Discharge and water quality of the Liesbeek River and implications for stormwater harvesting

By-pass channel for recharging the Valkenburg wetlands and groundwater during peak flow: (April 2014)

Fahad Aziz and Kevin Winter

Environmental & Geographical Science and Future Water, UCT

Worldwide urban river catchments are deteriorating as a result of five main factors that are typically cited in the research literature: elevated peak flows causing flooding and erosion; increased nutrient levels; contamination from heavy metals from stormwater runoff; decreasing biodiversity and support for habitat; and declining ecological services. Once degraded urban waterways are often treated as stormwater conduits that are a nuisance factor and are pronounced as ecologically sterile or dead. The condition of the urban river syndrome is the result of a combination of good intentions with unintended consequences, benign neglect and limitations of resources occur from the restoration of urban waterways. Cape Town has learnt a few lessons during the recent drought and now aspires to create a water sensitive city by 2040 one in which water is valued, conserved, well managed and used sustainably for human and ecological purposes.

This report suggests how stormwater is used for various non-potable water use and for recharging groundwater by harvesting water from the Liesbeek River during rainfall event to improve water security, prevent or reduce flooding and improve the condition of urban waterways through flow modulation. The study is also describes the methods and results that were achieved by capturing high resolution data on current discharge and water quality of the lower Liesbeek River, and the implications for groundwater and aquifer recharge. A predictive modelling exercise is presented in the final discussion about an increase in rainfall events are likely to affect flooding and water quality in the lower Liesbeek.

Discharge and water quality in the Liesbeek River

High resolution monitoring sensors and loggers were used to capture stream discharge and water quality in three sections of the Liesbeek River: upper, middle and lower reaches. The study was conducted during 2018 and 2019 by capturing 14 different rainfall events. This report is an extract from MSc thesis by Fahad Aziz (researcher) and, for the sake of brevity, is limited to a discussion to the lower Liesbeek River, i.e. the Durban Road bridge site, Mowbray. The report explores the relationship between discharge and water quality, and the implications for stormwater management and groundwater recharge.

Discharge and rainfall

The highest recorded rainfall was measured at Kirstenbosch (19-20th May 2019) at the start of the winter rainfall season but this did not produce the highest peak discharge (Table 1). However, the next recorded rainfall event (4-5th June 2019) produced the highest peak discharge with 71.6mm measured at Kirstenbosch and 44.4mm at Observatory (SAWS data). The lowest peak discharges were observed following the lowest rainfall event (17.8mm at Kirstenbosch and 9.2mm at Observatory).

Table 1: Rainfall (SAWS) and peak discharge at the study site

Date	Rainfall (mm)		Peak discharge (m^3/s) Durban Road
	Kirstenbosch	Observatory	
19-20/05/19	88.2	22.4	7.5
4-5/06/19	71.6	44.4	15.2
9/06/19	17.8	9.2	2.7
21-22/06/19	56.6	20.8	5.1
27-28/06/19	41.2	11.8	4.0
18-19/07/19	30.2	4.0	3.7
22-23/07/19	74.2	13.4	9.1
29-31/07/19	42.2	14.4	3.4

