Session 5 – Paper 14

Using water butts to reduce flood risk

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Abstract

Sewerage undertakers face an increasing challenge to reduce the risk of sewer flooding in light of additional sewer capacity demands from new development, impermeable area creep and climate change. Holistic and sustainable solutions incorporating SuDS and source control features are increasingly required and help drive towards long term sustainable drainage aspirations.

This paper outlines the work Severn Trent Water have undertaken with our research and development (R&D) partner, Atkins, to evaluate the potential benefits of adapting standard water butts to allow them to partially self drain, thus automatically freeing the top part of the butt to be used for rainfall attenuation. Whilst singularly they are ineffective due to their low attenuation volume, when used in combination in high numbers across a catchment, they could help to represent a reduction in flood risk, particularly during short duration lower return period storm peak events.

This paper describes the approach taken to evaluate the potential benefits of using partially self draining attenuation water butts, findings from R&D bench tests, modelling results and the experiences of trying to installing them in a live catchment environment.

Concept

Historically, conventional water butts have been promoted for water efficiency benefits, the idea being that harvesting rain water for watering gardens will reduce potable water demand. The basic design is simple, whereby a moulded plastic device is fitted to a rainwater downspout to divert water to a nearby water butt. Harvested water in the butt is then stored until used/drained away by the customer. During storm conditions the cumulative effect of several water butts across a catchment could potentially provide a low cost means of storm water attenuation but only if customers have emptied/used the water beforehand.

The concept behind attenuation water butts is to establish whether a standard water butt design can be adapted to incorporate a self emptying element and the impact this would have on catchment wide drainage. It is envisaged the adaptation would not only provide storm water management benefits in the sewerage system, but also still provide a reasonable volume of water for customers to use in their gardens, thereby maintaining the incentive for customer acceptance of the modified butts.

Research

Severn Trent Water commissioned Atkins, our R&D framework partner, to investigate the potential benefits of using attenuation water butts. This included bench test trials of the conceptual design, development of a modelling methodology and assessment of the cost benefits of applying the butts to a small catchment. Subject to the findings of this work a small village of around 300 properties in Warwickshire was identified as a pilot site with the intention to undertake live catchment trials to do before/after flow monitoring but more importantly to understand the willingness of customers to engage with water companies and co-operate with such projects.

The initial phase of the work was to understand the basic principles of how attenuation water butts would work to allow impact modelling assessments to be undertaken. This R&D element considered the basic components of the concept, namely transferring roof water into the water butt, optimising the design of water butt adaptation and understanding the self emptying discharge characteristics. A simple test rig was fabricated and set up at Atkins Derby office to allow experimental trials to be carried out.

Rain diverters

Most water butt arrangements use a rain diverter to transfer water from the property downspout into the butt. Usually made of plastic, these devices intercept rainwater running down the inside face of the downspout and divert flow through an outlet pipe into the water butt. When the water butt is full the rainwater overtops a small weir wall within the diverter and continues down the downspout.

Figure 1 shows the basic principles of how a simple rain diverter operates:

