Deconstructing the sustainable drainage management train in terms of water quantity - preliminary results for coventry, UK

Lashford, C. , Charlesworth, S.M. , Warwick, F. and Blackett, M.

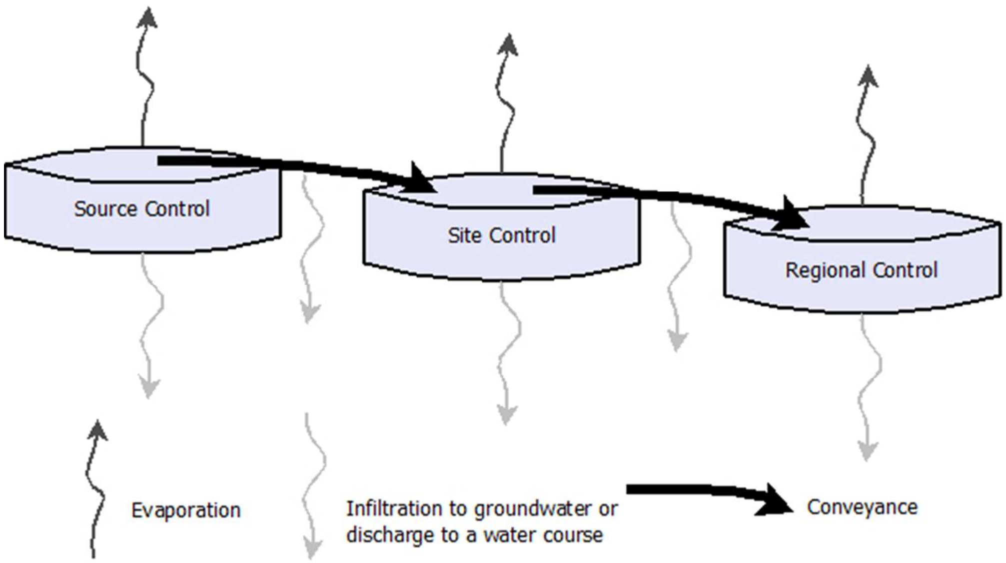
Original citation & hyperlink:
Lashford, C. , Charlesworth, S.M. , Warwick, F. and Blackett, M. (2014) Deconstructing the sustainable drainage management train in terms of water quantity - preliminary results for coventry, UK. Clean - Soil, Air, Water, volume 42 (2): 187–192
http://dx.doi.org/10.1002/clen.201300161