Hydrograph of highest rainfall at the Durban Road Bridge, Mowbray

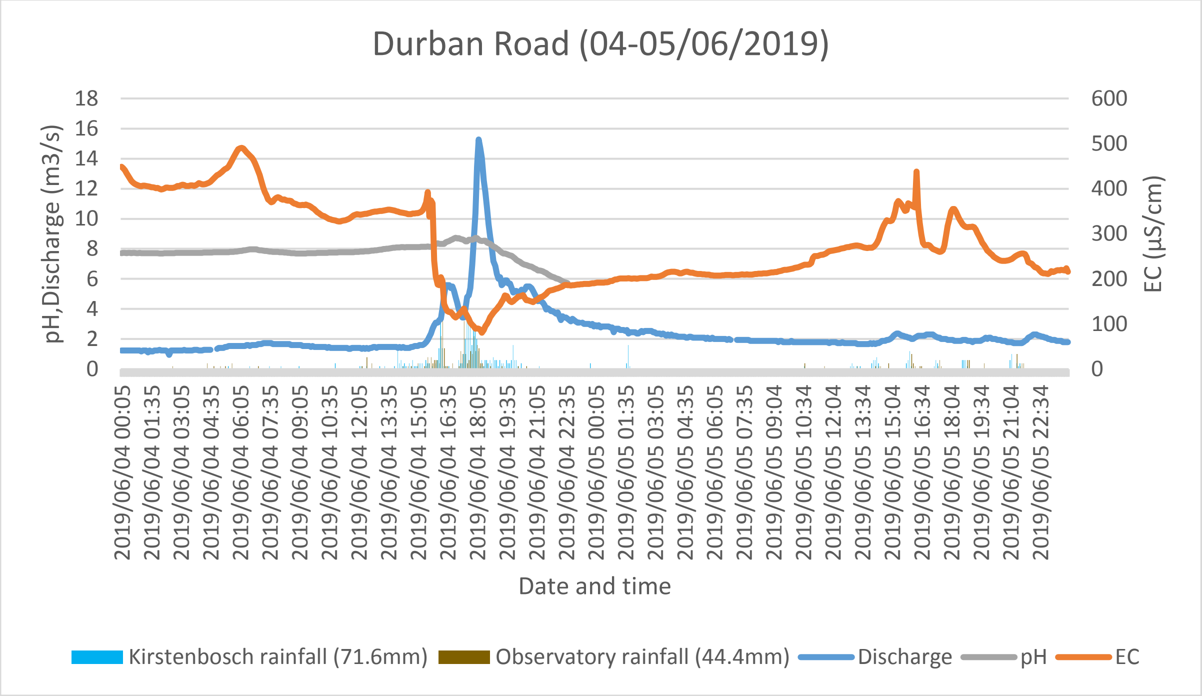

Figure 1: Hydrograph showing discharge and water quality at the Durban Road site for the highest rainfall event recorded at Observatory (04-05/06/2019).

The Durban Road bridge site shows a typical urban hydrograph with a short lag between peak rainfall at Kirstenbosch occurring between 16:00 and 17:30, and a rapid rising limb and peak discharge at approximately 18:15 (15.2 m^3/s). During the event, electrical conductivity (EC) was used as a proxy to measure the general contamination conditions which were observed to be inversely proportional to the level of discharge. Lower contamination levels are the result of dilution and the distribution/dispersion of in-stream pollutants. Conductivity levels return to average conditions approximately 24 hours after the peak discharge. Average conductivity for the site fell with the range of 244 µS/cm and 237.1 µS/cm. It is worth noting, as an example, that conductivity values for the Liesbeek River were much lower compared to the Philippi horticultural area on the Cape Flats Aquifer (CFA) where, in a study by Aza-Gnandji *et al.* (2013), borehole water sample ranges were between 850 µS/cm and 2840 µS/cm.

Observations of each of rainfall event and an analysis of the respective hydrographs show that the point of peak discharge precedes and the lowest conductivity levels. In other words, improved water quality occurs only after the occurrence peak discharge. Water quality during these events was benchmarked against the South African Water Quality Guidelines (SAWQG) and US EPA to determine the suitability of the water quality (Table 2) to provide an indication of the relatively high quality of water that was found in the Liesbeek River at the Durban Road bridge monitoring site.

Table 2: Water quality guidelines for EC.

EC		
South African Water Quality standards	**Water quality target range**	**Comment**
Domestic use (DWAF, 1996a)	≤700 µS/cm	No obvious health effects are likely above this limit but the water will have a saltier taste to it
Industrial use (DWAF, 1996c)	≤150 µS/cm	No damage due to scaling or corrosion below this limit
Agricultural use: irrigation (DWAF, 1996c)	≤400 µS/cm	No damage to salt-sensitive crops below this limit
Aquatic systems (DWAF, 1996f)	150 – 500 µS/cm (Behar *et al.*, 1996)	This is the acceptable range for freshwater streams to support diverse aquatic life

Potential for Cape Flats Aquifer recharge

A study by Mauck (2017) modelled and mapped the capacity of the CFA. The study showed that the highest potential for aquifer recharge occurred in areas that have the highest topographic elevation, such as in the eastern face of the Table Mountain region adjacent to the Liesbeek catchment. Figure 2 shows the potential to recharge the CFA around the Table Mountain region within the western region of the CFA. There are higher groundwater elevations in the western parts of the CFA model around the Table Mountain region and therefore potential for higher rates of groundwater flow.