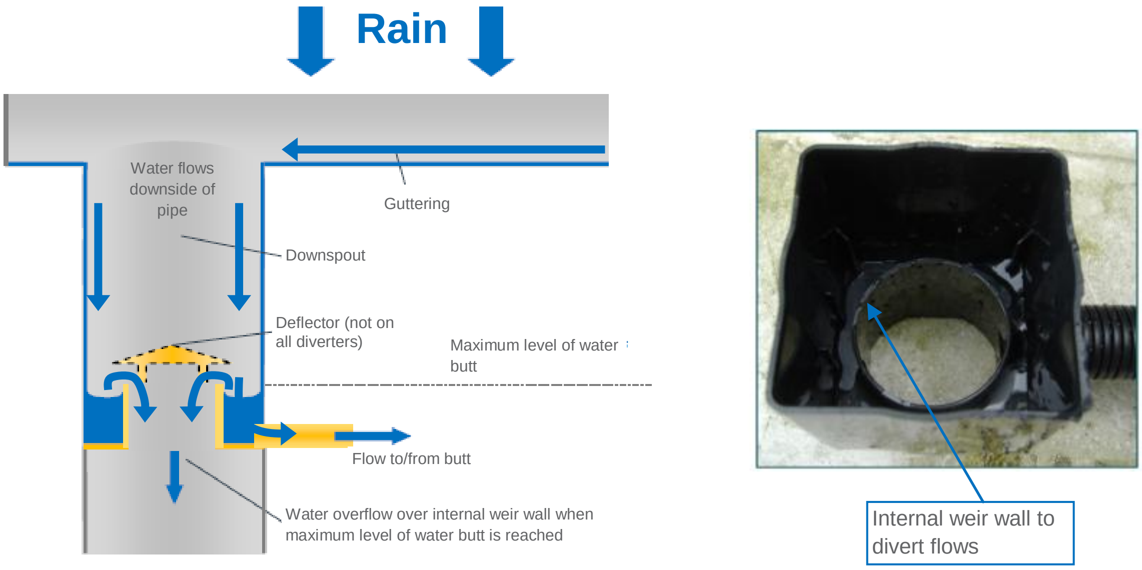


Figure 1 – Basic principles of a rain diverter.

There are a wide range of rain diverters available to suit a wide range of applications at a variety of costs. The more complex rain diverters include aspects such as filtration and user defined seasonal settings to vary transfer efficacy. The study conducted by Atkins included an assessment of rain diverter design and performance. Through discussion with Severn Trent Water's water butt framework supplier, Straight plc, three flow diverter products were identified as shown in Figure 2 and subsequently evaluated by Atkins.

Simple rainwater diverter kit
(Wickes - £5.99)

Guttermate with fine filter mesh
(Guttermate.co.uk - £33.31)

Regendieb De Luxe (Giant Diverter)
(Evergreener.com - £50.00)

Figure 2 – Rainwater diverters kits tested.

All three devices employ the same basic principles using internal weir walls, as outlined in Figure 1. However, as expected, there are varying levels of merit for each device in terms of efficiency, ease of maintenance/installation and cost.

Bench test trials were undertaken using a simple test rig (Figure 3) to assess the effectiveness of each rain diverter. This used controlled inflows from a mains water supply to mimic the expected peak flow from an average sized 17m^2 pitched roof area for simulated 1, 2 and 5 year return period design storm events of 15 minute duration (estimated from the Modified Rational Method).

Figure 3 – Diverter testing rig.

Each rain diverter device was evaluated in terms of efficiency of transferring water from the downspout to the collection outlet as summarised in the following table.

Diverter Name	Approximate efficiency at diverting flow to butt		
	1 in 1yr storm	1 in 2yr storm	1 in 5yr storm
Simple Diverter Kit	35 %	30 %	25 %
Giant Diverter	70 %	75 %	85 %
Guttermate (without fine mesh)	85 %	75 %	65 %
Guttermate (with fine mesh)	95 %	90 %	75 %

Figure 4 – Table showing rain diverter efficiency.

One of the key issues identified with the simple rain diverter kit was that even in low rainfall events its smaller outlet (17 mm diameter) performed poorly in comparison to the other devices which had much larger outlets. It was established that the smaller outlet pipe size forced the internal diverter weir to frequently overtop resulting in excess flow escaping out of the diverter as shown in Figure 5.

