**Dienie Steenkamp**

# The impact of storm water on Langenhoven Park: an integrated approach can make a difference

*Peer review*


## Abstract

Langenhoven Park is a suburb situated north-west of Bloemfontein, Mangaung. It started as a garden suburb but is increasingly characterised by town house developments. The increase in impervious surfaces contributes to the amount and speed of storm water runoff.

The storm water runoff negatively affects the groundwater levels. As an arid country, South Africa cannot afford to lose water, albeit on the surface or as groundwater. Recent literature regards the treatment of storm water at source as the best solution.

This article examines the role of legislation in dealing with storm water and how to treat storm water as an asset, and not as a problem. Storm water in Langenhoven Park needs special attention with regard to all the hard surfaces in recent residential developments.


Keywords: Storm water, town houses, drainage channels, amenity, asset


## Abstrak

Langenhovenpark is 'n woonbuurt aan die westekant van Mangaung. Dit is begin as 'n 'tuinstad', maar tans word dit oorheers deur meenthuisontwikkelings. Die harde oppervlakke het toegeneem wat geen water dreineer nie en dit vermeerder die hoeveelheid en spoed van stormwater.

Die wegvoer van stormwater het 'n negatiewe effek op grondwatervlakke. Suid-Afrika as 'n water-skaars gebied kan nie bekostig om water so te verloor nie. Die nuutste gevolgtrekking is dat stormwater by die oorsprong hanteer moet word.

In hierdie artikel word gekyk na maniere om stormwater vanaf vanaf wetgewing tot die optrede van ontwikkelaars, huisbewoners en besighede te hanteer. Stormwater word beoordeel as 'n bate vir die gemeenskap en nie as 'n probleem nie. Stormwater in Langenhovenpark moet aandag geniet weens al die harde oppervlakke geskep deur die nuutste residensiële ontwikkelings.


Sleutelwoorde: Stormwater, meenthuise, dreineringskanale, bate

Mrs. Glaudina Maria Steenkamp, Programme Director, Department of Urban and Regional Planning, University of the Free State, South Africa. Phone: +27 51 401 3210, Fax: +27 51 444 6550, email: <steenkgm.sci@ufs.ac.za>

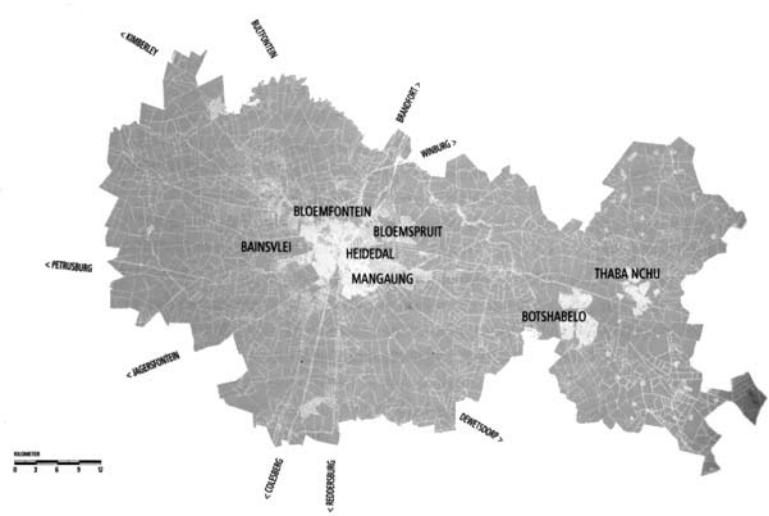


Figure 1: Locality plan of Mangaung Local Municipality with Bainsvlei (Langenhoven Park) to the west
Source: MLM 2004: 8

## 1. Introduction

Langenhoven Park is situated to the west of Bloemfontein. This suburb was originally the farm of Andrew Hudson Baines and Bainsvlei served as homestead from 1905[1]. In the 1980s Langenhoven Park was designed as a garden suburb, but it has since developed to include numerous town house complexes and duet houses. This area is relatively flat and interspersed with small koppies. The drainage of storm water is no problem under normal circumstances but with all the town house developments and the increase in hard surfaces the storm water could become a problem in this area. On 26 January 2006 a rainstorm in Langenhoven Park flooded the area. There was so much surface water that the children played with boats in the streets. These floods resulted in substantial damage to infrastructure and private property (Sauer, 2006:1).