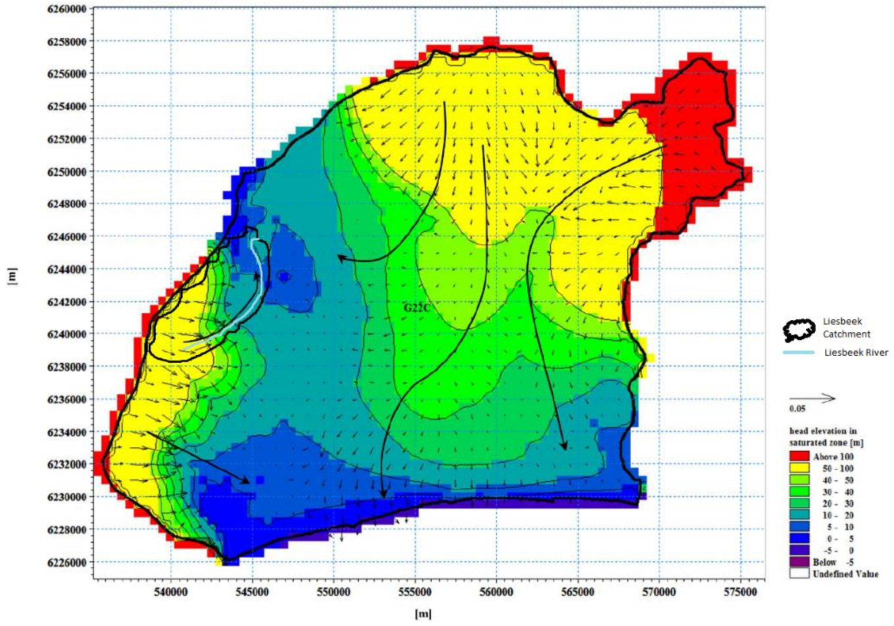

Figure 2: Simulated head elevation and generalised flow direction based on flow (Adapted from Mauck 2017). Note the Liesbeek catchment and river overlaid on the western side of the CFA map.

The location of the Liesbeek catchment on the western side of the CFA has the potential for various water sensitive and urban design interventions such as wetlands and detention ponds to capture stormwater and the recharge of the groundwater. The big advantage is the relatively clean and high quality of water from the Liesbeek that could be used to raise groundwater level though infiltration of floodplains and ultimately to recharge parts of the CFA aquifer.

Water quality and flood modelling

A PCSWMM model was used to create two main scenarios: water quality and flooding based on incremental increases in rainfall. The model was calibrated by using 2/3 of the rainfall events and 1/3 of these was used for validation. The calibration results for all rainfall events were acceptable with an ISE rating of 'excellent' while one event was rated 'very good' (Figure 3). The details of the calibration and validation process are not discussed in any detail in this report.

All rainfall events tended to produce respectable coefficient of determination (R2) values (0.5>) except for the rainfall event on the 29-30th June and 12-13th August. This high coefficient of determination (R2) values shows good correlation with observed data. The lowest coefficient of determination (R2) value was produced for the lowest rainfall event (7.8mm in Kirstenbosch and 0.6mm in Observatory).