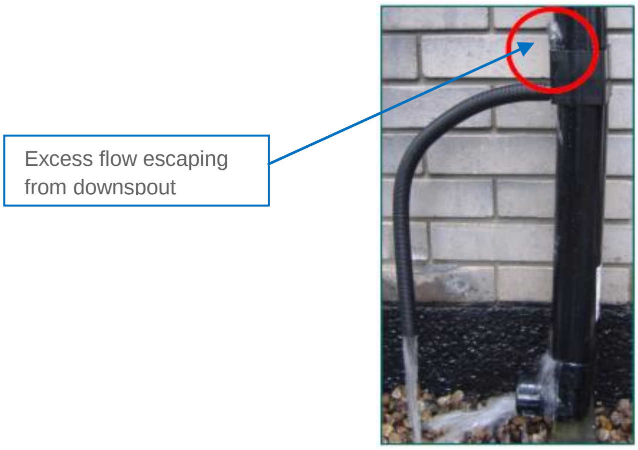
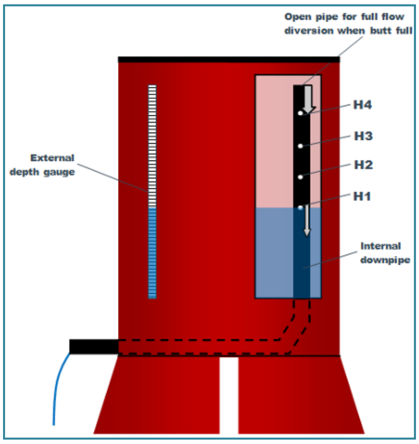


Figure 5 – Photograph showing spill exceedance of the basic diverter.

However, whilst the other devices were more efficient, the additional cost was not considered cost beneficial for domestic properties where storage capacity would be limited to 200 litre water butts. The more efficient diverters would be more suitable for larger buildings such a village halls, schools where larger volumes of attenuation could be provided.

Water butt and discharge arrangement

A test water butt was developed to trial different discharge combinations and compare practical against theoretical performance. The adapted water butt was a standard 200 litre cylindrical drum type model, which was fitted with internal discharge pipe work, fabricated from 32mm waste pipe/tee pieces, onto which changeable plugs could be fitted for different sized orifice trials. The changeable plugs were drilled with orifice sizes of approximately 3mm, 5mm and 8mm with a set of blank plugs retained for added variability.



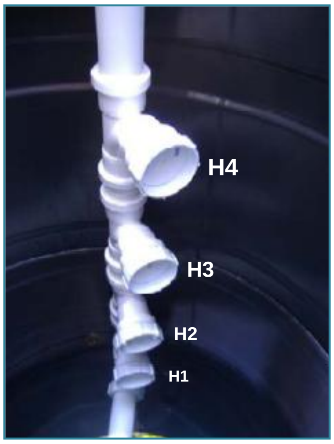


Figure 6 & 7 – Internal discharge arrangements.

The top of the internal discharge pipe was left open to represent the butt overflow arrangement and an external depth monitoring gauge was added to the water butt for ease of testing. Different orifice combinations were trialled to evaluate influence of orifice diameter and static head using configurations shown in Figure 8.

		Orifice diameters (mm)					
Orifice	Height above datum (mm)	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*
H4	375	3	5	8	–	–	8
H3	249	3	5	8	–	–	5
H2	127	3	5	8	5	8	3
H1	0	3	5	8	–	–	3

Figure 8 – Table showing different orifice combinations.

A series of tests were then undertaken to understand head discharge relationships for each orifice configuration. The results from these tests were used to calculate the co-efficient discharge using Bernoulli's principle and these are shown in Figure 9.

Test Ref	Orifice Configuration H1 / H2 / H3 / H4	Coefficient of discharge, C_d
E1	3 / 3 / 3 / 3	0.80
E2	5 / 5 / 5 / 5	0.72
E3	8 / 8 / 8 / 8	0.75
E4	- / 5 / - / -	0.73
E5	- / 8 / - / -	0.80
E6	3 / 3 / 5 / 8	0.82

Figure 9 – Discharge coefficients resulting from different orifice combinations.

Modelling Approach and Results

Analysis from the bench tests was applied to the hydraulic sewer model for the Warwickshire village identified for the pilot. This catchment was chosen due to its compact size, the driver to reduce sewer flood risk, potential for positive customer engagement and the mix of different properties types.