The objective of this article is to consider all the legislation pertaining to storm water and to find cost-effective solutions for storm water

1 On 24 August 1860 the biggest hunt was conducted on this farm that when Prince Albert (Queen Victoria's son) and Sir George Grey and others shot more than a thousand buck within an hour (Steyn & Wessels 1999: 65).

management in Langenhoven Park that will be financially, socially and ecologically acceptable.

## 2. The causes of the amplification of storm water

Storm water and floods are natural phenomena that occur from time to time, while inundation is generally promoted by man and urbanisation. One of the most famous and earliest mentioned floods occurred when Noah and his family survived in the Ark. All life forms depend on water and soil; and they should thus receive priority in any development context (CSIR, 2000: 6, 9). Some floods are not natural disasters, but are man-made inundations, for instance in the case of developments in floodplains (Olivier, 2006: 7).

The actions of man, such as urbanisation, deforestation and agricultural drainage, aggravate problems relating to storm water (Turner, 1998: 280). Urbanisation increases the prevalence of impermeable surfaces such as roofs, streets, sidewalks and other paved areas, resulting in more runoff and less infiltration, which must be drained (Gaspar, Tavares & Azevedo, 2005: 275). Development, coupled with a lack of vegetation, causes an increase in the quantity and peak flow rate of the runoff (CSIR, 2000: 6, 6). The velocity and the level of the water determine the degree of flooding and the resultant damage. In a study conducted in Iran, Hosseinzadeh (2005: 427) found, that the length of time during which the concentration of urban floods is at full force doubled, and that urbanisation increased flood frequencies by up to 100%. The actions of man are causing increases in storm water.

## 3. Increased density and storm water

Sustainable development requires a dense urban form to prevent urban sprawl and loss of biodiversity; and mixed uses to reduce travel costs, energy and resource consumption (Beisi, 2001: 26).

"Compact cities bring a kind of ambivalence, as high densities are not always compatible with the natural environment and green cities" (Stapelberg, 2006: 2, 3). Compact cities, however, mean more hard surfaces and runoff and hence increased storm water. All the town house developments in Langenhoven Park could make it a compact city if it were not for the homogeneous residential land use (see Figure 2).

> *… it is now largely a car dependant suburb where inhabitants have to reach schools, jobs and to a large extent recreational*

> *facilities by car as the only modem of transport (Steÿn & Schoeman, 2006: 9, 15).*

If we regard compact cities as sustainable, the issue of storm water has to be considered and mitigated.

Figure 2: Homogeneous residential developments
Source: Steÿn & Schoeman 2006: CD- ROM

## 4. Recent handling of storm water

Engineers calculated the runoff and planned to discharge it by means of an underground drainage system or concrete channels (Turner, 1998: 286). Purseglove (1988: 2) considers such drainage channel as 'strait-jackets of steel and concrete'. Turner (1998: 285) condemns the use of public funds to destroy public assets such as streams, wetlands and floodplains. Accommodating this rapid run-off and discharging it into the storm water system causes flooding downstream, if the stream is not widened to accommodate the additional volumes of water. To compensate, upstream landowners should contribute to river works downstream (Turner, 1998: 286, 287). Many streams in urban areas are dangerous and enclosed by barbed wire. The incorrect handling of storm water in urban areas can exacerbate desertification in rural areas. Problems in this regard include storm water drainage, destruction of wetlands and floodplains, and the planting of alien vegetation (Olivier, 2006:

5). Usually the 'improvement' of rivers means increasing their flow capacity (Turner, 1998: 295) (see Figure 3). According to these authors, the handling of storm water creates problems for the environment, not solutions.