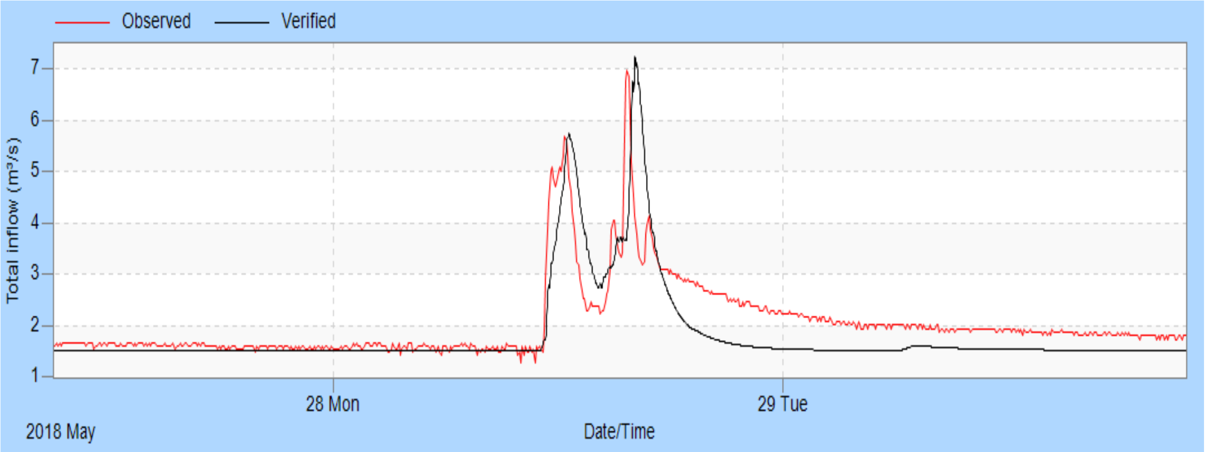

Figure 3: Durban Road site – observed vs modelled data (Verification)

The purpose of modelling the Liesbeek Catchment was to understand the hydrological conditions and the catchment response to rainfall events under various conditions.

The modelling exercise introduced scenarios that were based on rainfall designs consisted of 20mm increments from the Kirstenbosch rain gauging station (20mm, 40mm, 60mm, 80mm and 100mm). The Observatory rain gauge records typically show 3 times less rainfall than the Kirstenbosch rainfall and therefore the rainfall designs were 3 times lower for Observatory (7mm, 13mm, 20mm, 27mm and 33mm). The rainfall designs were all based on 24-hour storm events. The reason for the modelling exercise was to model the discharge in the Liesbeek Catchment in order to predict peak discharges under hypothetical rainfall designs. The peak discharges in the modelling exercise were then used to predict EC based on the linear regression equations (Table 3).

Table 3: Hypothetical rainfall designs showing average and peak discharge, volume and nodes flooded at the Durban Road site.

Event	Rainfall (mm)		Average discharge (m^3/s)	Peak discharge (m^3/s)	Volume (m^3)	Nodes flooded
	Kirstenbosch	Observatory				
1	20	7	1.9	4.2	171900	4
2	40	13	2.4	6.5	212800	13
3	60	20	2.9	9.7	254200	22
4	80	27	3.4	10.7	290800	29
5	100	33	3.7	12.2	319600	33

Table 4: Predicted EC values for May, June and July based on modelled discharges (Durban Rd Site)

Event	Rainfall (mm) site3		Modelled peak discharge (m^3/s)	Predicted EC in May (µS/cm)	Predicted EC in June (µS/cm)	Predicted EC in July (µS/cm)
	Kirstenbosch	Observatory				
1	20	7	4.2	156.9	133.2	142.5
2	40	13	6.5	112.5	100.4	122.1
3	60	20	9.7	82.9	77.5	106.0
4	80	27	10.7	77.0	72.8	102.4
5	100	33	12.2	69.7	66.8	97.7

Table 3 shows how the average discharge, peak discharge, volume and number of flooded nodes (small areas delineated by the model in the Liesbeek catchment) increased with incremental increases in rainfall. The modelled peak discharges were slightly higher than the observed peak discharges for rainfall events that were of similar depth.

Table 4 shows the predicted EC values for May, June and July based on the peak discharges from the model. EC decreases as the rainfall and discharge increases. This was expected as EC and discharge has a strong negative relationship. The peak discharges for all the designed rainfall depths, were capable of diluting the EC levels that were adequate to meet domestic, industrial, and agricultural water use and to meet aquatic system thresholds. The designed rainfall depths also produced high quantities of volume which could be used for stormwater abstraction.

Concluding remarks

Stormwater harvesting could help diversify the city's water resources and increase the city's resilience to changes in rainfall patterns in the future. Stormwater harvesting systems makes use of a number of storage systems which includes, *inter alia*, retention ponds, detention ponds, rain gardens and wetlands as well as sub-surface storages such as aquifer recharge to store the harvested stormwater. The lower Liesbeek area has a number of sites or nodes that could be used for recharging the groundwater, for example, the Valkenburg wetlands and floodplains, the Raapenberg wetland, sections of the River Club and surroundings, and PRASA railway yards. All of these areas require further investigation to determine their suitability as stormwater infiltration ponds and the potential to manage these sites as recharge zones. According to Fisher-Jeffes (2015) the Liesbeek Catchment experiences more evaporation than rainfall, making sub-storage of stormwater a more attractive option for aquifer recharge.

