increased capacity. Rural poverty stricken environments are characterised as having poor service delivery and an abundance of illegal dumping areas resulting in masses of litter which get carried by storm water into the streams. Waste water infrastructure is continually leaking into streams which together with a lack of enforcement with regard to littering and dumping have resulted in streams becoming highly polluted with major impacts occurring downstream. It is thus that there needs to be greater management of the storm and waste water to ensure the sustainability of water use and a decrease in impacts downstream. Without proper management and regular assessment and monitoring the state of the environment will continue to deteriorate.

**Key Words:** Storm water, waste water, management, sustainability

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## **Introduction**

“Urban areas are hot spots that drive environmental change at multiple scales” (Grimm *et al.*, 2008)

“Urbanization is an important cause of eutrophication in waters draining urban areas.” (Taylor *et al.*, 2004)

These statements are but some of the proof that internationally, water as a resource is being affected by the continual rise of urban populations. This has led to the increase over the past few decades of research in urbanized areas, as well as the observed ecological degradation of streams draining urban land; or as Walsh *et al.*, (2005) calls it, the “urban stream syndrome”. With Globalization looming, Morrison *et al.*, (2003) notes that in terms of storm and waste water management, the problem of fast population growth and rapid urbanization, the amount of sludge being produced is a growing problem. Remaining on the international front, in recent years, a more integrated approach to the management of natural resources has been advocated. The form of management called Integrated Water Resource Management (IWRM), as recognised by the Global Water Partnership, does not compromise the sustainability of vital ecosystems (Haigh *et al.*, 2010).

In almost all South African metropolitan areas, the consumer is provided with high quality drinking water. However, in many rural communities, the situation is very different. In 1994, an estimated fourteen million people had no access to clean or safe water. Although initiatives were undertaken and improvement measures implemented, seven of the fourteen million people in rural areas still lack safe and clean water (Osode, 2010).

The population of the Eastern Cape Province is largely non-urban, poor, and with an inadequate water supply infrastructure. Rural communities of this province comprise both scattered villages and subsistence farmers, and formalised towns serving subsistence farmers (Osode, 2010). The poverty rate in 1998 was 78% and only 25% of the households had a pipe-borne water supply inside their dwellings. This implies that many people depend on surface and/or groundwater sources for their daily water needs (Osode, 2010).

Haigh *et al.*, (2008) states that the situation in the Makana Municipality is no different to that occurring in many other municipalities. The Makana Municipality one of nine under the Cacadu District municipality, which falls under the Great Fish River Catchment Water Management Area (WMA) 15, and is the largest, geographically, of the nineteen WMA's (Haigh *et al.*, 2008).

Even though the Cacadu District itself comprises six of the seven biomes that make it an area bountiful in environmental initiatives, Grahamstown is the most densely populated of the Districts' urbanised areas (Haigh *et al.*, 2008). This undoubtedly puts a lot of pressure on the water resources in the area, and leaves risk for improper management higher than in other parts of the District. Fearing that the water supply would not efficiently meet Grahamstown's population growth, the wall of Settlers dam was increased by 2.3 m in 1981 and in 1992 water from the Orange River Inter-basin Transfer Scheme reached Grahamstown (Haigh *et al.*, 2008). These changes may have been adequate then, but are they keeping up?

Grahamstown has two water purification plants; Waainek and James Kleynhans (Haigh *et al.*, 2008). These may be enough in number, but the quality of the waste water is still compromised as it seems that the water disposed to the environment by these communities is usually faecally contaminated, and affected by inadequately treated effluents from municipal waste water plants as receiving water bodies (Osode, 2010).

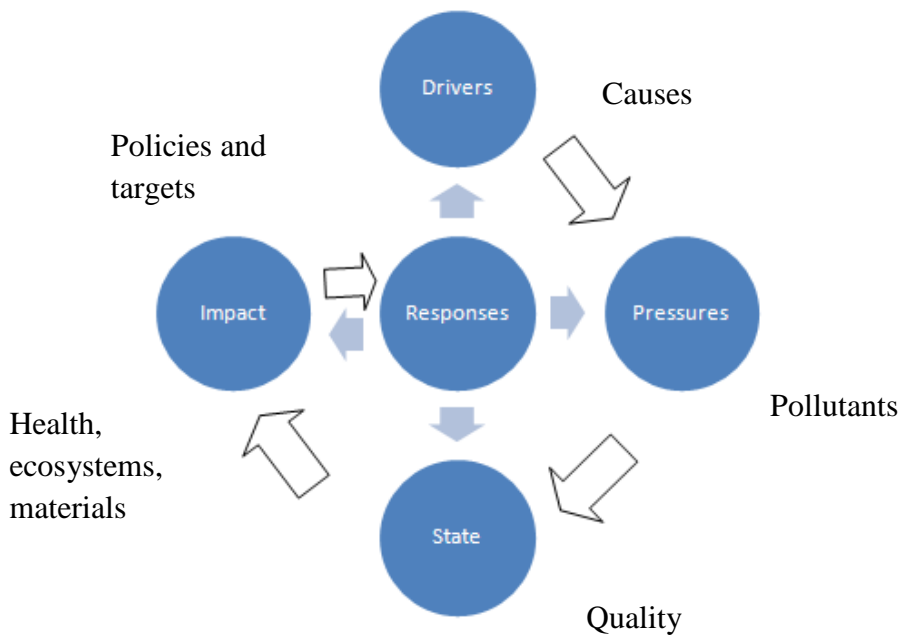
This may be due to the fact that there has not been sufficient training of some of the employees in these plants. Haigh *et al.*,(2008) also stresses that the present state of storm water removal, particularly in the low income - high density areas of Makana, together with poor litter control, ensures serious contamination of storm water drains and ultimately water resources.

Owing to the increase in storm and waste water mismanagement reports in Grahamstown, it is perfectly clear that there needs to be a change in Municipal management structures. The context of this study is that of a small town in the Eastern Cape with a population of approximately 124,758 (Wikipedia, 2011).

“Grahamstown-Rhini was established on the headwaters of the Bloukrans River, which flows into the Kowie River and out to sea at Port Alfred. Ongoing development, invasive alien plant growth and irresponsible waste disposal and public abuse over the years has altered and polluted our streams to unacceptable levels.” (KCC, 2007: 6). In response to these issues, a State of the Environment Report is being formulated. This report describes the main drivers of

change, identifies trends, and notes current responses to environmental change as withheld by the South Africa Environment Outlook, (2006).

The framework used for indicators of sustainable development was the Driver-Pressure-State-Impact-Response (DPSIR), which was adapted by the United Nations Commission on Sustainable Development in 1995, based on a modification of the pressure-state-response model for state of the environment reporting (State of the Environment: Department of Environmental Affairs South Africa, 2007).



**Figure 1: The DPSIR Framework (Adapted from: Kristenson, 2004)**

According to Kirstenson, (2004) DPSIR is useful in describing the relationships between the origins and consequences of environmental problems, but in order to understand their dynamics it is also useful to focus on the links between DPSIR elements. In this case, the relationships described will be those in relation with storm and waste water. This model forms the basis for most state of the environment reports within South Africa (State of the Environment: Department of Environmental Affairs, South Africa, 2007).

## **Aim and objectives**

The main aim of this State of the Environment report is to predict, review, assess as well as draw conclusions on the management of storm and waste water giving future scenarios for Grahamstown, as well as impacts on downstream users if the storm and waste water is managed in the same manner as present; also what recommendations can be put in place to achieve the most optimal management scheme.

In order to achieve our aim, we set out to achieve a number of objectives as follows:

To investigate how storm water has affected river flow quantity

To investigate how storm water runoff has affected water quality

To investigate how waste water has affected river flow quantity

To investigate how waste water has affected water quality

To analyse the effects of storm and waste water on downstream water resource users

To assess what managers are doing to reduce the impacts of storm and waste water quality and quantity on downstream users

The key questions involved asking various key informants concerning the sustainability of the management of storm and waste water.