Draining most of the rain away from an area diminishes the groundwater table with a detrimental effect on all vegetation. Boreholes will dry up, and people who are dependent on water from boreholes will be affected.

The practice of channelling storm water and draining it as fast as possible has serious effects on the environment and other ways to handle storm water should be investigated.

Figure 3: Storm water channels which increase the speed of the storm water
Source: Steenkamp 2008: own picture

## 4.1 Calculation of flood lines

Heavy rainfall causes floods, especially in urban areas. Engineers classify the size of floods in terms of the probability of such a flood occurring again within a certain period of time. The storm water system should be able to handle floods up to the five-year level. When a ten-yearly or 100-yearly flood occurs, buildings and roads

are flooded, resulting in inconvenience and injuries and damage to people and property. Building flood-defence works is expensive, depleting public funds; there are also environmental consequences including exacerbation of flood-related problems downstream. This problem could be addressed by managed flooding; for example, certain facilities, called multifunctional landscapes such as playing fields, parks and gardens, could be built below the flood lines. Pervious pavements could improve infiltration, vegetated channels could slow down the velocity of the flow, and grass buffer strips could remove pollutants.

An annual flood could be accommodated by means of non-essential car parks and roads, whereas 100-yearly floods could be accommodated in some urban areas with non-essential services (though not in areas comprising hospitals, for example). If people wish to build under the prescribed flood lines they should know that extra costs are involved, and that they should not lay any claim to public funds (Turner, 1998: 299-300). This is illegal in South Africa in terms of the Water Act and the National Building Regulations.

Buildings could be made 'flood- tolerant' or flood-proof by:

- Sealing electrical services;
- Using water-sealed doors;
- Raising buildings on stilts, and
- Waterproof concrete or extra foundations.

Traditionally, the storm water drainage system accommodated frequent storms and associated runoff. Current property values have increased to such an extent that engineers must take the possibility of more severe storms into account (CSIR 2000) Global warming is changing our weather, with increased severity of storms. *Guidelines for Human Settlement Planning and Design*, commonly referred to as the red book, discusses a dual system which makes provision for both of these eventualities. The frequent storms are accommodated by the normal storm water drainage system, referred to as a minor system. The severe storms are accommodated in terms of a major system, which includes conduits, channels and the road system, so that the water can be conducted to suitable points of discharge, such as parks and sports fields (CSIR, 2000: 6, 3).

## 4.2 Present regulations and policies

The *National Water Act* (Act 36 of 1998) requires a 100-year recurrence interval flood line for all development plans. Municipal authorities may also require other flood lines (CSIR, 2000: 6, 6).

Many property deeds have a built-in requirement that the lower land must receive the runoff from higher properties along the natural course of the land (CSIR, 2000: 6, 1).

Prevention of water pollution is regulated by the Departments of Water Affairs and Forestry, Environmental Affairs and Tourism, and Health (CSIR, 2000: 6, 7).

The *National Environmental Management Act (NEMA)*, Act 107 of 1998 (South Africa, 1998) and regulations in terms of Chapter 5, Government Notice regulations 385, 386 and 387 regulate developments and determine when Environmental Impact Assessments (EIA's) are necessary.

Township establishments are done according to the legislation of the different provinces where the 1:50- and 1:100-year flood lines are required on layout plans; authorities usually do not permit construction under these flood lines. Storm water forms part of the services reports compiled by engineers.

## 3.3 Stormwater and the Mangaung Municipality

The Integrated Development Plan of the Mangaung Local Municipality states that roads and storm water infrastructure services are expensive to construct and maintain, and it is not an income-generating service. It is funded by property tax income, property developers or grants for lower income areas (MLM, 2004: 127).

According to an official (who wishes to remain anonymous) of the Mangaung Municipality, the municipality caters for 1:5-year floods in the underground system. More severe floods should be handled by means of the roads. The layout is handled by the town planners, who try to handle storm water *via* the streets, and avoid allowing the storm water to flood property from the streets.