Modelling was undertaken using an InfoWorks CS model. Water butt attenuation was represented by dummy sub-catchments using a suitable head-discharge relationship. This approach was taken in preference to the 'Orifice' function within InfoWorks CS as there was concern that the small flows involved could result in modelling instabilities. The discharge coefficient was obtained from the bench test results (Figure 9). An overland flow route was also added to the model in order to represent the water butt reaching capacity and re-entering the drainage network.

Scenario modelling was undertaken for different storm return periods/durations using the discharge co-efficients shown in Figure 9 to represent each different orifice configurations. Catchment performance was then evaluated at two locations within the catchment and at the sewage treatment works. Water butt attenuation was modelled on all pitched roof properties in the catchment and catchment information upstream of the evaluation locations is shown in Figure 10.

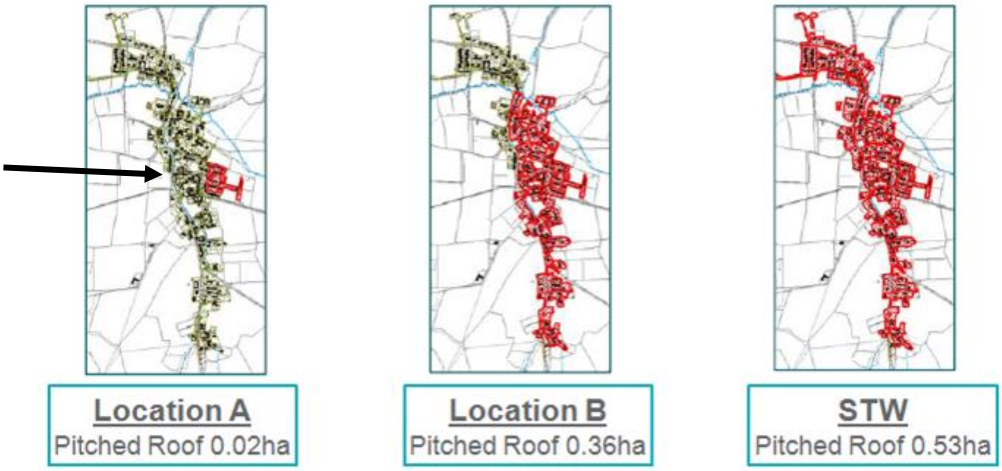


Figure 10 – Catchment assessment locations and upstream catchment indication.

The average variation in peak flow (expressed as a percentage) by storm event, orifice configuration and evaluation location is shown in Figure 11.

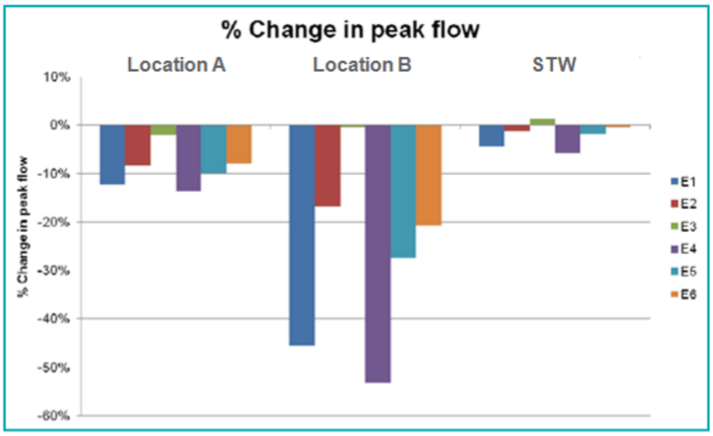
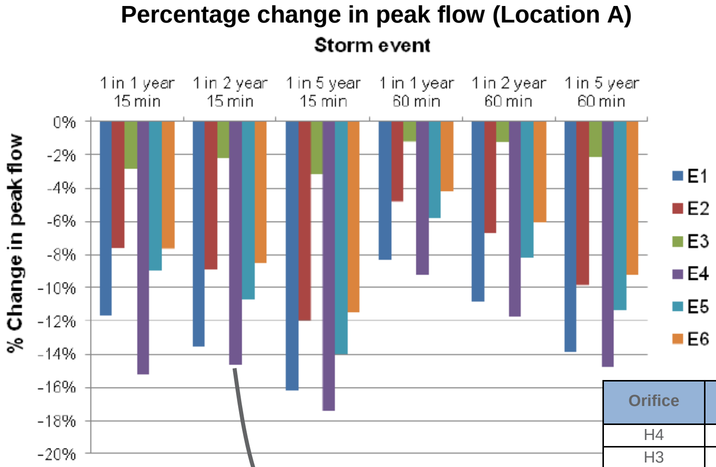


Figure 11 – Change in peak flow.