The results of this study, which are summarised in this report, indicate that during rainfall events, particularly during the falling limb of the hydrograph, water quality meets various water quality guidelines which could then be used for purposes such as aquifer recharge and therefore is an important consideration for the future of land use and water management within the lower the Liesbeek River before this high quality water mixes with the polluted waters of the Black River.

Disclaimer
This report is an extract from an MSc research thesis that is being prepared for university examination purposes. The report was written by the supervisor with the sole purpose of informing interesting stakeholders about the ongoing work that aims to improve our collective understanding of elements of the Liesbeek River and the potential for stormwater harvesting in particular. The accuracy of the data, results and conclusions are the sole responsibility of the authors and not the University or the Future Water Institute. No peer review process has been enlisted in the presentation of this report.

References

Armitage, N., Vice, M., Fisher-Jeffes, L., Winter, K., Spiegel, A. and Dunstan, J. (2013). Alternative technology for stormwater management. The South African Guidelines for Sustainable Drainage Systems. *Report TT*, *558*, p.13.

Armitage, N., Fisher-Jeffes, L., Carden, K., Winter, K., Naidoo, V., Spiegel, A., Mauck, B. and Coulson, D. (2014). Water Sensitive Urban Design (WSUD) for South Africa: FRAMEWORK AND GUIDELINES. WRC Report No. TT 588/14. Urban Water Management Research Unit.

Aza-Gnandji, C.D.R., Xu, Y., Raitt, L. and Levy, J. (2013). Salinity of irrigation water in the Philippi farming area of the Cape Flats, Cape Town, South Africa. *Water SA*, *39*(2), pp.199-210.

Brown, C., and Magoba, R. (Eds.). (2009). Rivers and Wetlands of Cape Town: Caring for Our Rich Aquatic Heritage (TT 376/08.). South African Water Research Commission. Cape Town. ISBN: 9781770057777.

COCT (City of Cape Town). (2012). *Trends and Change - 10 years: Census 2001 – Census 2011*. Cape Town: Information and Knowledge Management Department using 2011 Census data supplied by Statistics South Africa.

DWAF. (1996a) South African Water Quality Guidelines Volume1: Domestic Use. Department of Water Affairs and Forestry, Pretoria, South Africa.

DWAF. (1996b) South African Water Quality Guidelines Volume 2: Recreational Use. Department of Water Affairs and Forestry, Pretoria, South Africa

DWAF. (1996c) South African Water Quality Guidelines Volume 3: Industrial Use. Department of Water Affairs and Forestry, Pretoria, South Africa

DWAF. (1996d) South African Water Quality Guidelines Volume 4: Agricultural Use: Irrigation. Department of Water Affairs and Forestry, Pretoria, South Africa

DWAF. (1996e) South African Water Quality Guidelines Volume 6: Agricultural Use: Aquaculture. Department of Water Affairs and Forestry, Pretoria, South Africa

DWAF. (1996f) South African Water Quality Guidelines Volume 7: Aquatic Ecosystems. Department of Water Affairs and Forestry, Pretoria, South Africa

Fell, J., Pead, J. & Winter, K. (2017). Affordable digital water monitoring technology. Institute of Electronics Engineers Consumer Electronics Magazine. (special issue on “Electronics for Sustainable Development” (in press).

Fisher-Jeffes, L. (2015). The viability of rainwater and stormwater harvesting in the residential areas of the Liesbeek River Catchment, Cape Town. PhD thesis, University of Cape Town.

Fisher-Jeffes, L., Carden, K., Armitage, N. and Winter, K. (2017). Stormwater harvesting: Improving water security in South Africa's urban areas. *South African Journal of Science*, *113*(1-2), pp.1-4.

Mauck, B. (2017). *The capacity of the Cape Flats aquifer and its role in water sensitive urban design in Cape Town* (Doctoral dissertation, University of Cape Town).

United States Environmental Protection Agency (1986). *Quality criteria for water*. Washington: Environmental Protection Agency.