water e-journal
Online Journal of the Australian Water Association
ISSN 2206-1991
Volume 1 No 3 2016
http://dx.doi.org/10.21139/wej.2016.025

WSUD STRATEGIES TO MINIMISE THE IMPACTS OF CLIMATE CHANGE AND URBANISATION ON URBAN SEWERAGE SYSTEMS

QUANTIFYING THE EFFECTIVENESS OF RAINWATER TANKS IN REDUCING SANITARY SEWAGE OVERFLOWS IN A CASE STUDY IN MELBOURNE, VICTORIA

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ABSTRACT

Urban drainage systems are frequently unable to cope with the increased intensity of storm events, mainly due to non-stationary climate and rapid urbanisation. As these systems become less efficient, issues such as urban flooding and sanitary sewer overflows (SSOs) increase. This, in turn, causes various detrimental impacts, both on human health and the environment.

Recently, there has been an increase in the implementation of water-sensitive urban design (WSUD) strategies to manage the urban water cycle in a more sustainable way. Common WSUD strategies include rainwater tanks, rain gardens, bio-retention cells, porous pavements, green roofs, infiltration trenches and vegetative swales. These strategies can reduce urban flooding and SSOs by controlling excess stormwater runoff that enters the drainage system. This study aims to quantify the impacts of implementing a commonly used WSUD approach, rainwater tanks, in terms of minimising SSOs.

SSOs are mainly caused by Rainfall Derived Infiltration and Inflow (RDII), which is the increased portion of flow in a sewer system that occurs during and after a rainfall event. For a case study catchment in Melbourne, Victoria, detailed hydraulic modelling of implementing rainwater tanks using PCSWMM (commercial stormwater management model) has been presented and results compared with the base case (no rainwater tanks). The values of various rainwater tank parameters were varied in the modelling to assess the reduction in SSOs. These parameters included: tank size, drain time, drain delay and the number of households in the catchment with rainwater tanks. It was observed that rainwater tanks could lead to a reduction in SSO volume by a maximum of 33% when compared to the base case. A much larger reduction in SSO volumes could be expected if other WSUD strategies were implemented in conjunction with rainwater tanks.

Keywords: Climate change, urbanisation, SSOs, urban flooding, WSUD, rainwater tanks.

INTRODUCTION

Urban drainage systems, which collect and convey stormwater and wastewater, are a critical component of a city's infrastructure. These systems are becoming more vulnerable to failure, partly due to the lack of consideration given to what occurs when their design criteria are exceeded. As a consequence of global warming, it is expected that high-intensity rainfall events will become more severe and frequent.

At the same time, increasing urbanisation (i.e. increase in surface imperviousness) in cities is leading to shorter response time of urban catchments, which increases stormwater runoff volumes beyond the capacity of existing urban drainage systems.

In a separate drainage system, intense rainfall increases flow not just into the stormwater drainage system, but also into the sanitary sewer network as well. This increased portion of sewer flow is called rainfall-derived infiltration and inflow (RDII), which is caused by the inflow and infiltration of stormwater entering the sanitary sewer network during intense rainfall events (Nasrin *et al*., 2013). The inflow into the sewer network is caused by flooding of gully traps, roof downpipes illegally connected to the sanitary sewers, broken manhole covers and cross-connections between stormwater and sewer pipes. On the other hand, infiltration into the sewer pipe occurs when stormwater runoff filters through the soil and then enters the sewer via damaged pipes, leaky joints or defective manhole walls.

Thus, as a consequence of intense rainfall events and urbanisation, there is a higher risk of hazards such as sanitary sewer overflows (SSOs) (Semadeni-Davies *et al.*, 2008; Yazdanfar and Sharma, 2015).

Recently, there has been an increase in the implementation of water-sensitive urban design (WSUD) strategies to manage the urban water cycle in a more sustainable way.

WSUD is a holistic approach to the planning and design of urban development that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems. There are different types of sustainable WSUD strategies available, including rainwater tanks, rain gardens, bio-retention cells, porous pavements, green roofs, infiltration trenches and vegetative swales (Myers *et al*., 2014). These WSUD strategies help in controlling the excess stormwater runoff that enters the drainage system and, thus, can reduce hazards like SSOs.

This study aims to assess and quantify the benefits of implementing rainwater tanks for the reduction in SSOs for a case study sewer network in Melbourne, Victoria. Rainwater tanks are one of the most widely used WSUD approaches in Australia for non-potable water supply with fit-for-purpose concept; however, in this study rainwater tanks are considered as an option for stormwater management only. A detailed hydraulic modelling of the case study sewer network has been performed with different rainwater tank parameters (namely tank size, drain time and drain delay) to analyse the performance of the sewer network during a wet year. The chosen wet year was 2010, which was identified as the third wettest year on record for Australia (BoM Australia, 2015), with several intense rainfall events in Melbourne.

The benefits of implementing rainwater tanks are assessed in terms of reduction in SSO volume. The results from this analysis are expected to be beneficial to the relevant water authorities to develop and target mitigation strategies for controlling SSOs.