As indicated by the results for all evaluation locations, the optimal performance is associated with orifice combination E4, represented by the purple bar in Figure 11. Considering specifically evaluation location A, the results for the range of storm events and the impact on the peak flow hydrograph is shown in Figure 12.



Orifice	Height above datum (mm)	Orifice diameters (mm)					
		E1	E2	E3	E4	E5	E6
H4	375	3	5	8	-	-	8
H3	249	3	5	8	-	-	5
H2	127	3	5	8	5	8	3
H1	0	3	5	8	-	-	3

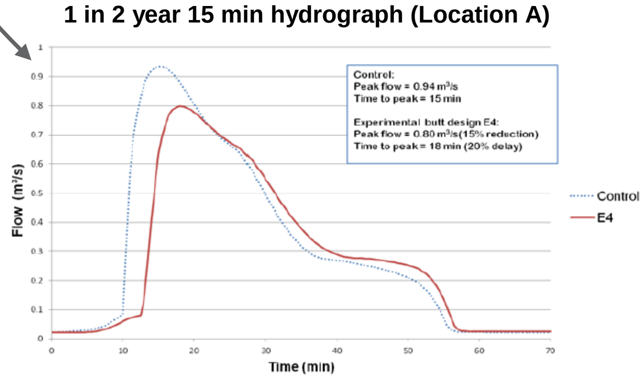


Figure 12 – Example of modelling results.

The results indicated optimal water butt performance benefit would be achieved from using a 5mm diameter orifice located halfway down the water butt. Although orifice combination ‘E1’ (four 3mm orifices) also offered good performance, the advantage of using a single orifice was its simplicity and would make adaptation design much easier.

The modelling highlighted the need to pay special attention to areas where there are known slow response issues in the catchment, where prolonged drain down from water butts could combine with catchment drain down resulting in an increase in flood risk. Similarly it may be appropriate to adopt different orifice configurations at different zones within the catchment to better optimise the attenuation effect for differing time of concentrations. For example, it may be appropriate to use 8mm orifices in downstream parts of the catchment and 5mm elsewhere to optimise overall catchment benefit. Also water butts may be detrimental in some areas whereas elsewhere you might want to maximise attenuation using larger butts or linking 200 litre butts together. The approach therefore has the flexibility to be adaptable.

Cost benefit

An assessment of the cost of water butts compared with installing equivalent sized storage within the sewer network was undertaken. This approach assumed the use of 1200mm diameter manholes to provide equivalent storage. Whilst this may not be representative of a more holistic infrastructure solution, it was used to replicate the decentralised increased storage capacity offered by the water butts.

Water butt installation costs were derived by assuming the installation of 164 units across 300 properties in the village. Based on using 200 litre, half empty butts, 16.4m^3 of attenuation storage would be provided. The total cost when including materials, delivery, installation, customer liaison and project overheads was estimated at around £24,800. This provided a cost benefit ratio of 1.7 when compared with the cost of utilising equivalent manhole sewer storage which was estimated at £42,100.

Maintenance and Operational Considerations

Compared to normal water butts, the attenuation butts are not considered to require any additional maintenance other than the need to keep the 5mm diameter orifice clear. Any silt/debris which finds its way into the butt will fall the bottom and the only risk of blockage to the orifice would be from floatables such as leaves and seeds or from algal build up. However, in the event of organic matter blocking the orifice then organic decomposition, in combination with the static head of water is likely to overcome this problem. Alternatively, if customer intervention is required then simply using a brush, jetting with a garden hose or running the easily removable orifice plug under a tap will suffice.