DOI 10.1002/clen.201300161
ISSN 1863-0650
ESSN 1863-0669

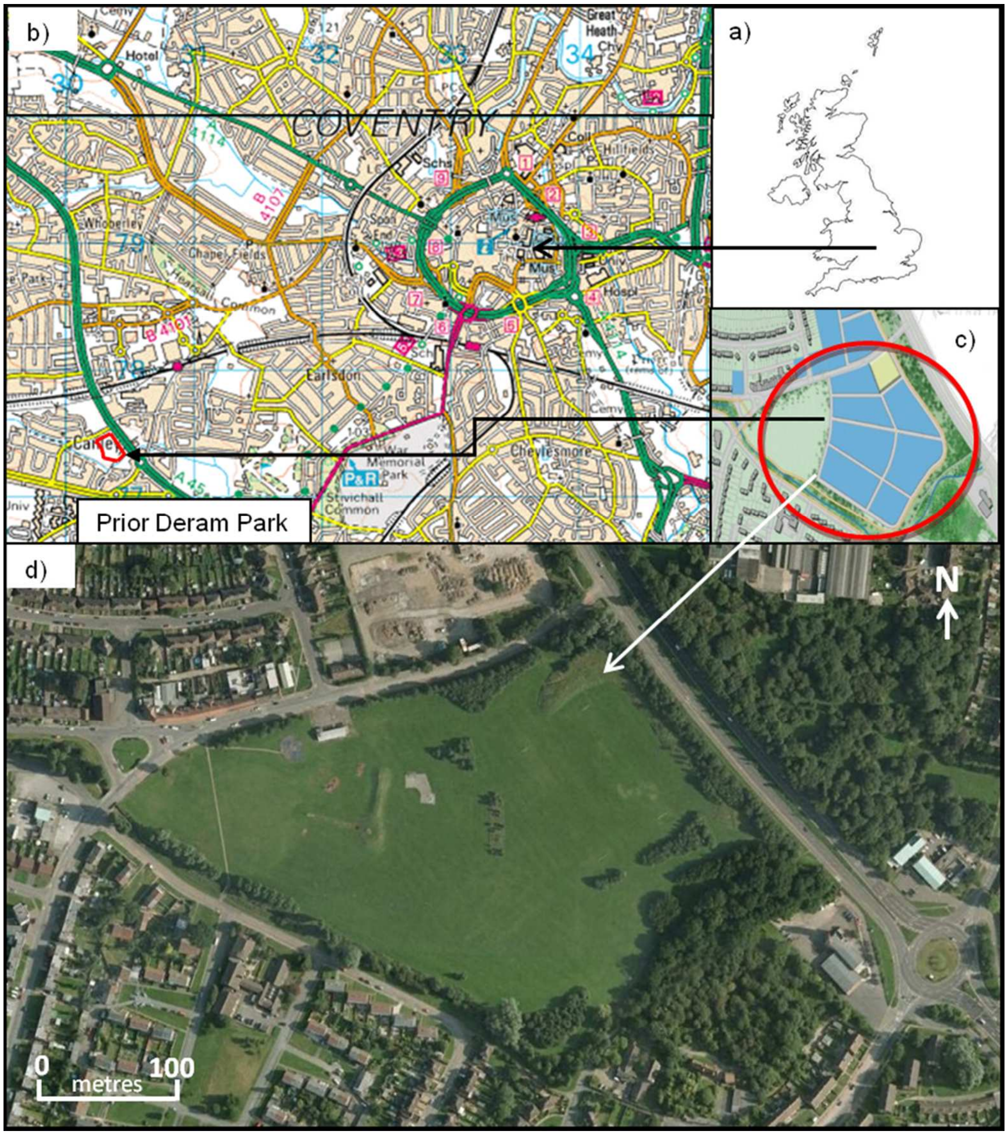
Publisher: Wiley Online Library

Deconstructing the sustainable drainage management train in terms of water quantity; preliminary results for Coventry, UK

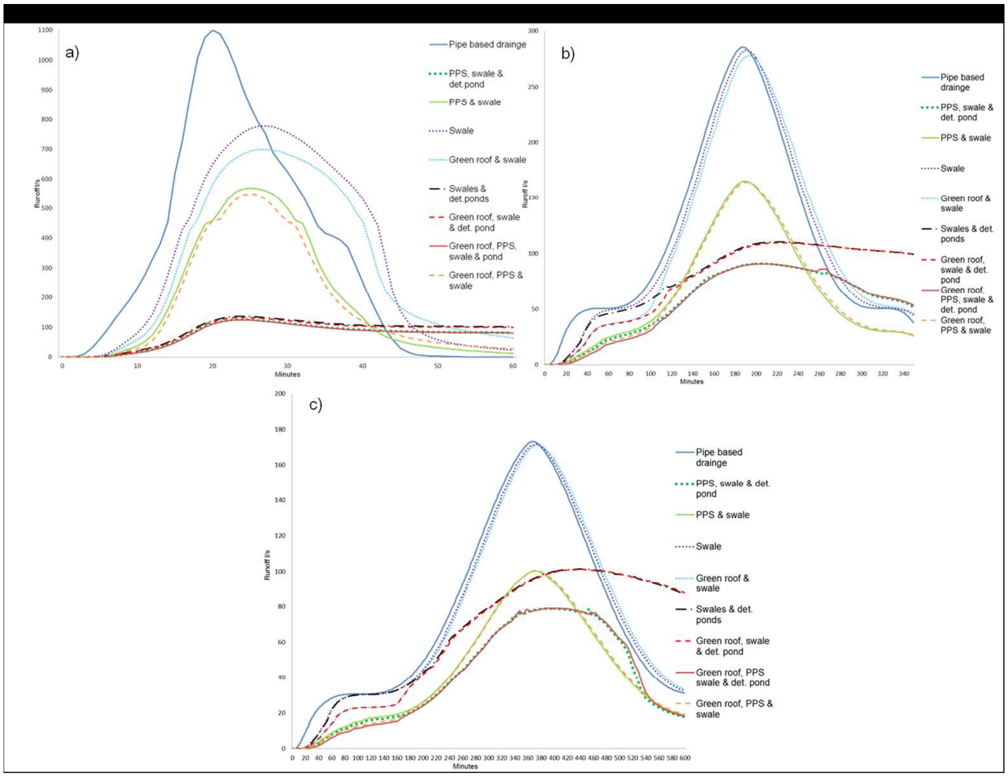
Journal:	*CLEAN - Soil, Air, Water*
Manuscript ID:	clen.201300161.R1
Wiley - Manuscript type:	Research Paper
Date Submitted by the Author:	n/a
Complete List of Authors:	Lashford, Craig; Coventry University, Geography, Environment and Disasters Charlesworth, Sue; Coventry University, Geography, Environment and Disasters Warwick, Frank; Coventry University, Geography, Environment and Disasters Blackett, Matthew; Coventry University, Geography, Environment and Disasters
Keywords (select from list):	water