WSUD STRATEGIES

In this study, PCSWMM has been used for the hydraulic modelling of the sewer network with rainwater tanks. PCSWMM uses the US Environmental Protection Agency's stormwater management model (EPA SWMM), which can be used to model five common types of WSUD strategies. These WSUD strategies are programmed into SWMM algorithms and can be accessed through simple dialog boxes (Rossman, 2010). Various parameters need to be added as input for developing the model. These five WSUD strategies are described below:

- Rainwater tanks/rain barrels are like storage tanks that capture direct rainfall and roof runoff during rainfall events. Rainwater tanks are usually placed beneath roof downspouts and store stormwater runoff during a rainfall event.
- Bio-retention cells act as depression storages that contain vegetation layers over an engineered soil mixture. There is a gravel bed underneath the vegetation. These bio-retention cells provide storage, infiltration and evaporation of direct rainfall and surface runoff. Rain gardens and green roofs are similar forms of bio-retention cells.
- Porous pavements are excavated areas where gravel is used to fill the area. Here, porous concrete or asphalt mix is used for paving the surface. Stormwater runoff can pass through the paved surface and enter the gravel storage zone beneath the pavement. After that, runoff can easily infiltrate the natural soil.
- Infiltration trenches are narrow ditches where gravel is also used to fill the area. They provide storage and capture runoff from the impervious area. The captured runoff then infiltrates the natural soil.
- Vegetative swales are depressed areas that act as channels to route the surface runoff. Grass or vegetation is used to cover the sliding slopes of the depression areas. Vegetative swales help to reduce the conveyance capacity of stormwater runoff and provide sufficient time to infiltrate the stormwater into the natural soil.

These WSUD strategies have benefits other than retarding stormwater runoff, including reducing pollutant load into receiving waterways, replacing potable water with alternate sources for non-consumptive uses and improving urban landscape. These benefits have led to various water utilities and local councils adopting the use of WSUD strategies as part of existing and new developments. In spite of these benefits, there are only a handful of studies available in literature that quantify the benefits of various WSUD strategies (Abi Aad *et al*., 2009; Khastagir and Jayasuriya, 2010; Rahman *et al*., 2012; Roldin *et al*., 2012; Myers *et al*., 2014; Walsh *et al*., 2014; Liao *et al*., 2015; Locatelli *et al*., 2015).

CASE STUDY AREA

The selected case study sewershed area is a residential suburb in Glenroy, which comes under the jurisdiction of one of Melbourne's three local water utilities, Yarra Valley Water. This area is serviced by a separate sewer and stormwater drainage system. The total contributing sewershed area of the catchment is 6.88km^2 and there are 3,750 households connected to the network.

The length of the major sewer pipe is approximately 3.2km. The pipe material is concrete and the sewer network of the area was constructed in 1940. It is expected that conduits would have some ageing effects (pipe cracks and joint defects), hence, RDII would be the major contributor for SSO and surcharge problems. One downstream manhole (named GLN8) was used to measure sewer flow data at six-minute time-steps during the period November–December, 2010. Flow data was measured continuously at the GLN8 manhole using an area velocity flowmeter, which continuously measures both velocity and level in the pipe. Such flowmeters provide accurate measurements even in full flow conditions and are widely used for long-term flow monitoring and sanitary sewer evaluation studies (Hach Sigma 940, 2007).

Six-minute resolution rainfall data were obtained from the Bureau of Meteorology for a nearby rain gauge station. The total rainfall in 2010 at this station was 681.2mm. The location of the study area and the layout of Glenroy sewer network with the downstream flowmeter location (GLN8) are shown in Figure 1. Detailed modelling of the existing sewer network was performed to evaluate its hydraulic performance in terms of SSO volumes.