One issue identified during the trials that could be important to customers was reduced water pressure at the tap outlet. As with all water butts, flow rate at the tap outlet reduces as the static head of water in the butt reduces. As the attenuation water butt is designed to be only partially full, the flow rate available to the customer to fill watering cans etc will be lower when compared to a conventional butt. The concept of dividing the butt volume vertically into a customer available partition and an attenuating partition was considered but discounted due to stability and manufacturing reasons.

In order to prevent customer dissatisfaction with outlet flow rates further study of the outlet tap arrangement was completed. Most standard water butt taps are designed to fit garden hose adaptors, but only have a small outlet (9mm diameter). To overcome the reduced static head issue it is possible to fit, slightly more expensive, high capacity taps which have a larger outlet (18mm diameter) as shown in Figure 13.

Figure 13 – Types of water butt tap.

On site Implementation

Based on the findings of the R&D work the final attenuation water butt design used the basic rain diverter (albeit a slightly different design with a 20mm diameter outlet rather than the 17mm diameter version used in the test rig). To represent the optimum orifice configuration, the drain down pipe in the attenuation water butt was to be fitted with a 5mm diameter orifice plug. The standard water butt linkage kit being used to drain down the butt has a pipe 15mm in diameter hence a means of reducing this to 5mm and still maintain ease of installation/maintenance was required. This problem was overcome through the use of plastic stoppers (normally used on the bottom of salt and pepper cruet sets or as money box stopper) purchased from an eBay supplier and adapted using a 5mm drill bit.

For the pilot work only 200 litre and 100 litre water butts were offered to customers due to cost/delivery/storage reasons but subject to customer feedback other designs could be considered to increase take up. Consequently the standard installation kit comprised the apparatus shown in Figure 14.

Figure 14 – Attenuation water butt components.

Customer engagement

Initial discussions were held with parish council representatives to discuss the pilot study of introducing the attenuation water butt concept. There was some scepticism that using water butts was a cheap fix for Severn Trent Water (which was the idea) but they could see the potential benefit and were pleased that their village had been chosen to be potential pioneers. Questionnaires were subsequently distributed to all 300 properties across the village to outline the attenuation water butt concept. At the same time the opportunity was taken to include additional information to educate customers of the risk of sewer blockage associated with inappropriate disposal of un-flushable products and FOG (fats, oils and greases) into the sewerage system. Severn Trent Water also attended a parish council organised 'Community Day' in the Warwickshire trial site to roll out the idea.

Whilst the primary objective of the questionnaire was to identify the customers willing to have a water butt, it was opportune to identify reasons for any customer reluctance. From 300 questionnaires distributed a total of 131 responses were received, representing a 44% return rate. Positive responses were received from 80 customers (61%), including comments that some would like multiple butts as they have a large roof. Of the 51 who declined, 28 already had a water butt, 10 believed they had no room for a water butt, 11 were concerned with visual impact, 1 was a thatched cottage with no downspouts and 1 gave no reason. As part of the initial pilot the retrofit installation to existing butts was not proposed, neither were linking additional butts or options to offer more visually appealing designs (to keep installation as simple as possible). Consequently there may be scope to increase acceptance if the range of water butts being offered is increased but non-standardisation is expected to increase cost, primarily due to the higher cost of more visually attractive water butts. All water butts as part of the trial were being supplied and installed free of charge but with the future ownership being transferred to the customer.

Live catchment findings

In hindsight the Warwickshire village was not the ideal catchment. It was originally chosen due to its compact size to allow before and after sewer monitoring to assess water butt performance and the fact that there was a good mix of property types/ages across the village. During detailed feasibility investigations it became apparent that some of the properties were connected to soakways and so no sewer capacity benefit from water butt installation. We also discovered that parts of the village were in a conservation area and that whilst water butts would still be permitted, the visual appearance was expected to be highly important. It was however these types of issues the pilot work was looking to unearth and so irrespective of these it has proved to be extremely useful to understanding what parameters are ideal for making water butts acceptable for customers.