## **Study Area**

### **Grahamstown**

The Makana Municipality is a relatively large municipality located in the Cacadu District in the Eastern Cape. It has a partly urbanized population that encompasses Grahamstown, Alicedale, Fort Brown, Sidbury, Riebeek East, Salem and Seven Fountains (Urban-econ, 2009). Makana has a developed economy characterised by tourist activity and large service and trade sectors in the urban node of Grahamstown (Urban-econ, 2009). In addition, agriculture, game farming and conservancy reserves can be found throughout the municipality's less developed areas. The municipality is also supplemented by the contribution of Rhodes University, an internationally renowned institute of higher tertiary education (Urban-econ, 2009). Our study area is centred on Grahamstown and its immediate surrounds as well as the Kowie River Catchment and the

Bloukrans River, a tributary of the Kowie River that stretches from Grahamstown to Port Alfred (see Figure 2 and Figure 3).

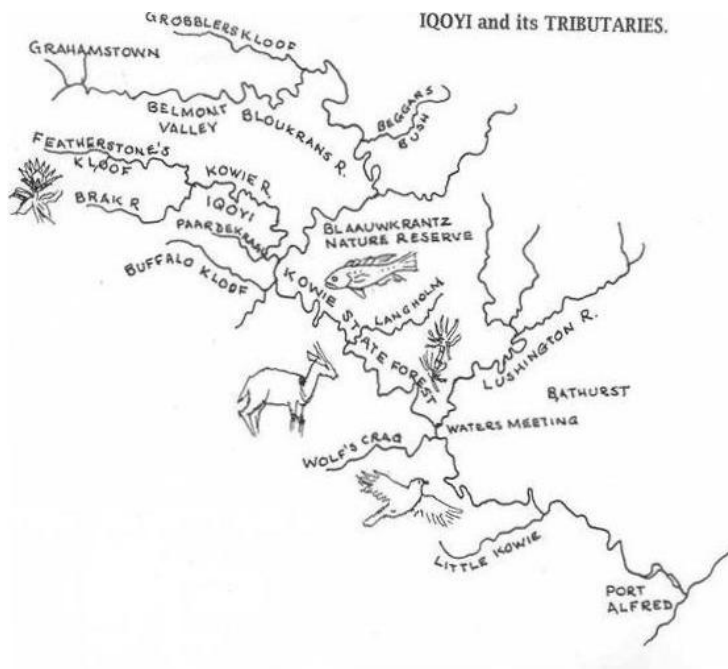


Figure 2: Illustrative map of the Kowie River

(KCC, 2010)



Figure 3: Illustrative map of the streams of Grahamstown

(KCC, 2010)

### Climate

The city of Grahamstown lies in a subtropical climatic zone, characterized by warm summers and cool winters and fairly evenly distributed rainfall throughout the year (Urban-econ, 2009). It experiences moderate weather conditions in relation to mean precipitation, temperatures, wind speed and direction. Rainfall occurs throughout the year with mean precipitation

averaging 680mm (Urban-econ, 2009). Summer temperatures vary from an average maximum of 26° to a minimum of 15°, while winter temperatures vary from an average maximum of 18° to an average minimum of 4° (Makana SDF, 2009 in Urban-econ, 2009).

### *Topography*

Grahamstown is elevated with a sloped terrain, which limits the ability for cultivation of some agricultural crops and is instead is used for grazing (Urban-econ, 2009). Flat topped hills that have been shaped by dolerite dykes, sills and chemical weathering are found throughout the region (Urban-econ, 2009). The study area is situated in a valley that cuts into a plateau with a highest point of 770 m above sea level and a lowest point of 490 m above sea level (Makana SDF, 2009 in Urban-econ, 2009).

### *Hydrology*

The major water related driver in the entire Makana municipal area is the Orange-Fish-Sundays Water Supply System (Urban-econ, 2009). It ensures continuous sustainable water supply for economic activity and is essential for community well-being and socio-economic prosperity in the area (Urban-econ, 2009). Surface water is largely provided by dams and reservoirs that are linked to perennial and non-perennial rivers with ground water provided by boreholes and springs that are evenly distributed throughout the municipality (Urban-econ, 2009). Grahamstown's water supplies are dominantly from local dams and sources transferred from the Orange River (Urban-econ, 2009). The high water demand set against limited supply necessitates the need for water recycling.

### *Socio-economic characteristics*

The Municipality boasts a range of products including game, beef and goats, as well as local mining products (kaolin) with associated value-adding opportunities in meat, wool, mohair and ceramics (Urban-econ, 2009). Tourism forms an integral part of local activity, centred on the internationally renowned National Arts Festival, while other attractions include public nature reserves, private game reserves and outdoor adventure activities, such as skydiving, hunting and hiking. There is also potential for further development of cultural and heritage tourism products (Urban-econ, 2009). Rhodes University is a major feature in the physical, social and economic landscape of Grahamstown, and the Makana municipality at large. Rhodes University has thus influenced how the city of Grahamstown has developed (Urban-econ, 2009).

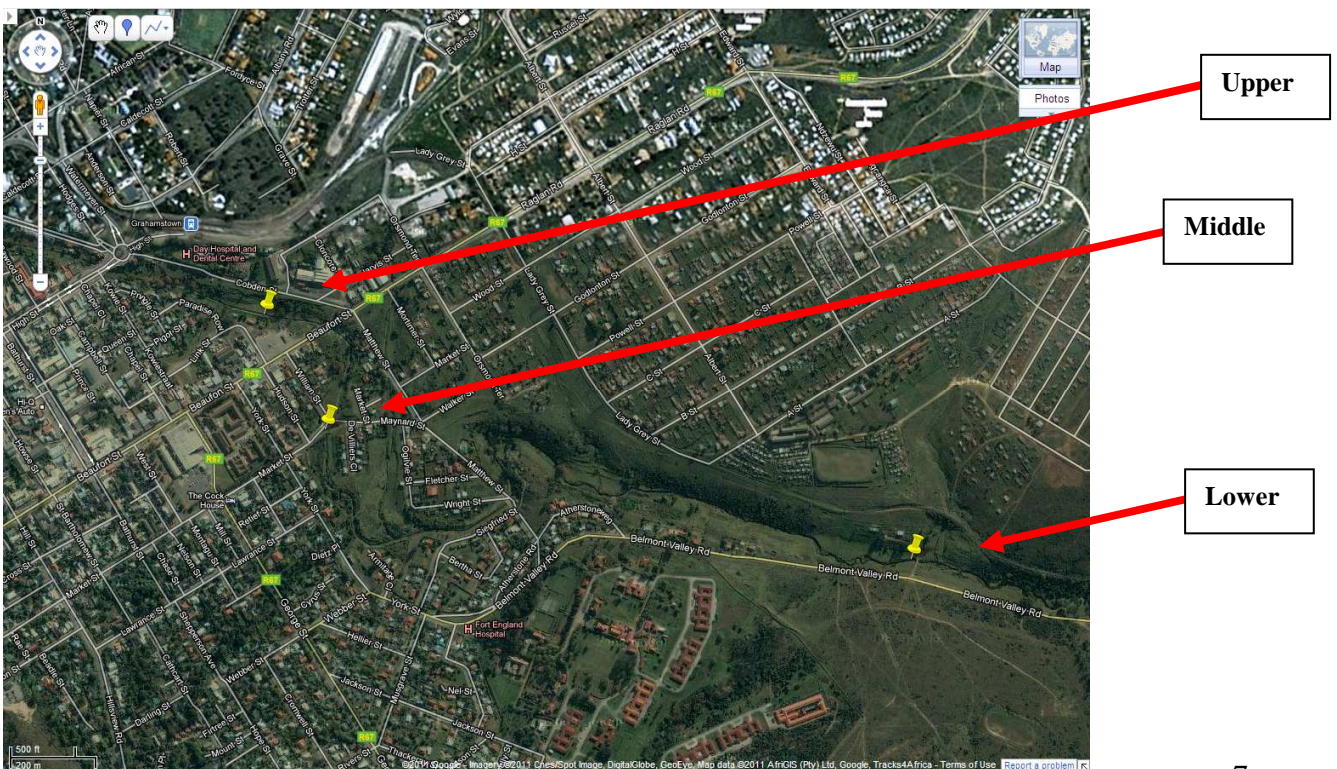
# Methods

## Sample sites

Three sites for collection of domestic litter and water quality measurements were sampled along the Bloukrans River to the south of Grahamstown. The sample sites varied in their distances from town. These sites were named upper, middle and lower according to their proximity from the city. Table 1 below summarises a description of the sample sites and the images provide photographic reference to each.