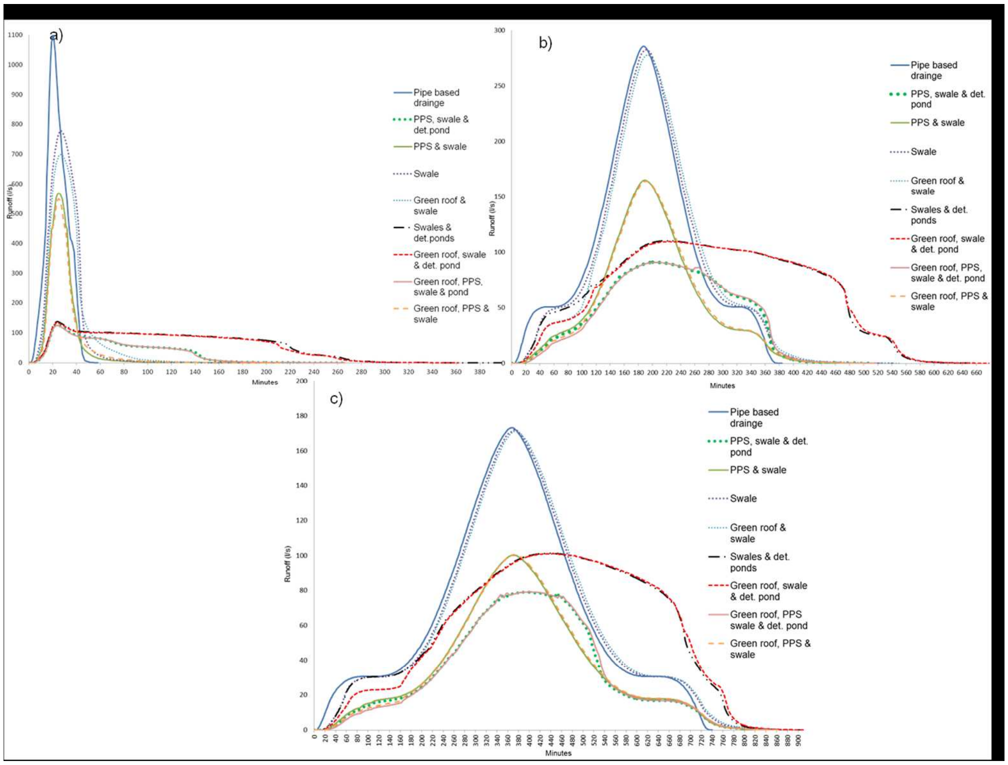
161x90mm (96 x 96 DPI)



141x159mm (150 x 150 DPI)



254x195mm (150 x 150 DPI)



257x194mm (150 x 150 DPI)

Deconstructing the sustainable drainage management train in terms of water quantity; preliminary results for Coventry, UK

Craig Lashford, Sue Charlesworth, Frank Warwick, Matthew Blackett

SUDS Applied Research Group, Coventry University, Priory Street, Coventry, CV1 5LW, England (craig.lashford@coventry.ac.uk)

KEYWORDS

Coventry, runoff reduction, SUDS management train, water quantity, *WinDes®*

ABSTRACT

The potential water quantity benefits of various SUDS management trains compared to conventional pipe based drainage systems are examined using the commercially available software *WinDes®* to model a site at Prior Deram Park, Coventry, UK, by investigating its response to a 1 in 100 year 30 minute, 360 minute and 720 minute winter rainfall event. The site is currently subject to a regeneration plan whereby the Park will be replaced with 250 houses. The housing layout was designed in ArcGIS and transferred to *WinDes®* and flood hydrographs of the likely outflow from each system simulated. The outputs from each system were then compared and it was found that an 88% reduction of peak flow was achieved using a SUDS management train that consisted of green roofs, porous paving, swales and dry detention ponds in comparison to pipe based drainage systems. The type of SUDS also appears critical; detention ponds can reduce peak flow by 82.9% when compared to systems without detention ponds. It is however likely that some form of flow control will be required at the outflow point as the peak runoff generated was significantly higher than acceptable values of 23 l/s for the site.