Lower-lying properties should accommodate water. Problems usually occur when walls and structures are built in water courses and drainage channels, or when underground systems are blocked. Blockages are caused by overgrowth of vegetation, or littering in the streets or at building sites.

The legal department is responsible for handling claims after flooding. The municipality does not become involved in disputes between neighbours regarding storm water issues.

Storm water is not a major issue for the Mangaung Local Municipality. In 2006, after exceptionally high rainfall, numerous complaints were

received. People normally tend to forget storm water until the next storm occurs. A lack of capacity makes it impossible to implement measures to handle storm water in a more sustainable way.

## 4.4 Storm water in Langenhoven Park

Langenhoven Park was established as a garden city in the 1980s. The character of the suburb changed from 1991 with the development of sectional title town houses on general residential sites of two to 11.28 hectares. Approximately 200 sectional titles were registered from 1981 to 1985 while this grew to approximately 1200 from 2001 to 2005. The area of town house development expressed in hectares was less than 10 hectares from 1981 to 1985 but from 2001 to 2005 it grew to nearly 60 hectares. The density increased with 30 town house units per hectare as the norm (Steÿn & Schoeman, 2006: 5, 6). According to Steÿn & Schoeman (2006: 12), the high density of the town houses in Langenhoven Park has a negative impact on civil municipal services such as storm water and sewerage due to increased surface water drainage.

Figure 4: Open spaces as a trench for storm water
Source: Steÿn & Schoeman 2006: CD- ROM

Figure 5: Storm water canal used as a dumpsite
Source: Steÿn & Schoeman 2006: CD-ROM

Open spaces are used to handle storm water in Langenhoven Park. Some of these open spaces are canals for storm water (see Figure 4). This could be an amenity to the community with the correct methods like swales and vegetation. At present it is an eyesore and used as a dump for rubbish and building rubble (see Figure 5). The surfaces of many other parks are also impervious. Swales and indigenous vegetation could help to slow down storm water.

Walls around town house developments can aggravate the damage during floods when it is built in water courses or in floodplains and if it cannot drain or if blockages occur. During the construction of the town houses many storm water channels were blocked by builder's rubble or broken by heavy vehicles.

In Langenhoven Park a public participation process was started to implement measures to inform the residents of ways to reduce storm water and to use the storm water channel in a more sustainable manner. Through ownership of the area the neighbours to these trenches could help to reform this area. Swales could slow down the water and help with water harvesting for trees and shrubs. Garden waste could be dumped in an organised manner to be used as

compost and mulch. A wetland could be developed if a wall with an overflow could be constructed at the lowest point of the trench.

## 5. Storm water as a resource

If storm water is regarded as a resource and not as something to drain as quickly as possible, there are many options to handle storm water, as demonstrated in the following paragraphs.

In future, river catchment management should refer to "multi-purpose schemes designed to improve the capacity of each river valley to function as a visual amenity, a recreation area, a fishery, a nature reserve, a water supply, a storm detention area, a drainage network and a movement corridor for boats, walkers, cyclists and equestrians" (Turner, 1998: 295). This can be achieved through multi-purpose planning, managed flooding, storm detention basins, infiltration facilities, vegetated roofs, porous pavements and natural river works (Turner, 1998: 295). Purseglove (1988:164) suggests that one side of the channel should be kept untouched. Water management planning should be conducted on a catchments basis, and the handling of storm water should form part of the bigger picture. Policies could restrict post-development runoff to pre-development runoff levels (CSIR, 2000: 6, 6). Developers should pay a large retention fee which the Local Authority should retain for approximately 18 months after 50% of the area is developed to ensure that they do not disappear, leaving home owners to manage storm water from poor design and construction.