**Table 1: defining the sample site characteristics**

Sample site	Co- ordinates	Elevation	Description
Upper	33°18'541" S 26°32'119" E	505 m above sea level	Close to a walkway/bridge over the stream just below parking lot for Shoprite Checkers. Also known as 'Stockenstream' in IWR data, see Discussion.
Middle	33°18'685" S 26°32'202" E	496 m above sea level	In a dip on Market street. Road goes over storm water concrete.
Lower	33°18'853" S 26°33'100" E	484 m above sea level	Along dirt road toward sewage works. Walkway/bridge going over stream toward railway line, equates with IWR site "Fort England" see Discussion.



**Figure 4: Google Earth image showing the locations of each site from upper to lower stream in the Belmont Valley**

a)



b)



c)



**Figure 5: a) Upper, b) Middle and c) Lower sites along the Bloukrans River**

With regard to collected water quality data provided by the IWR (Institute for Water Research) at Rhodes University from mid- 1992 to 1995, the data was used from the Botanical Gardens, Stockenstrom, and Fort England. These data were compared to our own to detect possible long term trends.

#### **How storm water has affected river flow**

Data on the stream flow along the Bloukrans River was unavailable and therefore volumes of treated water were used to indicate the contributions of water from inter-basin transfer schemes into the town. Volumes of treated water at the James Kleynhans and Waainek Water Treatment Woks were plotted on a line graph for the years 2007- 2009.

### **How storm water has affected water quality**

Following a storm event, litter was collected in 3 plots of 2 m radius each at each site, determined by placing a peg attached to a string of 2 m in length into the ground. The string was pulled and moved accordingly and all litter within the circular plot was collected and placed into large bags. Each bag was then marked according to the site and the plot number and weighed using a hanging balance. The three plots within each site were distanced 5 m away from each other in a fashion parallel with the stream. At each of the plots water quality readings were taken using a YSI meter. Electrical conductivity, pH and temperature were recorded. The water quality readings and the weights of each bag for each site were then tabulated into a Microsoft Excel Spreadsheet. Bag weights were averaged for each site and the standard deviation was calculated.

DWAF, (2008: 37) states that in order to see if the natural river temperature has deviated at all it must be compared to the natural monthly temperature range. DWAF, (2008: 37) states that the 10<sup>th</sup> and 90<sup>th</sup> percentile must be used in order to see if any deviation has occurred, but this is not possible due to the data set being so small. Additionally DWAF, (2008: 35) states the correct way to analyse the pH and to see if any change has occurred is by using table 4-4, this can be seen in Appendix 1.

An analysis of the data provided by the IWR from 1993- 1995 for the sites of Stockenstroom and Fort England was conducted. For this the average monthly electrical conductivity (EC) over a three year period was plotted against monthly rainfall data over the same three years. The EC for the readings taken in this study were similarly plotted against monthly rainfall and compared to the same three months of 1993- 1995.

A GIS (Geographical Information System) Map was created using ArcMap 10 to represent the positions of sites and calculate the quantity of litter in upper to lower sections of the river. In order to do so an image of Grahamstown was obtained off Google Earth and loaded into ArcMap. Data on Grahamstown rivers obtained from the Geography Department website were loaded as a layer on top of the image. Co- ordinates of the three sites were tabulated in Microsoft Excel and added as X,Y data in ArcMap. The sites showed appeared on the map as points. Thereafter 'polylines' were created along the Bloukrans River to represent the lengths of upper to lower stream sections. A buffer was created along each stream section of 4 m on either side of the stream. The area of each buffer was then calculated and multiplied by the average weight of litter per unit area (over 3 months) of the same site. For example area of

upstream buffer was multiplied by the average weight of litter for the upstream site. It was assumed that average litter per unit area would remain the same at 4 m on either side of the river bank. Additionally 'polygons' showing catchment areas were also created as an indication of Grahamstown's impacts on the river. Thereafter the map was adjusted in layout view until cartographically correct.

### **How waste water has affected river flow quantity and quality**

Gary Everton manager of the Makana Municipality Waste Water Treatment Works provided the data for this objective. Water quality values were tabulated and compared to acceptable water quality guidelines as stipulated by the Department of Water Affairs.

### **Interviews**

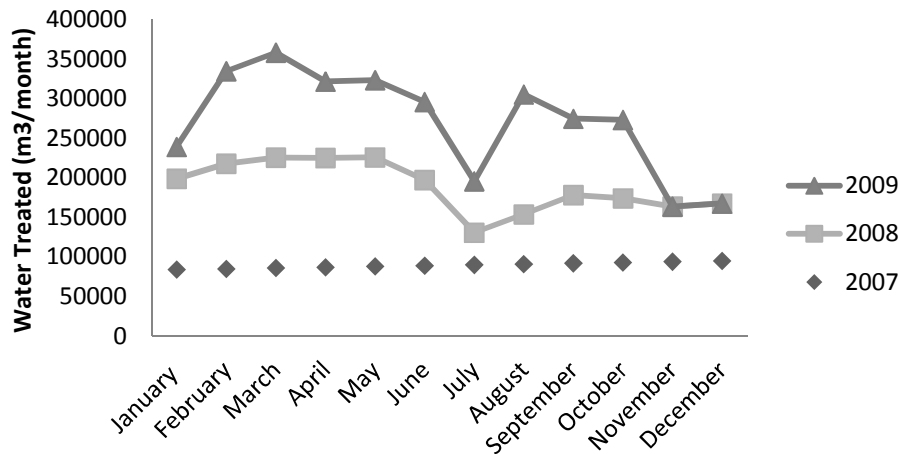
Thirty six questionnaires were conducted with people living along the water courses of Grahamstown. The questionnaires were designed for those who would be interacting with the water courses on a regular basis in order to gain a community based view on water quality issues for both storm and wastewater. Questionnaires were compiled and analysed to obtain the most valuable information. See Appendix 2

Key informant interviews were conducted with individuals of NGO's and other organizations that would have knowledge on the management of storm and waste water. Any initiatives in place to control storm water sustainably were investigated, as well as if storm and waste water infrastructure within Grahamstown is able to keep up with the increasing development within Grahamstown.

## Data analysis

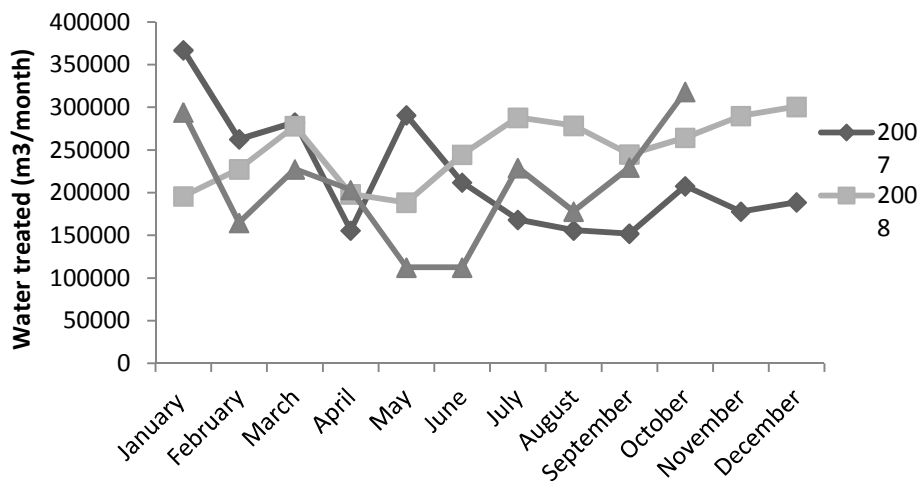
### Increase in volumes of Grahamstown's water usage

Figure 6 and 7 represent the data on the quantity of water treated over a three year period (2007- 2009) at Grahamstown's Water Treatment Works. Quantities are measured in cubic meters per month. The water treated provides an indication of Grahamstown's water usage over time as supplied by the Orange- Fish Inter-basin Transfer Scheme.