1. Introduction

Sustainable Drainage Systems (SUDS) mimic the natural hydrological processes that have been lost due to urbanization and resultant impermeable surfaces such as roofs and roads [1, 2]. Urbanization also results in soil compaction and a reduction in vegetation cover which decreases the land's ability to infiltrate storm water effectively, increasing the amount of overland flow [3]. Furthermore, hydraulically efficient conventional pipe based drainage systems that generate high peak flows are often implemented as a result of urbanization [4].

A SUDS management train is a system whereby SUDS are connected rather than each device being utilized as a standalone unit (Figure 1).

Insert Figure 1 here

An initial component of a successful management train is source control; SUDS that tackle water directly after precipitation [6]. Runoff is often released at this point through evaporation or to groundwater via infiltration. The remaining runoff is conveyed to a site control device, often by means of a swale [7]. Site control devices deal with runoff from multiple source control devices and can again allow evaporation as well as infiltration into surrounding soils. Runoff may then be conveyed to another site for regional control where devices deal with high volumes of runoff and represent the last point in the train. They should allow for moderate levels of pollutant removal, although much should already have been filtered out. After this step, the remaining water in the management train may be slowly released to a water body or infiltrate out of the system [8]. Individual SUDS devices have differing capacities in terms of their ability to successfully manage stormwater as shown in Table 1.

Insert Table 1 here

Previous research [9] examined the holistic approach provided by a SUDS management train. Focussing on Clyde Gateway, a regeneration site in Glasgow, Scotland, benefits included improved water quality, potential cost savings, an increase in the site's biodiversity and amenity and reduction in water quantity. Additionally, [10] reported their SUDS selection and location tool (SUDSLOC) which was used to suggest possible locations and impacts of installing SUDS devices at a site in Birmingham, West Midlands, UK. For example, they calculated that a stand-alone Porous Paving System (PPS) could reduce flow by up to 28% [10].

The aim of this research is:

1. To model potential benefits of various combinations of SUDS management trains for reducing water quantity in comparison with pipe based drainage
2. To deconstruct these management trains to assess the efficiency of individual components.

2. Experimental

To model the drainage systems, *WinDes®*, a drainage simulation tool developed by Micro Drainage, was used. The software has the capability to evaluate the benefits of implementing a SUDS management train. The chosen site for the research is Prior Deram Park, Coventry, UK, part of the proposed Canley Regeneration Plan [11] located in Coventry, UK (see Fig 2).

2.1 Study Site

2.1.1 Prior Deram Park

Prior Deram Park is located in Canley, 4Km south west of Coventry City Centre (Fig 2) in the West Midlands, England. Canley has an approximate population of 5,500 and is ranked in the top 20% of most deprived areas in England [12]. The majority of present housing was constructed between 1938-1950, utilizing a combined sewer system. This created the possibility of combined sewer overflows contributing to poor river quality therefore greater use of SUDS for stormwater management could relieve potential capacity issues in the combined sewer system. Prior Deram Park itself (Fig 2d) was used for landfill [11].

Insert Figure 2 here

Coventry City Council's regeneration proposal involves the construction of 250 new houses across a 5 hectare (ha) brownfield site currently used for recreational purposes. The outline planning proposal provides only a layout for the roads (Fig 2c) with no design or plan for the potential housing layout. Three sections to the east of the site currently have planning permission for three story housing, with the remaining four zones on the west side designated for two story housing. There is also a requirement to build affordable, social accommodation in keeping with the current development of Canley [15]. A flood risk assessment for the site [16] indicated that it is partially classified under the UK Environment Agency's Flood Zones 2 (between 0.1% – 1% likelihood of flooding) and 3 (greater than 1% chance of flooding) due to the presence of the Canley Brook to the south of the site; any development must therefore be designed to deal with rainfall scenarios up to a 1 in 100 year return period, taking climate change into account.

The elevation of the site is fairly constant at around 90-95m above sea level, but the acid loam and clay soil type limits the amount of infiltration possible. Previous use as a landfill [11] indicates infiltration is inadvisable due to the risk of groundwater pollution. The draft National Standards for SUDS [17] defines a hierarchical structure for runoff destination:

1. Discharge into the ground
2. Discharge to a surface water body
3. Discharge to a surface water sewer
4. Discharge to a combined sewer

As discharge to the ground is unsuitable, the most appropriate option is to discharge to a water body, in this case, the Canley Brook. However, this may increase local flood risk if not implemented appropriately.

2.2 Method

2.2.1 WinDes®

WinDes®, a commercially available urban stormwater drainage design model [18] incorporating several SUDS devices at source, site and regional level in the design of drainage systems [7, 19], was used to generate outflow hydrographs from the various drainage systems *(see section 2.2.3)*. The DrawNet module, one of the main packages for stormwater simulation and drainage design within *WinDes®* was used, and the Simulation functionality was added, which enabled various rainfall events to be simulated.