We will be reviewing the effectiveness of the water butts we have installed in 2015 following the completion of before and after flow monitoring.

The main benefit from the pilot has been to get customer buy-in. Although many customers were willing to be involved, a high proportion already had a water butt and were not always amenable to having them converted, whilst others were worried about the appearance. Consequently, whilst the R&D evidence indicates attenuation water butts should have a noticeable impact on sewer flows, the key to their successful implementation is to identify the catchment areas with the right type of properties, (ideally one of a similar type with plastic downspouts and gardens), and with the right customer demographics who are willing to be involved.

This is supported by another water butt location in Ludlow which, at the same time as the Warwickshire pilot, was identified as an opportunity to install attenuation water butts to reduce flood risk ahead of a flood alleviation project. Whilst the Warwickshire pilot was been affected by different property types and a wide customer demographic, the Ludlow site consisted of a residential complex for elderly people which is managed by a housing association. This made the ideal location as it has similar property types suited to water butt installation and the customers/housing association were keen to be involved to help reduce the flood risk. As a result on a single day a team of 12 installed 53 water butts across the estate.

Initial feedback from customers has been positive albeit that the use of water butts is only part of an ongoing wider catchment flood risk solution. Post installation reviews and customer feedback are planned for 2015.

Figure 15 – Photos showing installation in Ludlow.

Learning Points

The findings from the study and experiences with the pilots in Warwickshire and Ludlow indicate that attenuation water butts could offer a potential cost benefit solution under the right circumstances.

The SWOT analysis below summarises the finding from our work to date:

Strengths

- Attenuation water butts can be installed very quickly and the only non-standard item is the 5mm orifice stopper.
- The concept is adaptable. Orifice sizes and water butt capacity can be easily tailored to different catchment characteristics to optimise performance.
- Compared to traditional storage solutions, water butts could provide a cheaper alternative for managing surface water flows.
- The principles will work with any water butt design/size. The key is to ensure the drain back orifice hole is the right size.
- Can be used on surface water and combined sewer systems.
- Existing water butts can be retro-fitted to convert to attenuation butts and can be linked.
- Large roof areas, such as village halls or schools can also be used.

Weaknesses

- Not suitable for all catchments, especially in catchments subject to slow response attenuation water butts could make the flooding worse.
- Reliant on customers being willing to be involved.
- Basic design does not remove rain water from the sewerage system, although the design could be adapted to drain to a rain gardens or irrigation systems.

Opportunities

- Provides an opportunity to educate customers on wider messages regarding impact of impermeable area on storm water flooding, sewer misuse and water efficiency.
- Could be integrated into other SuDS solutions. For example instead of draining flows back to the downspout, the water could be diverted to rain gardens or irrigation systems.

Threats

- Ability and inclination of customers to maintain them.
- Risk that customers could block the 5mm drain hole to maximise garden watering potential or could just remove the water butt completely without letting us know.
- Water butts are plastic and open to the elements, hence have a limited design life and could be affected by water freezing in the winter.

Future Development and Next Steps

The focus of the pilot work to date has been to offer standard green 200 litre water butts which are connected back to the downspout, hence whilst there is attenuation benefit, surface water is not removed from the sewerage system. Based on customer feedback there is potential benefits to offering a wider range of water butt designs or offering retrofit options to increase acceptance. There are also options to consider the potential of connecting water butts to rain gardens which provides the added benefit of removing surface water from the sewerage system.

The next phase of our work is to use the findings from the water butt pilots and integrating water butts into wider SuDS solutions. Clearly there is a need to continue to monitor customer acceptability and Severn Trent Water intend to maintain contact and engagement with customers to establish any longer term concerns or issues.

The study and trials have provided Severn Trent Water with sufficient feedback to progress the concept further and wider catchment trials are being investigated to evaluate the long term effectiveness of attenuation water butts for inclusion in the storm attenuation/flood risk toolbox.