**Figure 6: The amount of water treated monthly at the Waainek Water Treatment Works from 2007- 2009**

The amount of water treated at the Waainek Water Treatment Works as seen in Figure 6, increased systematically by a small amount in 2007. In 2008 the amount of water that was treated was much higher than in 2007 where it increased further in 2009. The data shows that in 2008 and 2009 there was an increase in the amount of water treated in the first five months, after which water treatment declined to a low level in July. In 2008 and 2009 water treated increased in the months following July and declined again in November and December.



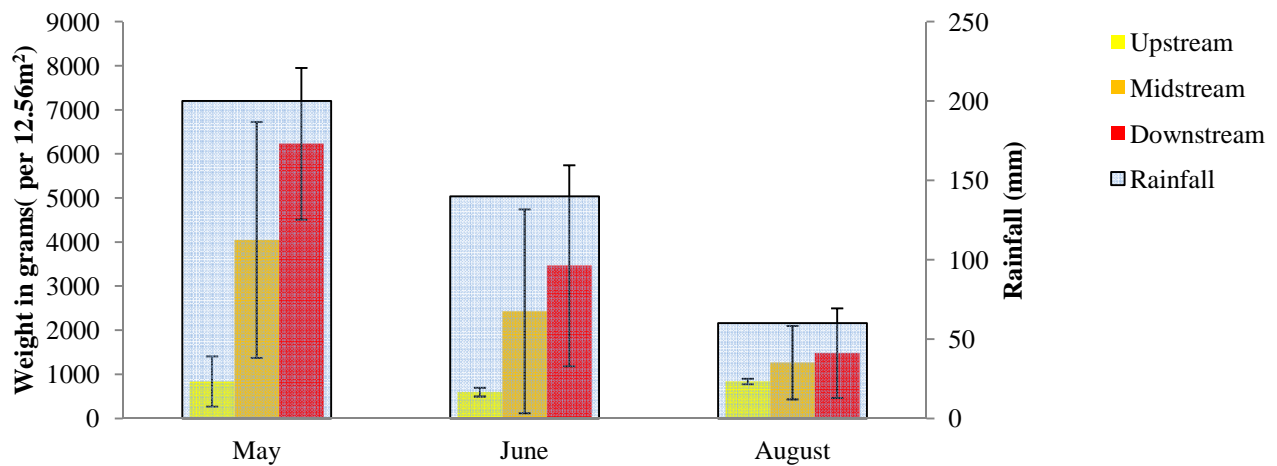
**Figure 7: The amount of water treated monthly at the James Kleynhans Water Treatment Works from 2007- 2009**

Figure 7 shows treated water at the Waainek Water Treatment Works has larger variations in quantities of treated water from 2007- 2009 than at the James Kleynhans Water Treatment Works. In 2007 treated water dropped in April and increased again for May, thereafter treated water gradually decreased with minor fluctuations. In 2008 water treatment at the James Kleynhans Water Treatment Works was at its steadiest with few sharp increases and decreases in treated water. In 2009 water treatment decreased to its lowest for May and June where it thereafter increased with a minor decrease in August.

### Storm water and its effect on water quality

#### *Variation in quantities of domestic litter*

Figure 8, represents the means and standard deviations of litter weight per site for the months of May, June and August 2011. The weights are an average for the area of each plot which is  $A = \pi(2)^2$  which equals  $12.56 \text{ m}^2$

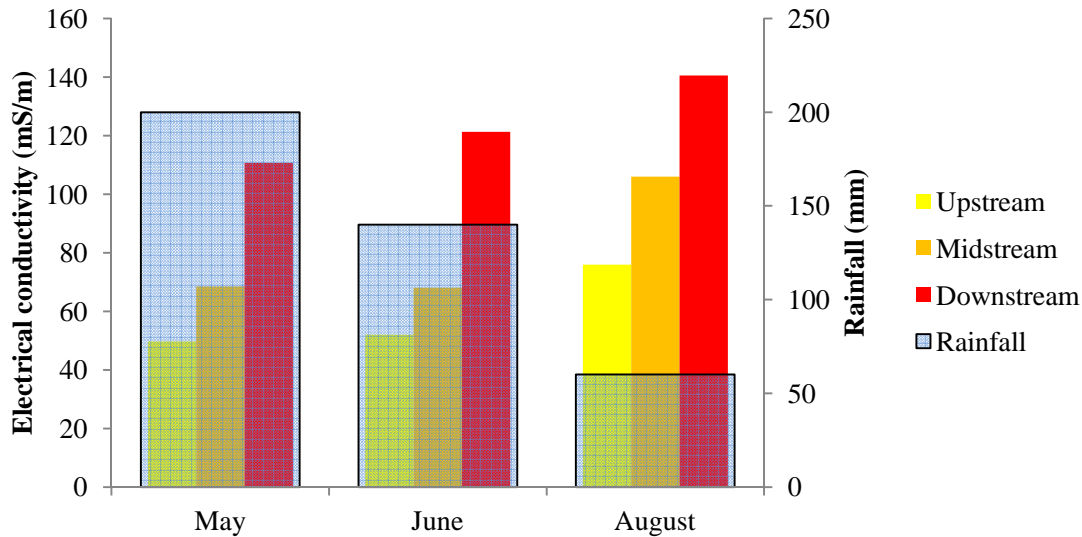


**Figure 8: Average weights ( $\pm$ S.D) of litter collected at three points along a stream compared to monthly rainfall (mm)**

In each of the collections it is evident that the amount of litter increases with distance downstream. Litter decreases over the three months. When comparing this to rainfall before the collections, amount of rainfall is consistent with high litter quantities. August collections do not have as high a variation between upper and lower sites along the stream as May and June.

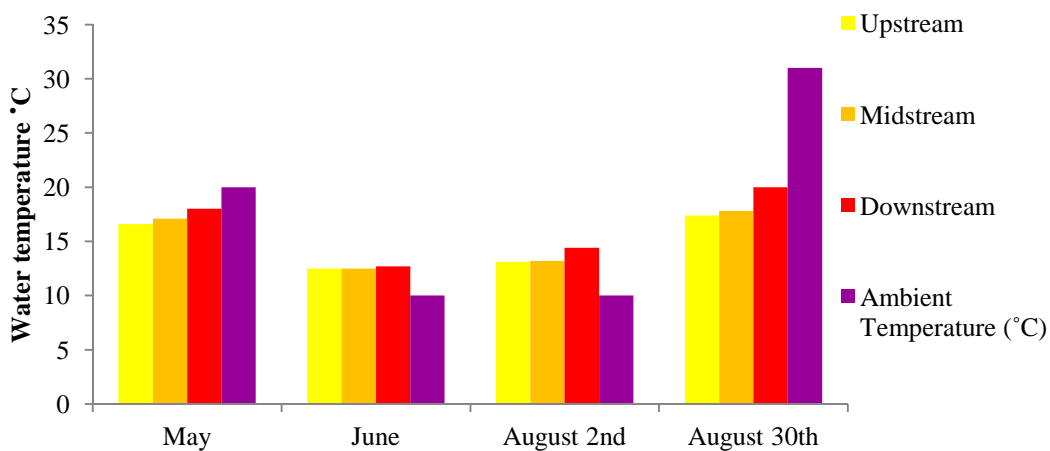
*Changes in stream quality with rainfall*

Figure 9, 10 and 11; represent the readings taken at the three sites over three months compared with the rainfall of that month. Readings included electrical conductivity (EC) and pH with water temperature in Figure 10 being compared to ambient temperature.