2.2.2 Designing the housing layout

Since the housing design had yet to be proposed for Prior Deram Park, a housing layout was designed in keeping with the original Canley Regeneration Plan [11] of 250 houses at 50 houses per ha. This was completed using ArcGIS [ESRI *ArcGIS* (version 9.2 Build 1380) [Computer Program]. Available from ESRI, 380 New York Street, Redlands, CA 92373-8100, USA 2006] utilizing the available road layout from Coventry City Council [11]. Of the 250 houses, 68 were semi-detached and the remaining 182 were in terraces; i.e. four or more in a row. All 68 semi-detached houses and 66 of the terraces were two story 5.5m x 8m in footprint area with 5.5m x 10m gardens. The remaining 116 houses were three story terraces, 4m x 10m in footprint area with 4m x 10m gardens. The size of the two housing styles was obtained after an investigation of the typical housing sizes of the surrounding area. The file was converted to .DXF (drawing exchange) format and exported to *WinDes®* to design the drainage systems.

2.2.3 Design of the drainage systems

Both a pipe based drainage system and a SUDS management train were designed for comparative purposes. The design for all systems assumed an impermeable site for Prior Deram Park, thus all runoff flowed into the Canley Brook. A 1m^2 vertical resolution LIDAR file was added to the layout to provide likely runoff routes. The pipe based system was designed to withstand storm events up to the 1 in 30 year scenario, in keeping with current England and Wales standards for pipe based drainage, to replicate a real life scenario [20].

An initial SUDS management train was designed for Prior Deram Park with all runoff entering the system. Selection of suitable SUDS, in terms of their ability to effectively manage stormwater was based on information provided in Table 1. Green roofs were added to each house while PPS was used for the driveways at every house for source control. Swales were used for conveyance and were typically designed to run alongside pavements; dry detention ponds were used for site control. All systems were modelled with no water residing in them. The total volume of each device is provided in Table 2. Due to the small scale of the site (5ha), it was unnecessary to utilize regional control. The SUDS devices used were selected from The SUDS manual [21] as they provide medium or high levels of attenuation. Some aspects of the site however required linkage using underground pipes or culverts, for example when conveyance was essential underneath a road. For the management trains that incorporated detention ponds, all runoff was directed into one of three detention ponds before being conveyed to the Canley Brook. For detention ponds to work effectively in *WinDes®*, it was necessary to design in an outflow control to attenuate runoff peaks, thus a *HydroBrake®* was added to the outflow point to constrain runoff to the site greenfield runoff rate of 4.6 l/s/ha as required by calculations in [22]. The SUDS system, unlike the pipe based system (which was designed to deal with the 1 in 30 year scenario), was designed to deal with the 1 in 100 year flood event as this is the required benchmark by the draft National Standards for SUDS [17].

Insert Table 2 here

2.2.4 Hydrological simulation

Further simulations were run for comparative purposes to gauge the response of both systems as a result of the 1 in 100 year storm, at three different winter storm durations; 30 minutes (73.13mm/hr.), 360 minutes (11.92mm/hr.) and 720 minutes (7.187mm/hr.). This generated the total amount of outflow likely from both drainage systems and provided information about how the site and the different types of SUDS would respond to different storm intensities. The simulation results were then compiled for both the pipe based system and the SUDS management train. The management train was then deconstructed, analysing various combinations of devices in order to compare and quantify the benefits of each individual SUDS type in reducing runoff quantity at Prior Deram Park. The resultant hydrographs were then compared to the hydrograph generated by modelling the response of the pipe based system and the initial SUDS management train to the 1 in 100 year events.

3. Results

3.1 Peak flow

Peak flow is shown in Table 3 for each designed drainage system. The pipe based drainage system produced the highest peak flow rate at each storm scenario. By introducing just swales to the site, it was possible to achieve a 29.3% reduction in peak flow for the 30 minute storm, however their impact reduced as storm intensity decreased. By designing a site that contained green roofs, PPS, swales and detention ponds it was possible to reduce peak flow by 975.5 l/s (88%) for Prior Deram Park. The choice of SUDS utilized is also a key factor in the peak flow reduction that is possible. All models that utilized detention ponds had a reduced peak flow rate than the system without the detention pond, with peak flow reductions of up to 82.9%. In terms of source control devices, Table 3a indicates that the use of PPS reduced peak flow rates due to a high intensity event by 48.3% as opposed to the 36.4% possible by the installation of green roofs to each house, and when each system was combined with swales. The difference was further exaggerated as rainfall intensity decreased; 42.2% compared to 2.7% for the 360 minute event and 42.1% versus 1.2% for the 720 minute event.