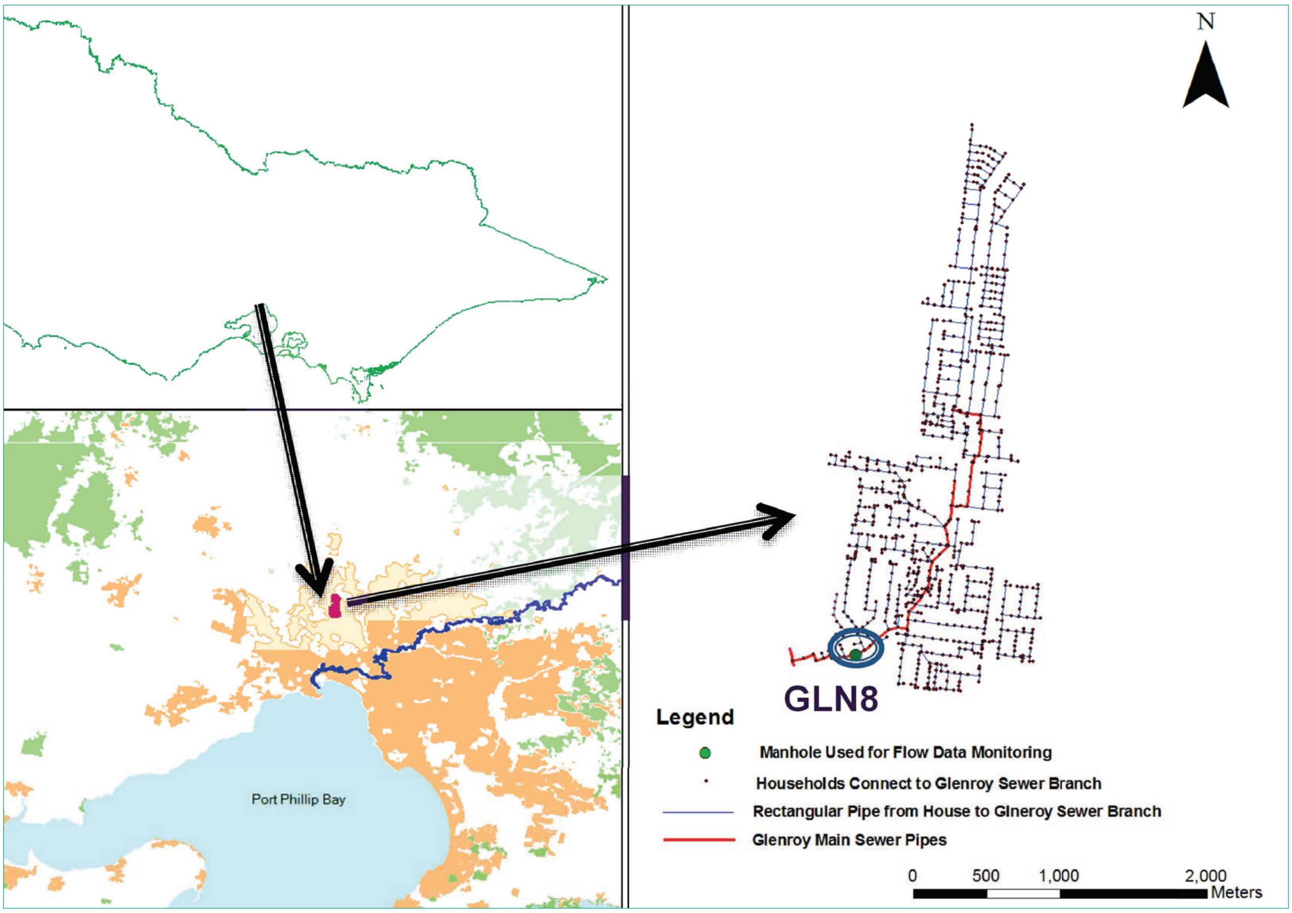

Figure 1. The case study area in Melbourne.

The sewer model was calibrated and validated based on measured sewer flow data at the downstream GLN8 manhole for the wet months of November–December, 2010. After calibration and validation, a continuous simulation was conducted for the year 2010 to evaluate the hydraulic performance of the network in a wet year with many intense rainfall events. Although PCSWMM provides various indicators related to sewer overflows and manhole surcharges to evaluate the performance of the sewer network, this study presents only the total annual overflow volumes (in ML) to assess the performance of rainwater tanks for SSO reduction.

The annual overflow volume is the total volume of sewage overflowing from the manholes throughout the year as a consequence of a large number of individual intense rainfall events. Since the sewer network in this case study area is quite old, RDII and consequent SSOs is expected to be a major problem. The hydraulic analysis indicates that the network failed to cope with the intense rainfall events and, as a consequence, the system experienced 23ML of SSO volume in 2010.

There were 11 manholes (out of 57 manholes in the 3.2km main network) that experienced overflows in the year 2010, with manhole GLN8A having the maximum overflows (of 8.8ML). This could have led to serious aesthetic, environmental and health problems for this residential catchment.

Figure 2 presents significant rainfall events that took place in November and December of 2010, resulting in sewer overflows from the GLN8 manhole (observed during the flow measurements). The developed model indicates that the GLN8 manhole starts to overflow at a flow rate of 0.084m^3/sec. The figure also indicates the RDII flows into the sewer pipe, determined by subtracting the dry weather flow (DWF) from the measured sewer flows. Fortunately, this manhole (GLN8) is located in a reserved park area and the residents may not have come directly in contact with the overflowing sewage during the rainfall events.

MODELLING OF RAINWATER TANKS

Table 1 presents the rainwater tank parameters used in SWMM for the WSUD modelling. The various rainwater tank parameters analysed included tank volume (in litres), drain time (T in hours) and drain delay (in hours).

Four different tank sizes (500, 1,000, 1,200 and 1,500L), four drain times (12, 24 and 36 and 48 hours) and four drain delay times (0, 12, 24 and 36 hours) were analysed. Drain time is the time allowed to drain the rainwater tank, hence, the shorter the drain time, the larger the flow from the underdrain orifice. On the other hand, the parameter drain delay is the number of dry weather hours that must elapse after the rainfall event before the underdrain orifice is opened. When the drain delay is taken as zero, it represents a continuously draining rainwater tank as the rainwater flows into it. Also, two scenarios were considered for the number of households that had rainwater tanks installed, namely 100% (i.e. all households) and 50% households.