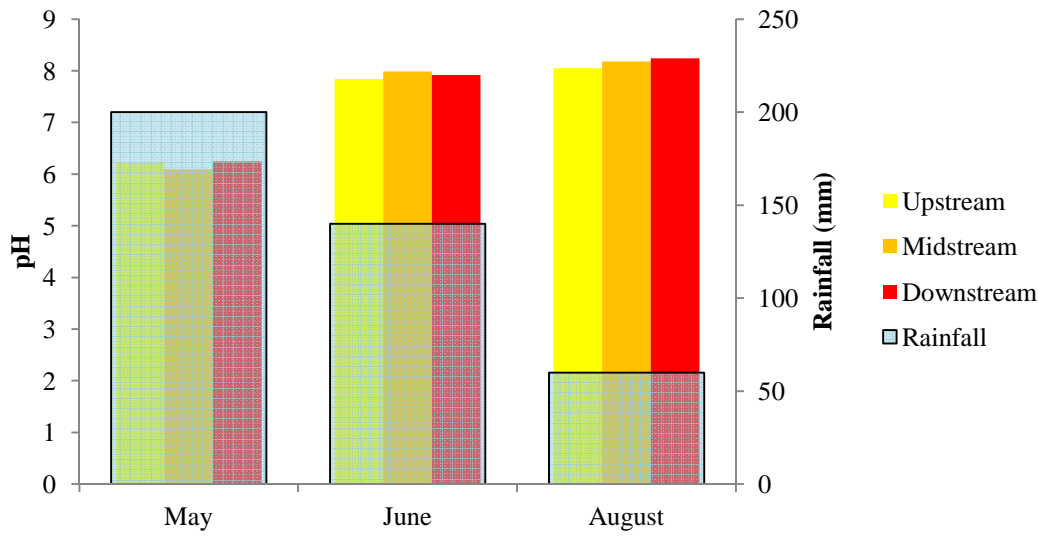
**Figure 9: Electrical conductivity of Bloukrans River at three different sites compared to monthly rainfall**

Figure 9 shows that an increase in rainfall results in a decrease in electrical conductivity as seen in May. In August EC is highest where rainfall is least. In all months EC is greatest downstream.



**Figure 10: Water temperature in relation to ambient temperature at three sites from May to August**

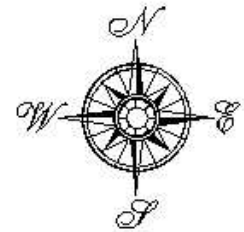
For each temperature reading, it is evident from Figure 10 that electrical conductivity increases downstream. Only in May and the end of August is water temperature higher than ambient temperature. In the winter month of June and beginning of August ambient temperature is at 10 °C but water temperatures are between 2 and 5 °C warmer. There has been a moderate change in the river temperature from its natural state, but this occurs infrequently (DWAF 2008: 37).



**Figure 11: pH compared to monthly rainfall (mm) over three months**

Using table 4.4 in the appendix, the pH of the river could be analysed. The lowest pH was 6.09 and the highest was 8.24, according to table 4-4, seen in Appendix 1, a change like this represents a small change from the natural state. Rainfall and pH have an inverse relationship, similar to that of conductivity, although it must be noted that a decrease or increase in rainfall has a very minimal effect on pH. It is, however, clear according to table 4-4 that there has been a change or deviation from the natural state or condition of the river.

Figure 12 below is a GIS map representing catchment sizes for upper, middle and lower streams of the Bloukrans River. The map illustrates the increase in litter quantities from upper to lower stream as can be seen in the legend. Upstream litter for this area amounts to greater than 100 kg but less than 500 kg, midstream greater than 500 kg but less than 1000 kg and downstream greater than 1000 kg with a value of 2500 kg of litter in the downstream area of the river.



**Legend**

**Weights of litter per stream area**

**Kg\_lit**

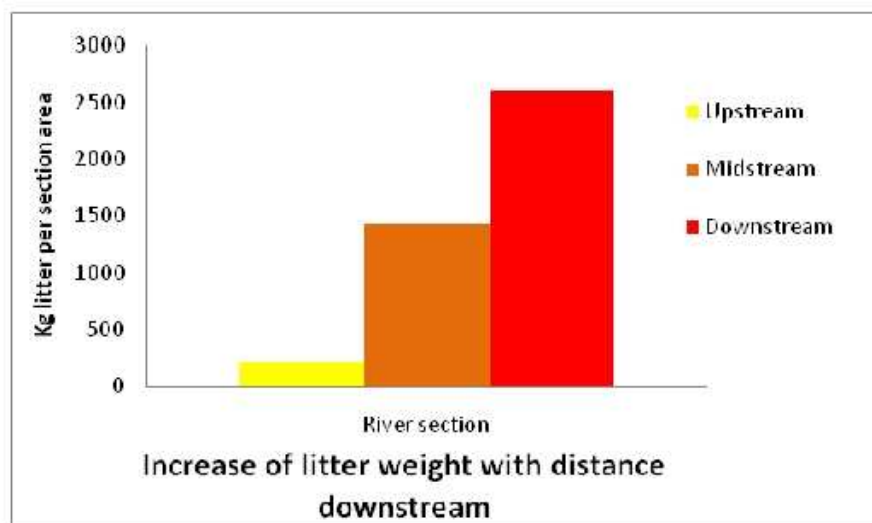
- 100
- 500
- 1,000

**Stream section**

- Upstream
- Midstream
- Downstream

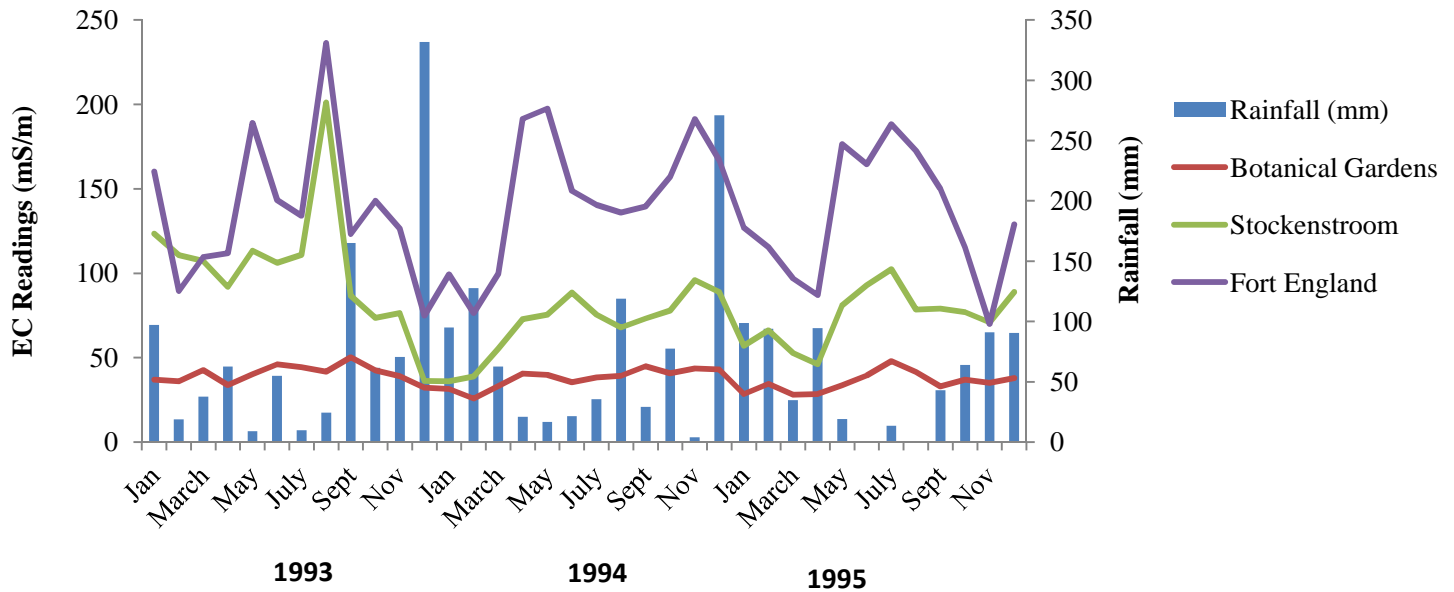
**Catchment Area Sq.m**

- 2938764
- 5907699
- 13581227



**Figure 12: GIS map of Grahamstown streams with accompanying graph showing increase in litter with distance downstream attributed to cumulative increase in catchment sizes within the Belmont Valley**

The data represented in Figure 13 is from a study conducted by a member of IWR between 1993 and 1995. It shows an inverse relationship between the electrical conductivity of the water in the Bloukrans River and the monthly rainfall.