Rainwater is free of charge; and it should be handled as a resource. The best way to handle storm water is at its source; runoff should be detained where it occurs, and released as slowly as possible. Rainwater should infiltrate the ground where it falls. Water infiltration has several advantages: enhanced soil moisture levels; river flow can be regenerated, and improved water quality. Retention of storm water helps with evaporation through the soil and plants, groundwater recharge and the remainder could be drained off after a delay (Göbel, Stubbe, Weinert, Zimmerman, Fach, Dierkes, Kories, Messer, Mertsch, Geiger, & Coldeway, 2004: 270).

If one uses swales as retention basins, they should be integrated with the landform design (Hosseinzadeh, 2005: 431). A drainage levy can be imposed on landowners who discharge water. The amount of drainage from an area can be calculated, and developers who exceed the maximum stipulated rate of runoff should pay compensation, or carry out work in order to detain the water

and prevent more problems from occurring downstream, or use a retention fee. Other land uses, such as forestry and wetlands, contribute towards retaining storm water and floods.

In South Africa, runoff usually has a high clay content; thus it is not economically viable to filter out the products of erosion (silts and clays). This would take too long, and would require large portions of land. Retention facilities should be used as water bodies and should allow natural processes to occur, for example in the case of wetlands (CSIR, 2000: 6, 21).

Edmond (2005: 215) describes the following uses for urban storm water:

- Irrigation of nearby parks;
- Navigation and transport;
- Aquaculture and the breeding of ducks and fish, as well as the cultivation of water plants;
- Using the fish population to get rid of mosquitoes;
- Fire-fighting;
- Washing down;
- Industrial use;
- Toilet flushing

In 1981, a survey on the handling of storm water was conducted in the USA and Canada. Nearly half of the 12 683 facilities were dry basins; 25% were car parks; nearly 20% were ponds; while 5.5% consisted of rooftop areas. It was determined that the detaining of storm water, and releasing it at a regulated rate, comprised the fundamental principle of storm water management (Turner, 1998: 303).

## 6. How to handle storm water in a more sustainable manner

Roofs are steeply inclined and smooth, and thus comprise the fastest rainwater discharge points of all urban surfaces. Turner (1998: 304) and Hosseinzadeh (2005: 427) advocate the use of vegetated roofs. Vegetated roofs could help with insulation in very hot or cold climates.

Porous pavements and streets could be used in areas where the roads are not so busy. The street could be used by pedestrians, cyclists and children; and the roughness of natural surfaces could ease the traffic (Turner, 1998: 306).

Structures that are built to control floods should have many purposes, including water storage, flood protection, aeration, storm detention, *etc*. Many structures could be used for recreation, such as canoeing, fishing, swimming, camping, *etc*. (Turner, 1998: 309). The Willamette

River Water Treatment Plant in Wilsonville, Oregon was planned in order to accommodate a park, as well as community facilities including a meeting room, a laboratory and an administrative building. Picnic pavilions, attractive scenery across the river, access to the river, and trails connecting the river to other open spaces in the city, all form part of this scheme. The water is pumped to the top, and waterfalls and ponds form an artificial water feature (Sensenig, 2004: 8).

Parks - It is better for ecosystem services if small areas are connected to form corridors, rather than isolated islands (Olivier, 2006: 6). Smaller parks could form part of the drainage system for the purposes of treatment and storage (Edmond, 2005: 212, 213).