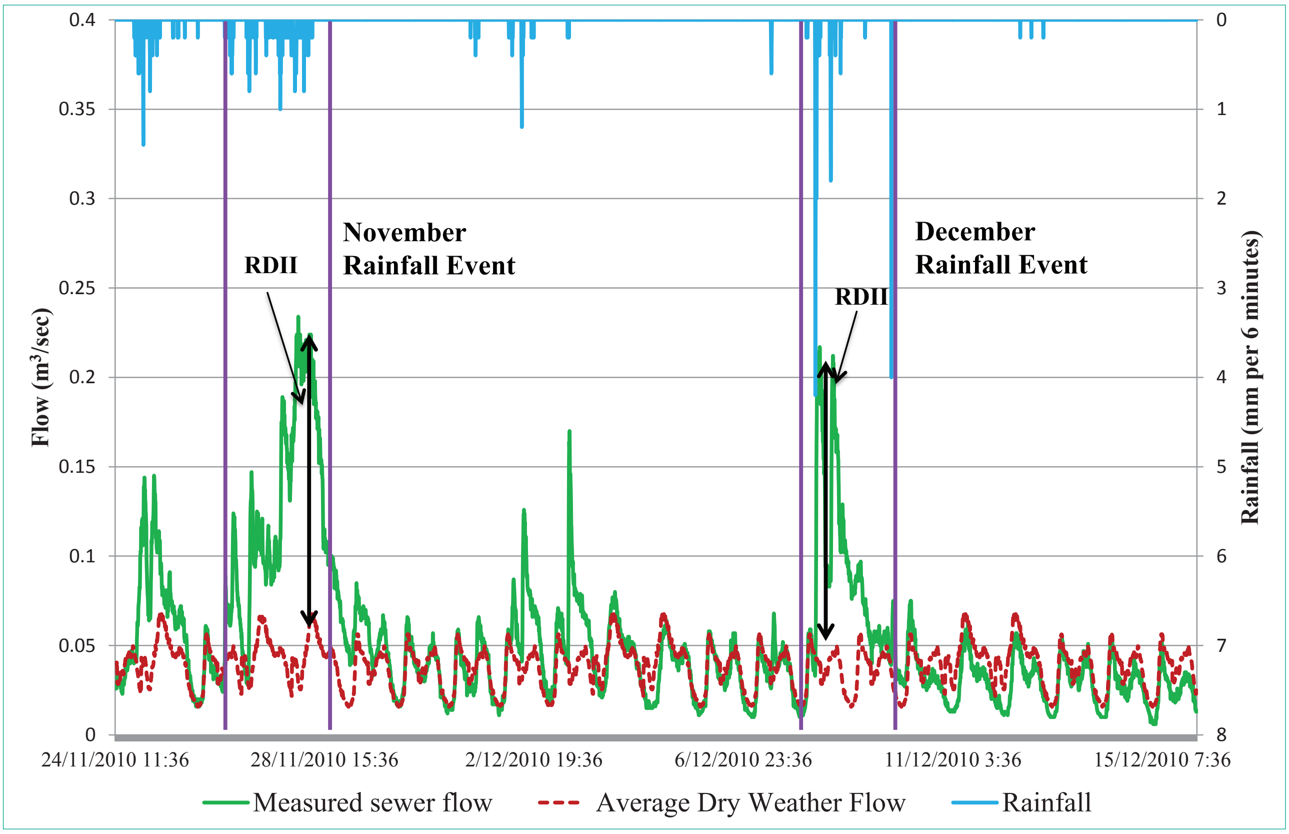

Figure 2. The RDII flows in the sewer pipe during intense rainfall.

In SWMM, flow through the underdrain from a rainwater tank is governed by the submerged orifice equation, as shown in Eq. (1) (Walsh *et al.*, 2014). C represents the drain coefficient, D is the height of stored water, Hd is the drain offset and n is the drain exponent.

$$q = C\,(D - H_d)^n \qquad (1)$$

The drain coefficient (C) can be estimated by integrating Eq. (1) and is presented in Eq. (2). As can be seen, C is a function of two variables, namely the drain time (T) and the depth (D) of the stored water. Drain time (T) is the time required to drain out a depth D of stored water in the rainwater tank.

$$C = \frac{2\,(D^{0.5})}{T} \qquad (2)$$

In SWMM, D is in units of inches and T is in hours (Walsh *et al.*, 2014). Therefore, for calculating C using the values of D in mm (as provided in Table 1), Eq. (2) has to be modified to that presented in Eq. (3). The values of C presented in Table 1 are calculated using Eq. (3) with the values of D and T in mm and hours respectively (as presented in Table 1).

$$C = \frac{2(25.4\,D)^{0.5}}{T} \qquad (3)$$

Since drain times (T) have an impact on the underdrain flow, four different drain times (of 12, 24, 36 and 48 hours) have been used in this study. The drain times were proposed to not exceed 48 hours due to the risk of mosquito breeding. The standard range of drain time for storage-based LID strategies is 24 to 48 hours (Walsh *et al.*, 2014). The drain exponent has been taken as 0.5, assuming the underdrain acts like an orifice (Walsh *et al.*, 2014; Rossman, 2010). Drain offset has been taken as zero, assuming that the orifice is at the bottom of the rainwater tank.