**Figure 13: Electrical conductivity of the Bloukrans River at two sites as well as the stream through Botanical Gardens, compared to monthly rainfall over a period of three years**

An increase in rainfall causes a decrease in the electrical conductivity of the water and vice versa. In December of 1993 Grahamstown experienced heavy rain which amounted to over 330 mm for the month, at this time the electrical conductivity of the river at both sites was at its lowest, whilst in July of the same year the electrical conductivity of the river was at its highest as the rainfall for that month was at its lowest. Both Stockenstroom and Fort England sites follow this relationship but the stream through the Botanical Gardens does not. The Stockenstroom and Fort England sites have huge variations in their electro-conductivity and these, as seen in Figure 13, can be directly related to rainfall. This relationship cannot be said to be the same for the stream running through the Botanical Gardens as electro-conductivity readings for the Botanical Gardens range between 26 (mS/m) to 50 (mS/m) and an increase or decrease does not bring about a change in the electro-conductivity as seen in the other two sites. This means that there must be something else, other than rainfall, which causes the EC to rise and fall like it does.

## Quality and quantity of treated waste

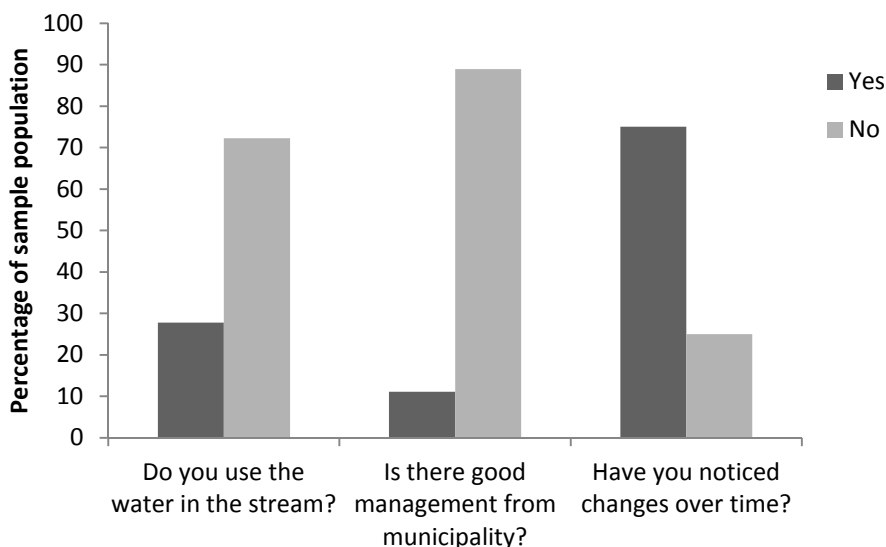
**Table 2: Water Quality results from the Grahamstown waste water treatment works compared to required standards**

Test	Result from Sewage works	Required Standard (DWA, 1984)
C.O.D (Chemical Oxygen Demand)	43 mg/L	Not exceed 30 mg/L
Conductivity	155 mS/m at 25°	Not exceed 250 mS/m
p.H	7.5 at 25°	Between 5,5 and 7,5
Suspended solids	11 mg/L at 10.5°	Not exceed 10 mg/L
Nitrate	30.96 mg/L	Not exceed 1.5 mg/L

From table 2 it is evident that chemical oxygen demand is 13 mg/L more than the required standard. Conductivity (EC) is lower than is required and p.H just meets required standards. Suspended solids are only 1 mg/L more than what is stipulated in the DWA guidelines. Additional information provided by Gary Everton stated that the estimated quantity of sludge removed from the sewage works per month is 3600 m<sup>3</sup> with volume of treated water leaving the sewage works, averaging on 6 ML per day. Accordingly the sewage works is designed to treat 5.4 ML of sewage per day, currently however it receives and treats 7.5 ML per day.

## Stakeholder interviews and questionnaires

Figures 14 and 15 provide a graphical indication of the responses to the most valuable questions as a percentage of the sample population.

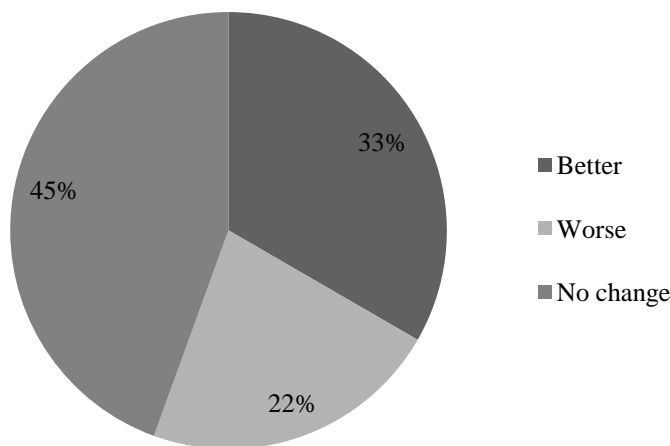


**Figure 14: Responses of individuals to questions regarding management, usage and changes of water (n=36)**

It is evident from the above graph (Figure 14) that most of the sampled population (84%), do not use the water in the streams. Of those who said that they do use the water, it was for non-potable purposes including washing of clothes and even disposal of waste.

The majority of people stated that changes to water quality were negative with most comments pertaining to changes in the colour, taste and smell of the water. Many said that the water sometimes tastes like bleach and sometimes the water makes them sick. A few individuals also stated that water quality changes depending on where you go, therefore in some areas water quality is worse than others

It was gathered from the Questionnaires that 66% of the sample population do not think that the Makana Municipality are managing the streams and storm water properly. Of these a few comments included that although there is management it is unsatisfactory. Storm drains are always getting blocked and that road and properties get flooded.



**Figure 15: percentage of responses to types of changes in the water quality (n=36)**

The opinion of individuals with regard to changes in water quality was fairly even (Figure 15). Of the 22% of individuals who stated that there is no change to water quality, they also said that the water has always been bad. Therefore on a whole it can be concluded that the majority of the population think that the water quality is bad and getting worse.

## Discussion

### Storm water and waste water relationship and it's effect downstream

Haigh *et al.*, (2008: 55) in a report for the Water Research Commission states that poor storm water removal in Grahamstown together with very poor litter control guarantees the contamination of storm water drains and receiving water courses, decreasing water quality. Wright *et al.*, (1993) states that storm water acts as a carrier of pollution and coupled with the effects of inefficient waste water disposal have an impact on ecosystems and livelihoods further downstream. Supporting this, it was clear from our study that storm water has an impact on the quality of the water as it is often contaminated with pollutants and litter. These are washed downstream quickly due to the modification done to the river in town. Storm water drains did not cope effectively with heavy rainfall in 2011 as there were widespread reports of storm water leaving the drains rather than entering the storm water systems. This led to flooding as well as burst sewage pipes. On two occasions during our data collection we found that raw sewage was leaking into the river because of a burst pipe. There is also widespread evidence that waste water drains that are designed to deliver domestic waste water to the municipal waste water treatment works are in an unacceptable state of repair (Figure 16 a, b, c, d).

In accordance to the above, Momba *et al.*, (2006) states that a substantial problem in modern waste water management has arisen as existing sewage systems are filled close to capacity and the infrastructure is poorly maintained. Many modern cities allow runoff from rainstorms to filter directly into the sewage system, which adds a stress to an already stretched system. As a result, during particularly heavy storms, or storms that last for long periods of time, the rainwater may cause the sewage system to exceed its capacity, creating what is called a combined sewer overflow, which can have a devastating affect within the cities and further on downstream (Momba *et al.*, 2006). From our results it has been gathered that Grahamstown's Waste Water Treatment Works are exceeding their capacity without the influence of storm water, thus increases in storm water are guaranteed to have effects downstream. Additionally results including C.O.D (Chemical oxygen demand) and nitrate already exceed the acceptable standards for treated waste water. The amount of sludge removed is on average 3600 m<sup>3</sup> per month. According to Morrison *et al.*, (2004) sludge is by far the largest in volume of all the