Insert Table 3 here

3.2 Time to peak

Figure 3 a-c focus on the initial response of the systems, giving more detail of the time to peak. Even in systems including at least one SUDS device response is much slower than pipe based drainage, with the arrangement of the devices varying in their time to reach peak runoff. Rainfall intensity is also a factor, with a simple swale system taking the longest time to reach peak flow for the 30 minute intense storm, however as the intensity decreased, designs including detention ponds took up to 137 minutes longer to reach peak flow than a simple swale system. The inclusion of PPS also reduces the time to reach peak runoff at both the 360 minute and 720 minute storm scenarios.

Insert Figure 3a-c here

3.3 Time to baseflow

The flood hydrograph outputs shown in Fig 4 a-c indicate how long it took the system to completely drain, i.e. return to baseflow. Using pipe based drainage, the Canley Brook returned to original baseflow after 63 minutes for the 30 minute event, 384 minutes for the 360 minute event and 741 minutes for the 720 minute event whereas all systems that included SUDS devices produced noticeable outflow after each conventional system had returned to baseflow. The quickest return to baseflow for SUDS systems was the PPS and swale arrangement at the two most intense storms, taking 199 and 507 minutes. The installation of detention ponds further increased the time taken for water to leave the system; taking an average 339 minutes to return to baseflow in comparison to the four systems without detention ponds which averaged 226 minutes, based on the high intensity 30 minute event; a trend that continues as intensity decreases.

Insert Figure 4 a-c

3.4 Discussion

3.4.1 Peak flow

That a pipe based system is likely to produce large flows shown is in Table 3 due to its efficiency in removing water from the urban environment to the water course [1, 23]. A potential reduction in peak flow of over 88% was achievable, based on the critical storm duration (30 minute winter storm) with the installation of a SUDS management train, which would therefore limit the amount of water leaving the site in one intense rainfall event. The lowest peak flow for the 30 minute and 360 minute rainfall events arose when more SUDS types were added to the system. However, in terms of reducing water quantity, certain SUDS devices have a greater impact [21]. By installing detention ponds at the site, peak flow decreased; this occurred in all examples as a result of the added attenuation and storage [8]. Additionally, when determining the primary source control device for mitigating peak flow, PPS provided a 17% reduction of peak flow rates, based on the 30 minute storm, compared to green roofs; highlighting the benefits of incorporating PPS into the design of a SUDS management train. This replicates results by [10] who identified that PPS is more effective than green roofs in terms of reducing flow rates, although their findings were at a smaller resolution, looking at hourly changes. Additionally, the minimal flow reduction achieved at Prior Deram Park for green roofs contradicts research by [24] who identified green roofs as being able to reduce 82% of runoff averaged over various rainfall scenarios. The results therefore show that when designing a SUDS management train at a site that is at risk of pluvial flooding, there should be a greater emphasis on incorporating detention ponds and PPS, which can both reduce peak flow rates. However, all drainage systems produce outflows in exceedance of figures suggested by the draft National Standards [17] of 4.6 l/s/ha, therefore for Prior Deram Park, flow must not exceed 23 l/s. As a result, a flow control device will be required to reduce the outflow rate to 23 l/s, if one of the drainage systems were utilized for the site.

3.4.2 Time to peak

Each SUDS system produced a longer time to rise than pipe based drainage. As the SUDS devices used aim to retain water in the urban environment [5], it will remain in the system for longer and therefore take longer to arrive at the water course. The swale system was the slowest to reach peak outflow for the high intensity event, this may be due to the large amount of runoff in the system. For the high intensity event, the four SUDS systems that included detention were only two to three minutes quicker to reach peak flow than the swale system but the peak flow rate was considerably smaller across all four designs than any of the other systems. As intensity decreased and rainfall persist, more runoff was held in the detention ponds, therefore resulting in these systems taking longer to reach peak flow at both the 360 and 720 minute storm duration. This is consistent with [21] who advocate that detention ponds considerably increase the amount of time to reach peak runoff. The implementation of PPS into the design reduced the time to peak flow as the site allowed for no infiltration; therefore each PPS device captured runoff and rapidly transported it throughout the management train, acting solely as conveyance device.

3.4.3 Time to baseflow

Pipe based drainage returned to baseflow at a much faster rate than systems that included SUDS due to the high peak flow occurring as a result of the efficient nature of the system. The SUDS systems varied in their ability to slowly release water back into the water course based on what device's were used. When detention ponds were installed, the time to return to baseflow increased due to increased detention capability [9, 25].