The stormwater from the outlet pipe (as well as the overflows from the tanks) is routed to pervious areas such as

Table 1. Rainwater tank parameters used in PCSWMM.

Volume (L)	-	500L	1,000L	1,200L	1,500L
Height (D) (mm)	-	500	900	900	1200
Drain Coefficient	T=36 Hours	C= 6.26	C=8.39	C=8.39	C=9.69
(C) ($mm^{0.5}/hr$)	T=24 Hours	C= 9.39	C=12.59	C=12.59	C=14.54
	T=12 Hours	C=18.78	C=25.19	C=25.19	C=29.09
Drain Exponent (n)	-	0.5	0.5	0.5	0.5
Drain Offset Height (H^d) (mm)	-	0	0	0	0
Drain Delay (hours)	-	0, 12, 24	0, 12, 24	0, 12, 24	0, 12, 24
Impervious Area Treated (%)	-	24%	24%	24%	24%

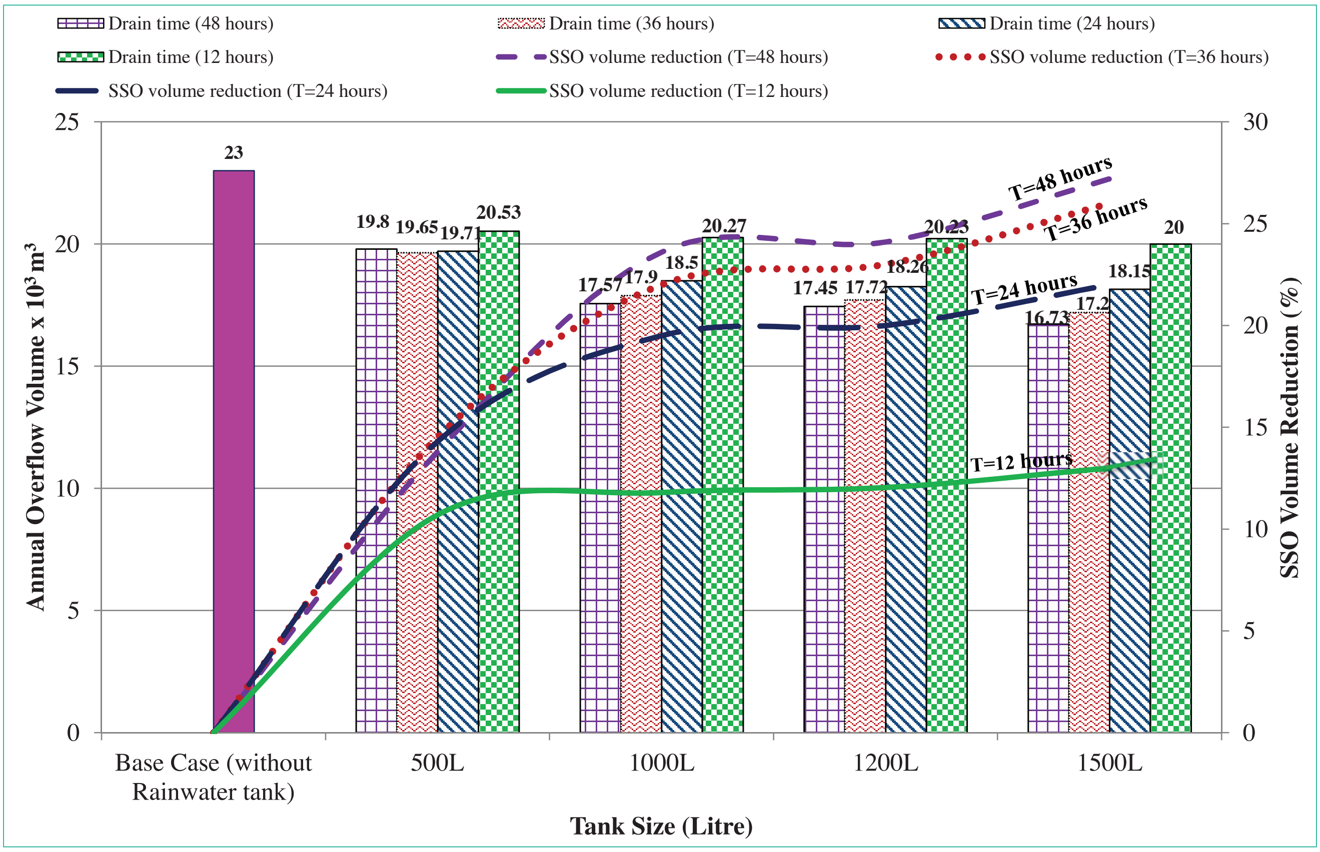

Figure 3. Annual SSO volume reduction for different tank sizes and drain times.

gardens. The parameter impervious area treated (%) in Table 1 represents roof impervious area, where runoff is captured in the rainwater tanks. The total impervious area of this sewershed is 4.128km^2 and the total roof area was estimated as 0.99km^2, which represents 24% of the total impervious area. The total roof area of 0.99km^2 was based on an average roof size of 264m^2 for the 3,750 households in the sewershed. Using this total roof area, the annual rainfall of 681.2mm and a runoff coefficient of around 0.85, the total volume of runoff captured by the rainwater tanks can be estimated as 573ML, which is assumed to flow over the previous area.