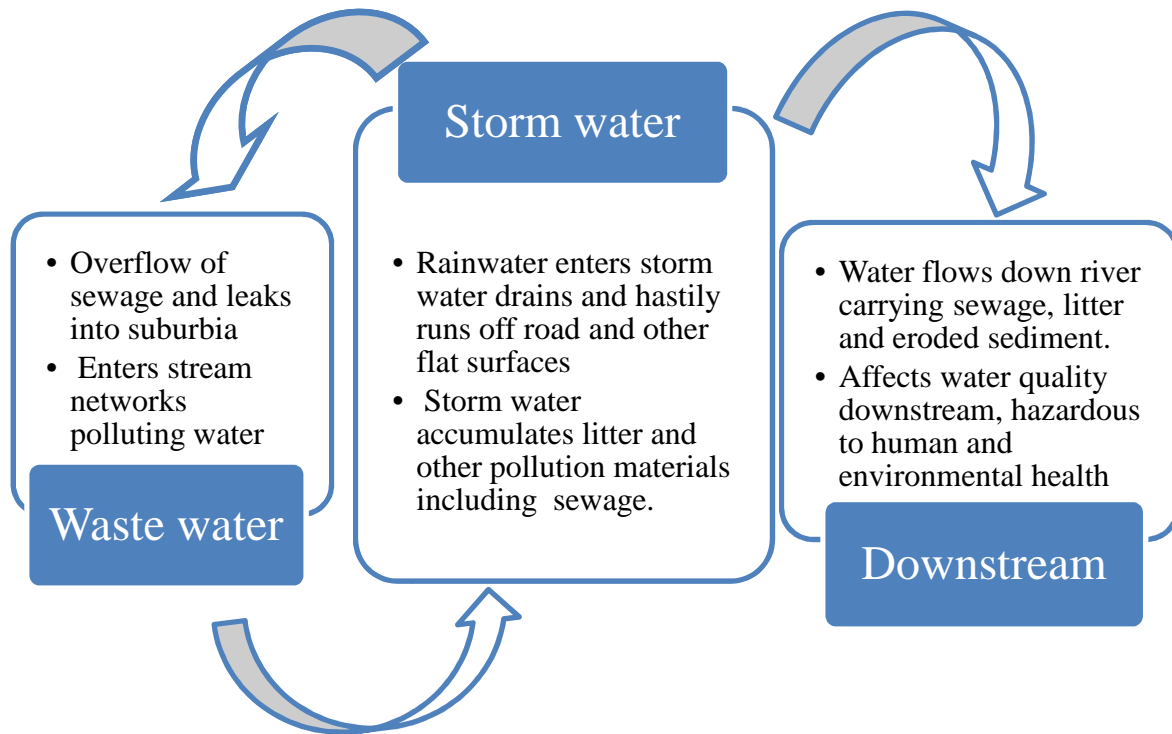
constituents removed from sewage treatment and its processing and disposal is perhaps the most complex issue in waste water management today. With the problem of fast growing population and rapid urbanization, the amount of sludge being produced is becoming a growing problem.



**Figure 16 (a) Wastewater leak near a school in Grahamstown East (Courtesy of the KCC) (b) Sewerage running into the Bloukrans stream (Courtesy of the KCC) (c ) Leak in Raglan road from a wastewater manhole (Courtesy of the KCC) d) Sewerage overflow off Beaufort Street (own image)**

It can be seen in the images above (Figure 16) that if infrastructural issues with regard to waste water are not maintained and improved the sewage pours out of the manholes and into the nearby streams which are the main recipients of storm water. Without a storm event however the sewage pollutes the streams and sludge develops on the surface where flow is not strong enough to carry it downstream. During the first storm or flush of water through an urban area the levels of pollution in the stream load can become more concentrated than the wastewater concentrations in dry weather conditions (Gnecco *et al*, 2005). Beneficially to Grahamstown's streams a storm event removes all the filth within the stream making the water cleaner, yet making the river banks dirtier with litter. This is disadvantageous to users of water downstream of the Bloukrans River as well as biodiversity within the river and the ocean as they receive the

continual and extensive pollution left by Grahamstown residents as well as the backlog of sewage from unfixed waste water leaks and spillage. Such is supported by (Walsh, 2000) where it was found that a catchment with increased urbanization showed a correlation to increased biotic degradation. The effect of storm and waste water can be summarised in the diagram below (Figure 17):



**Figure 17: Diagram showing a conceptual model of the relationship between storm and waste water and downstream**

Increased runoff due to road infrastructure causes increased rates of erosion, reduction in water filtration and rates of water recharge for groundwater and aquifers, change channel shape and increase rates of stream discharge (Forman and Alexander, 1998). As can be seen in Figure 16, urban water systems have entities that are interrelated. Both waste and storm water marry upstream and within the catchment, resulting in a significant impact on downstream quality and quantity. As a result of poor (leaky) infrastructure, sewage flows into residential areas, streams, as well as storm water drains. This is in turn exacerbated by the lack of storm water infrastructure.

Kirstenson, (2004) describes the DPSIR driving force and pressure relationships as “The environmental pressures that result from human activities, and are a function of two types of variables: (i) the level of these activities, and (ii) the technology applied in these activities”. In this case, the driving force is the dreadful storm and waste water infrastructure in

Grahamstown that results from a combination of poor management, insufficient infrastructure and high levels of litter in streams and other waterways. The level of these activities is high and the technology to mitigate the activities' effects is low.

### **Litter collections and water quality readings**

Following litter collections along the Bloukrans River, Figure 8 shows that at each site even after our first collection a vast amount of litter in and along the river still remained. The majority of this litter is at the downstream site as the river has been modified into a canal throughout the town, this means that the flow of the water has been increased and so most of the litter that is not washed up onto the banks, during a major storm event, is flushed further downstream. Additionally vegetation downstream is thicker with an increase in alien invasive that trap much of the litter onto the banks during high water levels following a storm event. From calculations done using GIS software, the amount of litter in an area for a length of the lower stream accumulates to nearly 2.5 tons (Figure 12).

An inverse relationship was discovered between rainfall and conductivity (Figure 9 and 13) this was confirmed by data supplied by the IWR as well as our own collected data over three months. An increase in rainfall brings about a decrease in the conductivity of the river whereas a decrease in rainfall brings about an increase in the conductivity. This is because electrical conductivity is measured through the concentration of dissolved inorganic salts in the water, and so an increase or decrease in rainfall will in turn affect the concentration of salts in the water (CWT Fact Sheet, 2002). Conductivity is an excellent indicator of water quality as it will vary with each different water source, such as rainfall or waste water; therefore it is able to indicate sewage leaks or groundwater seepage (CWT Fact Sheet, 2002). The CWT give 5 things that affect conductivity in water, but only two are applicable for Grahamstown and this study, namely rain and evaporation (CWT Fact Sheet, 2002). The conductivity of rainwater is 0 and so when it falls into a river or is part of runoff into the river it will decrease the conductivity, as shown in Figure 13. This though is for a pristine environment and in most cases the runoff will increase the conductivity as litter and other pollutants are washed into the river with the runoff, as has been the case in Grahamstown. Evaporation on the other hand increases conductivity as there is less water and so the concentration of dissolved salts increases.

There has been a moderate change in the temperature of the river (Figure 10), which although partly due to the seasons and the climate is also due to storm water and litter, as these have played a major role in changing the river. This temperature change, although not good, is according to Sherman, (2008) an infrequent occurrence.

### **Sustainability of waste and storm water management in Grahamstown**

The Water Act, (1998) recognizes that the protection of the quality of water resources is necessary to ensure sustainability of the nation's water resources in the interests of all water users. To assess this in Grahamstown, interviews were held with stakeholders and key informants.

Following interviews with key informants (excluding municipal managers as they could not be contacted) as well as from visual evidence, the management of storm and waste water is most certainly unsustainable. In an interview with Nikki Kohly, secretary of the KCC and environmental officer at Rhodes University on storm water management it became clear that there are issues with regard to maintenance of infrastructure and knowledge on how to manage storm water. Grahamstown suffers with an incapability to manage the vast volumes of storm water that it receives. According to Nikki Kohly the management is highly unsatisfactory due to 'a lack of expertise and institutional knowledge'. Impacts of a lack of management include road damage in the form of potholes, health risks and effects on ecosystem processes. In asking if the management of storm water would improve in the next 5 years, it was said that it will not change because enforcement is weak and there would need to be a big change in the willingness of the local government to do something about storm water. Additionally it was said that waste water infrastructure and drainage needs to be better maintained and improved

### **Recommendations**

#### *Storm water management*

Burkhard *et al.*, (2000) states that effective and sustainable water management practices requires a multidisciplinary approach including a balance of technical, economic, environmental and social aspects while holding the satisfaction of developers, planners, environmental protection agencies and customers. In addition to this Wright, (1996) identifies storm water management as being multifaceted and complex in both urban and rural areas.