Wetlands play an important natural role in the handling of storm water. Wetlands are those areas that are inundated or saturated by surface or groundwater, at a frequency and duration that are sufficient to support - and which, under normal circumstances, actually do support - an abundance of vegetation and animal life typically adapted to life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas. The advantages of wetlands include the filtering of pollution, the purification of our drinking water, the recharging of groundwater aquifers, and the absorption of floodwaters (Maret & Blakeman, 2005: 454; Olivier, 2006: 7). Soft-edged wetlands provide storage for the purposes of flood control, drainage, and the treatment of water for re-use (Edmond, 2005: 210). Building up to the edge of the wetland does not destroy the wetland itself; but over time, it becomes uninhabitable for fauna and flora. Wetlands contain unique birdlife, medicinal plants and grass that can be used for making mats, hats and other artefacts. They also help to contain fires (Olivier, 2006: 8). Wetlands create environments for microbial populations, which alter contaminating substances by using the nutrients or energy contained therein. Other advantages of wetlands (constructed or natural) include low maintenance levels, as well as the fact that they provide habitats for plants and animals. Wetlands can be regarded as an asset, offering opportunities for recreation and education (CSIR, 2000: 6, 21). Reed-bed systems purify water, and should form part of the water-management system (Turner, 1998: 301). Water quality could be improved by the installation of litter- and oil-traps before the water enters the wetland. Water could be cleaned by using natural ultra-violet light, and nutrients could be absorbed by macrophytes.

In Norway, the construction costs of an open drainage system are 30% lower than the cost of a conventional pipe system. Operational

costs were approximately the same (Astebol, Hvitved-Jacobson & Simonsen, 2004: 247).

Handling storm water naturally holds benefits for the environment and the population, and is also beneficial from a financial point of view.

## 7. Management of storm water

Management of storm water is important and should include enforceable regulations for settlement development in order to encourage water savings and groundwater recharging. A programme for infrastructure repair and maintenance is the task of the local government (Du Plessis & Landman, 2002: 79). The funding of storm water management is important. In Canada, the system of payment by property owners for the use and benefit they derive from storm water management and on estimates of impervious property area is popular, because it is fair and equitable. An equitable system of payment can serve as an incentive to adopt on-site best practices (Cameron, J. & Cincar, C. & Trudeau, M. & Marsalek, J. & Schaefer, 1999: 255).

The following measures could help to reduce and handle runoff:

- Detention/retention ponds or rooftop detention;
- Overland flow in open channels should be planned at the outset in collaboration with the road layout planners;
- Preference should be given to pervious surfaces;
- The maintenance of vegetation and alternative fuel sources should be developed to retain the vegetation (burning plant material for heat and cooking). Trees and plant beds can use storm water if they are not enclosed (see Figure 6)

Figure 6: Verge around the tree that catches the water
Source: Joubert 2007a: own drawing

- The use of contour planning and swales to retain runoff water;
- Soak-ways could be used to detain runoff water in wetlands (CSIR, 2000: 6, 8).

All the measures for handling storm water could be implemented if they are included in guidelines and enforced by the Local Authority. According to legislation, storm water

is not important until a storm turns into a flood that causes damage. The following measures can be taken, namely the developers could use pervious paving; the residents could use less paving and more soak-aways and water tanks; the construction teams could ensure that the storm water drainage systems are not blocked. The handling of storm water should be part of integrated planning. From the layout of the township, the construction of the houses and infrastructure and the residents' gardening habits to the municipality's management of open spaces, all parties involved have a role to play.

## 8. Recommendations

Storm water must be handled in an integrated manner from the inception of the township, including the construction of the services and buildings and the maintenance of the open spaces and the individual properties.

### 8.1 Planners

- Water management should be done for the entire catchment area, including rain, surface and groundwater. Cognisance should be taken of water reticulation, sewage and storm water. The Department of Water Affairs and Forestry has legislation in this regard.
- The regulations for EIA should require the developer to determine the runoff before development and calculate the runoff after development. The measures to minimise and detain storm water should be stated in the report as part of the EMS and must form part of the Record of Decision.
- Planning according to contours helps to minimise storm water and reduce the speed of the runoff. From the onset the drainage should be planned especially before paving (see Figure 6). Examine alternatives for hard surfaces.
- Development should not occur in drainage areas, floodplains or wetlands.

- Open spaces should be connected and planted with indigenous vegetation (vegetated channels). Trees should be planted but also ground cover in beds to help with the drainage of storm water.
- Multi-purpose planning of open spaces could help to create amenities for the entire community. Such spaces could be used for recreation, water detention (grass buffer strips), relaxation, exercise and biodiversity.
- Wetlands and artificial wetlands should be created in open spaces to contribute towards water purification.