RESULTS AND DISCUSSION

The outcomes of the sewer modelling with the different rainwater tank parameters during 2010 are presented in Figures 3 and 4. For the results presented in both these figures, the number of households is taken as 100% and a comparison with the base case (which is the current condition without implementing rainwater tanks) is also presented. In these figures, the reduction in overflow volume when compared to the base case (in %) is also shown on the secondary x-axis. As mentioned earlier, the overflow volume for the base case was 23 ML.

Figure 3 presents the annual overflow volume for the four different drain times (T). In these model runs, the rainwater tanks are assumed to be continuously flowing (i.e. with a drain delay of 0 hours). As seen in this figure, the drain time of 48 hours resulted in the maximum reduction in sewer overflow when compared to the base case.

For the 500L, 1,000L, 1,200L and 1,500L rainwater tanks, the reduction in SSO volumes was by 13.8%, 23.6%, 24.1% and 27.2% respectively (for the drain time of 48 hours). In the continuous draining process, the outlet orifice pipe is assumed to be open during rainfall events and the stormwater is continuously routed to the pervious area. Therefore, rainwater tanks lead to a reduction in surface runoff since it slowly releases the stored water through the outlet orifice pipe. Thus, for a fixed tank size, the increase in drain time increases the SSO volume reduction. Hence, in our case, the 1,500L rainwater tank with a drain time of 48 hours provided the maximum SSO volume reduction.

Figure 4 presents the annual overflow volume for drain delays of 0, 12, 24 and 36 hours. In these model runs, the drain time (T) was kept as 48 hours, since it had resulted in the maximum reduction in sewer overflows. It can be seen from this figure that the rainwater tanks of volume greater than 500L, with a drain delay of 12 hours, resulted in the maximum reduction in sewer overflows (when compared to the base case overflow volume of 23 ML). In the drain delay options, the outlet orifice pipe is assumed to be closed during the rainfall events, and drain delay is the time that must elapse after the storm before the outlet orifice is opened.

The 1,500L tank with a drain delay of 12 hours resulted in a 33% reduction in SSO volume, whereas the same tank with continuous draining resulted in a 27% reduction. The results also indicate that shorter drain delay times reduce more SSO volumes than longer drain delay times. Hence, the 1,200L tank with 12 hours drain delay resulted in a 28% reduction in SSO volume, whereas the