4. Concluding Remarks

This study has shown that there are many benefits by designing a drainage system in the urban area that includes SUDS, instead of relying solely on pipe based stormwater drainage. An optimal SUDS management train for Prior Deram Park has also been designed, highlighting the devices that provide the best runoff reduction. In this example a management train reduced peak flow by up to 88% in comparison to pipe based drainage. The benefits of a SUDS management train to address water quantity concerns were provided, and the deconstruction of a number of management systems exemplified their usefulness in reducing water quantity. Detention ponds reduced peak flow by 82.9%, when compared to a management train without detention ponds and resulted in outflow over a significant amount of time. In terms of source control devices, PPS provided a greater peak flow reduction when compared to green roofs.

Although these results can provide a guideline, due to site specificity such as the inability to infiltrate, final design of the housing estate, former land use etc. the results are only comparable to similar sites where infiltration is also limited. Therefore it is highly possible that a reduced number of devices could be integrated at a site with even limited infiltration. It should also be acknowledged that although the systems provide a source for comparison, the outflow values are often much greater than the required level: 4.6 l/s/ha. If these systems were to be installed at Prior Deram Park, a form of outflow control would therefore be required to bring the systems in line with the draft National Standards [17]. Additionally, although water quantity forms one aspect of the SUDS triangle, and is often the yardstick most commonly used to assess the benefits of drainage schemes in planning terms, it is not the sole priority of SUDS. For a SUDS management train to be successful there must also be the realization of water quality and amenity benefits.

Tables

Table 1: The stage of the SUDS management train that each device is most suited to deal with stormwater (X – most suitable O – less suitable) and the effectiveness of each device. * dependent on size. Adapted from [18]

	Source	Site	Regional	Conveyance	Effectiveness at reducing water quantity
Rainfall harvesting	X	X			Low*
PPS	X	X			High
Filter strip	X				Low/Medium
Swale	X	X		X	Medium
Pond		X	X		Medium/High*
Wetland		X	X	O	Low/Medium
Detention basin		X	X		High*
Soakaway	X				Medium
Infiltration trench	X	X		O	Medium/High
Infiltration basin		X	X		Medium*
Bioretention device	X	X			High
Sand filter		X	O		Low
Green roof	X				Medium

Table 2: Total volume of each SUDS device modelled at Prior Deram Park

SuDS device	Total volume (m^3)
Swales	728.7
PPS	760.68
Detention ponds	6890
Green roofs	2024

Table 3: The peak flow (l/s) of each designed drainage system and the percentage difference of each SUDS system compared to conventional drainage for:

a.) 1 in 100 year 30 minute winter storm scenario
b.) 1 in 100 year 360 minute winter storm
c.) 1 in 100 year 720 minute winter storm

Drainage System	Peak at outflow (l/s)	% reduction in outflow comparison to conventional drainage	Time to peak (mins)	Time to baseflow (mins)
A. 1 in 100 year 30 minute winter storm				
Conventional	1100.3		21	63
Swale	778.1	29.3	28	235
Green roof & swale	699.3	36.4	28	255
PPS & swale	569	48.3	26	199
Green roof, PPS & swale	550.3	50	26	218
Swale & det. pond	137	87.5	25	399
Green roof, swale & det. pond	133.1	87.9	25	394
PPS, swale & det. pond	126.1	88.5	25	281
Green roof, PPS, swale & det. pond	124.8	88.7	25	283
B. 1 in 100 year 360 minute winter storm				
Conventional	285.6		188	384
Swale	282.7	1	191	542
Green roof & swale	278	2.7	194	553
PPS & swale	165.1	42.2	190	507
Green roof, PPS & swale	164.1	42.5	191	514
Swale & det. pond	110.4	61.3	220	675
Green roof, swale & det. pond	109.6	61.6	222	679
PPS, swale & det. pond	91.1	68.1	203	508
Green roof, PPS, swale & det. pond	90.9	68.2	205	519
C.1 in 100 year 720 minute winter storm				
Conventional	173.2		369	741
Swale	171.9	0.8	373	891
Green roof & swale	171.2	1.2	374	899
PPS & swale	100.3	42.1	370	856
Green roof, PPS & swale	100.6	41.9	372	862
Swale & det. pond	101.4	41.5	437	904
Green roof, swale & det. pond	101.3	41.5	445	911
PPS, swale & det. pond	78.9	54.4	388	856
Green roof, PPS, swale & det. pond	79.1	54.3	398	864

Acknowledgements

Acknowledgments are given to BWB consulting for providing technical support for the project and MicroDrainage for providing a license to use *WinDes®*.