Management according to Wright, (1996) includes the physics of catchment runoff, changes due to urbanization, the hydraulics for storm water and sewage conveyance and collection, and the source and nature of the contaminants carried by these water flows. In order to successfully manage storm water sustainably we recommend that the municipality improve services of refuse collection, environmental health and cleansing, town planning, parks and recreation and water and sewage. Law enforcement needs to be improved such as through fines with regard to littering, illegal dumping and wastewater discharge as without awareness the public ignorance makes it difficult to improve service delivery (KCC, 2007). It is important to deal with the source of the problem before it becomes a cause of poor water quality. As a cause of poor water quality, litter found on river banks need to be cleaned up regularly to reduce impacts downstream for both humans and the aquatic biodiversity of both



fauna and flora. The clean ups should include the removal of alien invasives as they trap litter and reduce the natural diversity of the riparian ecosystem. Such can be assisted by Working for Water. A particular example of alien invasive includes *Xanthium spinosum* (left) which is noticeably a particularly bad invasive in the downstream areas as it traps litter onto its prickly seed pods creating an eye-sore in the landscape.



**Figure 1: *Xanthium spinosum* plant at lower site**

We also recommend that the municipality look into installing Sustainable Urban Drainage Systems or SUDS which are an easy to manage, cost-effective solution to the current drainage system. SUDS are designed to manage runoff flowrates, reduce the impact of urbanisation and danger of flooding, provide water treatment and protect water resources from pollution (CIRIA, 2011). The type of SUD is dependent on different variables such as land availability, costs and ecology parameters. We recommend that Grahamstown look into the possibility of installing SUDS such as ponds, wetlands, retention ponds, swales, infiltration trenches and porous pavements (CIRIA, 2011). It is important to note though that SUDS will need to be maintained and repaired when necessary, which is currently not occurring in Grahamstown and so is worsening the storm water problems. Walsh, (2000) states that one can use catchment imperviousness and drainage design as a framework for assessment and management of water resources.

### *Waste water management*

A major issue with regards to waste water or sewage is that treatment facilities, mainly in developing countries, lack the infrastructure and technology to efficiently and adequately rid the effluent of its polluting agents (UNEP, 2001). Although the waste water treatment works themselves are maintained and managed very well, the issue is in terms of waste water infrastructure before it is able to reach the sewage works. Makana municipality need to improve networks of storm and waste water by fixing leaks and damage to piping. Without attacking this issue as a source of all problems management cannot possibly be achieved with any level of success. Makana Municipality therefore also need to contribute more of their funds to fixing and maintaining waste water infrastructure which will in turn improve the quality of storm and stream water.

Newman and Mouritz, (1996) call for the development of local by-laws and regulations to ensure that the water cycle, which is a localized system, is managed at a local community scale (1995: 340). The paper also highlights the possibility of the privatization of water management which may be beneficial to Grahamstown, as local authorities and municipalities usually lack the capacity and funding to perform their duties and functions efficiently (Owusu-Asante and Ndiritu, 2009).

### *Integrated Water Resources Management (IWRM)*

Newman and Mouritz, (1996) and Jonker, (2007) both emphasize the need for integrated water resources management in order to efficiently and sustainably manage water resources. IWRM is defined as “a process which promotes the coordinated development and management of water, land and related resources, in order to maximise the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (Jonker, 1995: 1257, Global Water Partnership, 2000).

With water availability and quality being one of the four environmental priorities, the South Africa Environment Outlook, (2006) recommends that land and water policy, as well as management be integrated, especially in integrated development plans and catchment management strategies. Rapport and Singh, (2006) also speak of a similar concept of adopting an ecosystem perspective, it represented a significant advance from the then prevailing engineering-based approaches, with their focus on contaminants in air, water and land; in

reference to the Pressure-State-Response (PSR) model. Therefore a holistic approach to training of Makana Municipal staff, such as Integrated Water Resource Management, must be executed adequately.

To lessen the costs of having to manage storm water and waste water the Makana Municipality should look into the sustainable integrated management of the two, which is the process of considering the two as inextricably linked (IETC, 2011). An important tool in this process would be the waste management hierarchy (Table 3), which provides a step by step procedure on how to ensure that waste management is an environmentally sound practice (IETC, 2011).

**Table 3: The waste management hierarchy**

Step 1: Prevent or reduce waste generation
Step 2: Reduce the toxicity or negative impact of the waste
Step 3: Recycle waste in its current form
Step 4: Reuse waste after further processing
Step 5: Treat waste before disposal
Step 6: Dispose in an environmentally sound manner

In a sustainable integrated water system, water and nutrients are reused and recycled where possible to limit the amount of chemical fertilisers used as well as reduce the amount of water being wasted. The integration of storm water and waste water does not mean that the two must be mixed or combined but just that they are linked and thus have a huge impact on one another.

## Drivers–Pressures-State-Impacts-Response (DPSIR Framework)

**Table 4: DPSIR of storm and waste water in Grahamstown**

	<b>Storm water</b>	<b>Waste water</b>
<b>Drivers</b>	Urbanization, increase in surfaces such as roads and decrease in natural vegetation, poor drainage infrastructure, lack of storm water management, lack of law enforcement for dumping and littering. Urbanization also creates a heat island over cities and towns causing more convection rainfall (EPA, 2011).	Population increases, urbanization, poor maintenance and development of waste water drainage before treatment works
<b>Pressures</b>	During dry periods in urban areas pollutants build up from mainly motor vehicle traffic and other human activities, the pollutants that accumulate are dissolved colloidal and solid constituents made up of organic and inorganic compounds, oil, nutrients, greases, heavy metals and accumulation of litter (Gnecco <i>et al.</i> , 2005).	Storm events cause an influx of water into the waste water system on top of the existing waste water. Coupled with the badly maintained infrastructure the excess storm water and the sewage produce combined sewer overflow (Momba <i>et al.</i> , 2006)
<b>State</b>	Poor water quality following a storm event, quality of storm water infrastructure is unsustainable. Water quantities too much for river system and infrastructure to handle	Drainage infrastructure unsustainable, leaks into storm water drains and streams, water treatment works in good condition, treated water for some tests does not meet quality standards.
<b>Impacts</b>	Hydrological impacts of storm water are both indirect and direct. Direct impacts include the enlargement of water channels through erosion and indirect impacts are an increased risk of flooding within urban environments (Walsh, 2000).	Impacts are on ecosystem functioning and health. Wastewater is causing adverse impacts of lakes rivers and coastal water systems; one of the most threatening effects of storm and waste-water is the

According to Forman and Alexander, (1998) roads have an impact on the physical processes of water runoff and sediment yield. Surface water flows through ditches along the roadside and either transfer to streams or gullies (Forman and Alexander, 1998) Increased runoff due to road infrastructure causes increased rates of erosion, reduction in water filtration and rates of water recharge for groundwater and aquifers, change channel shape and increase rates of stream discharge (Forman and Alexander, 1998) Impacts for human health downstream, on riparian vegetation, aquatic and terrestrial biodiversity and ecosystem functioning on the whole. Storm water affects water properties including; temperature, pH, electrical conductivity, minerals and nutrients. Can lead to eutrophication and introduction of alien invasive species in areas of increased disturbance from pollution

microbial contamination of these habitats. This contamination is altering the abundances and the diversity of the aquatic organisms (Chambers *et al*, 1997). A loss in ecosystem functioning effects the ability for people to sustain their livelihoods due to the vulnerability placed onto ecosystem services.

<b>Response</b>	IWRM, multidisciplinary approach, monitoring, improvement of services, law enforcement
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## Conclusion

In order to ensure a future where water shortages are not exacerbated, we need to start now and develop a multidisciplinary approach to the planning, specification, costing and evaluation of water and waste water options, specifically in the domestic and industrial context (Burkhard *et al.*, 2000). Storm water is unsustainably managed in Grahamstown with its impacts stretching into the already stressed and poorly maintained infrastructure of both waste and storm water. Without proper management of storm and waste water it can be expected that with increasing development, the problem of poor water quality within the town will continue to get worse. Not only does mismanagement have human health effects but also impacts on river ecosystems including aquatic and riparian biodiversity. Excesses in water from surface runoff during storm events changes channel shape and increases erosion along river banks. It is clear from this study that there is a dire need for the sustainable management of storm and waste water in Grahamstown.

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