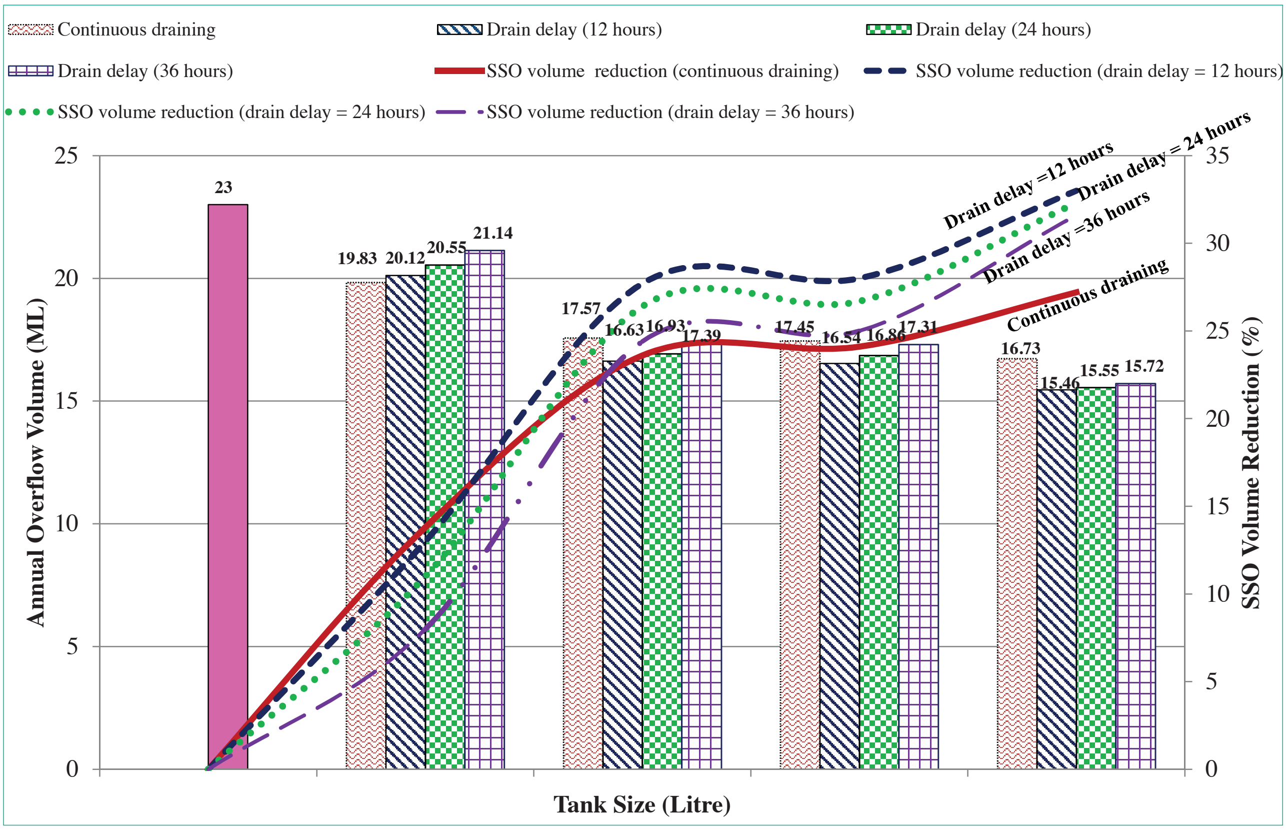

Figure 4. Annual SSO volume reduction for different tank sizes and drain delays.

same tank with 36 hours drain delay resulted in a 25% reduction.

For longer drain delay options such as with a drain delay of 36 hours, the outlet orifice pipes were opened after 36 hours of a storm event. The stored stormwater is then gradually released to the pervious area (with a maximum drain time of 48 hours). The results indicate that for the drain time of 48 hours, the shorter drain delay times (not more than 24 hours) need to be chosen. Otherwise, the tank would not be able to store enough roof runoff from the next event, which would lead to more surface runoff.

On the other hand, for the smallest tank size of 500L, the reduction in SSO volume was much less when compared to that in the 1,000L–1,500L tanks. This is obviously because the 500L tank collects less volume of stormwater when compared to the larger tanks. Also, for the 500L tank the reduction of SSO volume with reduction in drain delay times was marginal.

The continuous-draining 500L tank (i.e. with no drain delay) reduced the SSO volume by 13.8%, whereas the tank with 12, 24 and 36 hours drain delay reduced the volume by 13%, 11% and 8% respectively. This is because by choosing a high drain delay, for example of 36 hours, the orifice pipe will open after 36 hours of a storm event and then the stored stormwater is gradually released (drain time of 48 hours) to the pervious area.

Thus, there is a high possibility that when the next storm arrives, the tank might already be full (or close to full), which does not lead to a reduction in surface runoff. Therefore, the 500L tank with 36 hours drain delay resulted in the least reduction in SSO volume (of 8% when compared to the base case).

In the results presented above, it was assumed that the rainwater tanks are installed in all the households. As this may not be practically feasible, further model runs were conducted with rainwater tanks installed in only 50% of the households. The drain time was kept as 48 hours and the drain delay was taken as 12 hours.

For the 500L, 1,000L, 1,200L and 1,500L rainwater tanks, the reduction in SSO volumes were 3%, 13%, 16% and 21% respectively when compared to the base case. It is worth mentioning that the results in terms of percentage reductions in SSO volumes are specific to this catchment and would vary from catchment to catchment. Moreover, as indicated earlier, the presented results are for the year 2010 and would vary for a different time period (when parameters like size of the storms and recurrence interval would be different).

It is to be noted that in this study the rainwater tanks are considered only as an option for reducing excess stormwater runoff flowing into the sewer network as RDII during intense rainfall events as part of the wider study. The rainwater tank was not considered as an alternative source of water supply for non-potable uses in the households. The use of rainwater tanks for non-potable household uses (along with reducing RDII into sewer networks) will be undertaken in a future study with other WSUD options for comparison.

It is also to be noted that strategies like rainwater tanks will be implemented in conjunction with other WSUD strategies like rain gardens, porous pavements, etc. This study has indicated that rainwater tanks by themselves can reduce the SSO volumes in the range of 20%–30% when compared to the base case. Hence, implementation of other strategies along with rainwater tanks is expected to provide a higher reduction in SSO volumes, which will also be undertaken in a future study.

CONCLUSIONS

Intense rainfall has an adverse impact on the performance of the drainage network by causing urban flooding, SSOs and manhole surcharges. Since stormwater management using water-sensitive urban design (WSUD) is expected to be a part of future urban planning, this study has explored the impact of a commonly used WSUD approach, rainwater tanks, on reducing the sewer overflow volumes during intense rainfall events.

The analysis presented in this study was for the year 2010, which was one of the wettest years experienced in Melbourne since records began. A different time period would have different storm characteristics (like storm size) and different catchment characteristics (like dry weather flow). This study will be further extended with climate data from relatively drier years (say, 2014 and 2015, when rainfall was 440mm and 446mm respectively) and recorded sewage flow data for the same period in collaboration with the local water utility.

The comparison between SSO volumes over different wet/dry years will then be presented for the benefit of water professionals. A comparison will also be made between the recorded flow data in 2010 and other recorded flow data including associated impact in sewer flows due to rainfall patterns.