The authors have declared no conflict of interest.

5. References

[1] A. Semadeni-Davies, C. Hernebring, G. Svensson, L. Gustafsson, The Impacts of Climate Change and Urbanisation on Drainage in Helsingborg, Sweden: Suburban Stormwater. *J. Hydrol.* **2008** *350 (1-2),* 114-125.

[2] M. Dale, Impact of Climate Change on UK Flooding and Future Predictions, *Water Management.* **2005**, *158*, 135-140.

[3] A. Swan, How increased urbanisation has induced flooding problems in the UK: A lesson for African Cities?, *Phys. Chem. Earth*. **2010**, 35, 643-647.

[4] A. Elliott, S. Trowsdale, A Review of Models of Low Impact Urban Stormwater Drainage, *Environ. Modell. Softw.* **2007**, *22*, 394-405.

[5] S. Charlesworth, A review of the adaption and mitigation of global climate using sustainable drainage cities, *Journal of Water and Climate Change*. **2010**, *1 (3)* 165-180.

[6] P. Hamel, E. Daly, T. Fletcher, Source-control stormwater management for mitigating the impacts of urbanisation on baseflow: A review, *J. Hydrol.* **2013**, *485,* 201-211

[7] V. R. Stovin, A.D. Swan, Retrofit SuDS – cost estimates and decision – support tools, *Water Management.* **2007**, *160*, 207-214.

[8] A. Kirby, SuDS – innovation or a tried and tested practice?, *Municipal Engineer.* **2005**, *158* 115-122.

[9] N. Bastien, S. Arthur, S. Wallis, M. Scholz, The best management of SuDS treatment trains: a holistic approach *Water Sci. Techno.* **2010**, *61 (1)* 263 – 272.

[10] C. Viavattene, B. Ellis, M. Revitt, H. Seiker, C. Peters, The application of a GIS-based BMP selection tool for the evaluation of hydrologic performance and storm flow reduction, *Novatech – 7th Int. Conference on Sustainable Techniques and Strategies for Urban Water Management*, Lyon, France, 27th June – 1st July, **2010**.

[11] WSP Environmental Ltd & Coventry City Council, *Canley Regeneration Project - Outline Planning Application Environment Statement: Non-Technical Summary*. **2008**.

[12] D. Jarvis, N. Berkeley, K. Broughton, Evidencing the impact of community engagement in neighbourhood regeneration: the case of Canley, Coventry *Community Development Journal.* **2011** *47 (2)* 232-247.

[13] Ordnance Survey *Canley, Coventry* 1:50,000 Raster **2013**

[14] Google Earth 7.0 *Prior Deram Park 52°23’37.51”N 1°33’22.37”W, elevation 93m.* **2013**

[15] Alliance Planning & Coventry City Council, *Affordable housing statement in support of planning application*. **2008**.

[16] Coventry City Council, Halcrow Group, *Canley regeneration flood risk assessment*. **2008**

[17] DEFRA, *National Standards for sustainable drainage systems*. **2011**.

[18] Micro Drainage, *Working with WinDes®: An example-led instruction to the Windows-based Micro Drainage Suite*. **2009**.

[19] S. Moore, V. Stovin, M. Wall, R. Ashley, A GIS-based methodology for selecting stormwater disconnection opportunities *Water Sci. Techno.* **2012**, *66 (2)* 275–283.

[20] Atkins *Development of guidance for sewerage undertakers on the implementation of drainage standards*. **2008**

[21] B. Woods Ballard, R. Kellagher, P. Martin, C. Jefferies, R. Bray, P. Shaffer, *The SUDS Manual.* **2007**.

[22] .R. Kellagher, *Preliminary rainfall runoff management for developments R&D Technical Report W5-074/A/TR/1 Revision E* **2012**.

[23] P. Jones, N. Macdonald, Making space for unruly water: Sustainable drainage systems and the disciplining of surface runoff *Geoforum.* **2007**, *38*, 534-544.

[24] N. VanWoert, B. Rowe, J. Andersen, C. Rugh, T. Fernandez, L. Xiao, Green roof stormwater retention: effects of roof surface, slope and media depth, *J. Environ. Qual.* **2005**, *34 (3) 1036-1044*

[25] C. Jefferies, A. Duffy, N. Berwick, N. McLean, A. Hemingway, Sustainable Urban Drainage Systems (SUDS) treatment train assessment tool, *Water Sci. Techno.* **2009***, 60 (5)* 1233-1240.

List of Figures and tables