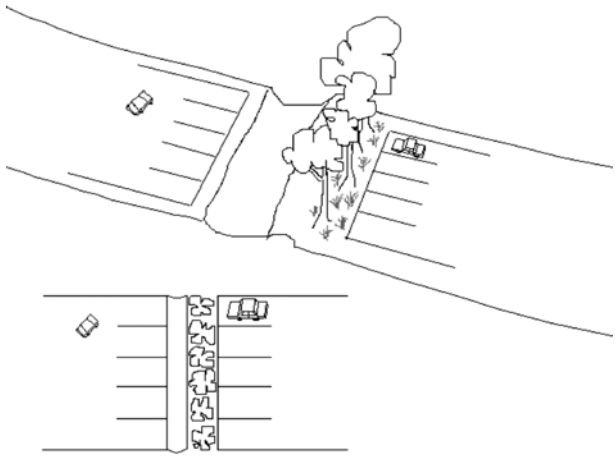

Figure 7: Schematic view of the use of swales in parking areas
Source: Joubert 2007b: own drawing

## 8.2 At home

- Plant an indigenous garden with swales to harvest water and prevent runoff.
- Install rainwater tanks.
- Refrain from paving large areas with impervious material, seek alternatives.

### 8.3 Communities

- Communities can work together and take ownership of the parks and storm water drainage channels in their area and create an amenity.

### 8.4 Local authority

- Ensure that the initial design of the township minimises or retains storm water and that that the construction of the area complies with the Record of Decision of the EIA.
- Restrict the construction of impervious surfaces. Parking areas could also be designed to minimise storm water. The use of plant beds and swales could help with the retention of storm water.
- Incentives and/or penalties could help to motivate developers to use appropriate surfaces and designs to minimise and detain storm water. Levies could be imposed for developments that increase runoff.
- Incentives could be used for residents who install water tanks and who use less paving material.
- A balance between housing densification and decreased storm water runoff should be pursued as an important objective.
- Infrastructure should include multi-purpose assets in the community. Storm water drainage and detention could be achieved by means of wetlands and parks. A wetland needs a dam wall with an overflow to contain the water.
- Streets with low traffic volumes could be constructed with pervious surfaces, with the dual purpose of easing traffic and draining storm water.
- Jobs could be created for entrepreneurs to produce pervious paving blocks.
- Public participation could help to change the storm water canals in something for the community to enjoy.

The Environmental Impact Assessment (EIA) process should inform all stakeholders on how to handle storm water in a sustainable manner. While the EIA process focuses on individual projects, the Strategic Environmental Plans could help with the bigger picture.

*Water is a unique commodity. Let us treat rain as the true blessing that it is.*

## References

Anonymous official of Mangaung Local Municipality, interview on 14 Feb 2007.

Astebol, S., Hvitved-Jacobson, T. & Simonsen, O. 2004. Sustainable storm water management at Fornebu – from an airport to an industrial and residential area of the city of Oslo, Norway. *Science of the Total Environment*, Vol. 334-335, pp. 239-249.

Beisi, J. 2001. Flexible housing, compact city and environmental preservation: A critical look at Hong Kong's experience. *Open House International*, 26(1), pp. 26-33.

Cameron, J., Cincar, C., Trudeau, M., Marsalek, J. & Schaefer, K. 1999. User pay financing of storm water management: A case-study in Ottawa-Carleton, Ontario. *Journal of Environmental Management,* 57(4), pp. 253-265.

CSIR. 2000. Guidelines for Human Settlement Planning and Design. Boutek Report No. BOU/E2001. CSIR Building and Construction Technology, Pretoria.

Du Plessis, C. & Landman, K. 2002. Sustainable analysis of human settlements in South Africa. Report No. Bou/C368. CSIR Building and Construction Technology, Pretoria.