Detailed hydraulic modelling was undertaken with different parameter values for rainwater tank capacities, drain times and drain delays. It was observed that the 500L rainwater tank can reduce SSO volumes by up to 13.8%, whereas the 1,500L tank reduces it by 33% when compared to the SSO volumes in the base case. The analysis indicates that drain time has an impact on the reduction of overflow volumes, with higher drain times leading to a larger reduction in SSO volumes. In summary, such an analysis is expected to provide a decision support tool for urban managers and water professionals to consider the installation of rainwater tanks as a sewer overflow mitigation strategy during intense rainfall events. This in turn will be beneficial for the health of the community and the environment. A detailed economic analysis would be required to develop any policy based on the presented investigation for SSO management.

ACKNOWLEDGEMENT

The Authors wish to thank Yarra Valley Water and the Bureau of Meteorology for providing the necessary data used in this study.

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REFERENCES

Abi Aad MP, Suidan MT & Shuster WD (2009): Modeling Techniques of Best Management Practices: Rain Barrels and Rain Gardens Using EPA SWMM-5. *Journal of Hydrologic Engineering*, 15, 6, pp 434-443. http://dx.doi.org/10.1061/(ASCE)HE.1943-5584.0000136

BoM Australia (2015): www.bom.gov.au/climate/enso/lnlist (Retrieved 28 September 2015).

Hach Sigma 940 (2007): Hach Sigma 940 Intrinsically Safe Area Velocity Flow Meter. Hach Company, USA. www.e-d-s.com.au/documents/sigma_940.pdf. (Retrieved 20 November 2015).

Khastagir A & Jayasuriya LNN (2010): Impacts of Using Rainwater Tanks on Stormwater Harvesting and Runoff Quality. *Water Science and Technology*, 62, 2, pp 324–329. http://dx.doi.org/10.2166/wst.2010.283

Liao ZL, Zhang GQ, He ZH, Wu Y & Chen H (2015): Combined Sewer Overflow Control with LID Based on SWMM: An Example in Shanghai, China. *Water Science and Technology*, 71, 8, pp 1136–1142. http://dx.doi.org/10.2166/wst.2015.076

Locatelli L, Gabriel S, Mark O, Mikkelsen PS, Arnbjerg-Nielsen K, Taylor H, Bockhorn B, Larsen H, Kjølby MJ, Steensen Blicher A & Binning PJ (2015): Modelling the Impact of Retention–Detention Units on Sewer Surcharge and Peak and Annual Runoff Reduction. *Water Science and Technology*, 71, 6, pp 898–903. http://dx.doi.org/10.2166/wst.2015.044

Myers B, Pezzaniti D, Kemp D, Chavoshi S, Montazeri M, Sharma A, Chacko P, Hewa GA, Tjandraatmadja G & Cook S (2014): Water Sensitive Urban Design Impediments and Potential: Contributions to the Urban Water Blueprint (Phase 1). Goyder Institute for Water Research Technical Report Series, (14/19). www.goyderinstitute.org/uploads/GoyderWSUD-Task-3-Final-report_FINAL-web.pdf (Retrieved 28 September 2015).

Nasrin T, Tran HD & Muttil N (2013): Modelling Impact of Extreme Rainfall on Sanitary Sewer System by Predicting Rainfall Derived Infiltration/Inflow. In MODSIM 2013: 20th International Congress on Modelling and Simulation, Adelaide, Australia, 1–6 December 2013. www.mssanz.org.au/modsim2013/L12/nasrin.pdf (Retrieved 16 September 2015).

Rahman A, Keane J & Imteaz MA (2012): Rainwater Harvesting in Greater Sydney: Water Savings, Reliability and Economic Benefits. *Resources, Conservation and Recycling*, 61, pp 16–21. http://dx.doi.org/10.1016/j.resconrec.2011.12.002

Roldin M, Fryd O, Jeppesen J, Mark O, Binning PJ, Mikkelsen PS & Jensen MB (2012): Modelling the Impact of Soakaway Retrofits on Combined Sewage Overflows in a 3km^2 Urban Catchment in Copenhagen, Denmark. *Journal of Hydrology*, 452, pp 64–75. http://dx.doi.org/10.1016/j.jhydrol.2012.05.027

Rossman LA (2010): *Storm Water Management Model User's Manual*, Version 5.0. National Risk Management Research Laboratory, Office of Research and Development, US Environmental Protection Agency (US EPA), Cincinnati, OH.

Semadeni-Davies A, Hernebring C, Svensson G & Gustafsson LG (2008): The Impacts of Climate Change and Urbanisation on Drainage in Helsingborg, Sweden: Combined Sewer System. *Journal of Hydrology*, 350, 1, pp 100–113. http://dx.doi.org/10.1016/j.jhydrol.2007.05.028

Walsh TC, Pomeroy CA & Burian SJ (2014): Hydrologic Modeling Analysis of a Passive, Residential Rainwater Harvesting Program in an Urbanized, Semi-Arid Watershed. *Journal of Hydrology*, 508, pp 240–253. http://dx.doi.org/10.1016/j.jhydrol.2013.10.038

Yazdanfar Z & Sharma AK (2015): Urban Drainage System Planning and Design – Challenges with Climate Change and Urbanization: A Review. *Water Science and Technology*, 72, 2, pp 165–179. http://dx.doi.org/10.2166/wst.2015.207