Edmond, R. 2005. Ningbo – a new sustainable city for China. Paper delivered at the Conference on Sustainable Development and Planning, 11 Sept., Bologna, Italy. In: Brebbia, C.A. (Ed.). *Sustainable Development and Planning II, Vol 1*. Southampton: Wit Press, pp. 207-218.

Gaspar, J., Tavares, A. & Azevedo, J. 2005. Environmental and hazard perception: A case study of a peri-urban area of central Portugal. Paper delivered at the Conference on Sustainable Development and Planning, 11 Sept., Bologna, Italy. In: Brebbia, C.A. (Ed.). *Sustainable Development and Planning II, Vol 1*. Southampton: Wit Press, pp. 271-280.

Göbel, P., Stubbe, H., Weinert, M., Zimmerman, J., Fach, S., Dierkes, C., Kories, H., Messer, J., Mertsch, V., Geiger, W.F. & Coldeway, W.G. 2004. Near-natural storm water management and its effects on the water budget and groundwater surface in urban areas taking account of the hydrogeological conditions. *Journal of Hydrology*, 299(3-4), pp. 267-283.

Hosseinzadeh, S. R. 2005. The effects of urbanization on the natural drainage patterns and the increase of urban floods: Case study Metropolis of Mashhad - Iran. Paper delivered at the Conference on Sustainable Development and Planning, 11 Sept., Bologna, Italy. In: Brebbia, C.A. (Ed.). *Sustainable Development and Planning II, Vol 1*. Southampton; Wit Press, pp. 423-432.

Joubert, S. 2007a. Artist of the drawing: Verge around the tree that catches the water. Bloemfontein.

Joubert, S. 2007b. Artist of the drawing: Schematic view of the use of swales in parking areas. Bloemfontein.

Maret, I. & Blakeman, H. 2005. Can we plan to protect our environment? Spreading urbanization in the state of Louisiana. Paper delivered at the Conference on Sustainable Development and Planning, 11 Sept., Bologna, Italy. In: Brebbia, C.A. (Ed.). *Sustainable Development and Planning II, Vol 1*. Southampton: Wit Press, pp. 451-461.

MLM (Mangaung Local Municipality). 2003/2004. Integrated Development plan.

Olivier, W. 2006. The importance of natural resources in the planning arena. Paper delivered at the South African Planning Institute's Conference in Cape Town: "Planning Africa 2006: Making the Connections", 22-24 March 2006, (Conference proceedings available on CD-ROM).

Purseglove, J. 1988. *Taming the flood*. Oxford: Oxford University Press.

Sauer, D. 2006. Groot reën in Bloemfontein saai verwoesting, mure tuimel plek-plek ineen. *Volksblad*, 27 Jan.

South Africa. 1998. *The National Environmental Management Act (NEMA), Act 107 of 1998*. Pretoria: Government Printer.

Sensenig, C. 2004 Willamette River Water Treatment Plant - Wilsonville, Oregon. *Places*, 16(3), pp. 6-9.

Stapelberg, H. 2006. Compact cities – can this work? Paper delivered at the South African Planning Institute's Conference in Cape Town: "Planning Africa 2006: Making the Connections", 22-24 March 2006 (Conference proceedings available on CD-ROM).

Steenkamp, G.M. 2008. Picture of storm water channels which increases the speed of the storm water. Taken at Bloemfontein, South Africa, June.

Steÿn, J.J. & Schoeman, A.D. 2006. Is ad hoc planning the death in the pot for urban neighbourhoods? Paper delivered at the

South African Planning Institute's Conference in Cape Town: "Planning Africa 2006: Making the Connections", 22-24 March 2006 (Conference proceedings available on CD-ROM).

Steyn, P. & Wessels, A. 1999. The roots of contemporary governmental and non-governmental environmental activities in South Africa. 1654-1972. *New Contree*, 45, pp. 61-81.

Turner, T. 1998. *Landscape planning and environmental impact design*. London; UCL Press.