LEIXLIP – SOCIAL HOUSING DEVELOPMENT

80196

DRAINAGE DESIGN REPORT - SUDS STRATEGY

October 2024

CLUID HOUSING

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DRAINAGE DESIGN REPORT

SUDS STRATEGY

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C					
D					

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1 INTRODUCTION

1.1 Purpose of This Report

This study is a continuation of Drainage Design Report issued November 2023. It focusses further on the application of SuDS (Sustainable Urban Drainage Systems) element, and how this could be incorporated with the storm drainage proposal. The above study acts also as a recommendation provided by Kildare City Council, following their internal feedback. The recommendation in this report assumed determination of extended SuDS strategy, demonstrating considered options, as well as providing further rationale as of why some options have been ruled out.

1.2 Site Information

Nicholas O'Dwyer Consulting Engineers, acting on behalf of Cluid Housing Agency, providing civil \ structural engineering services for a proposed new build of an older person social housing scheme at the 0.491 hectare's site is located at a former ESB site off Main Street, Leixlip, Co Kildare.

Figure 1 Site Location Plan

2 DESIGN CONSIDERATIONS

2.1 Infiltration Rates

Infiltration rate is the velocity at which water disperses into the ground. It is usually measured in m/s.

The infiltration rates depend on the type of soil encountered on site. Table 1 below shows a description typical infiltration value.

Typical infiltration coefficients based on soil texture (after Bettess, 1996)		
Soil type/texture	**ISO 14688-1 description (after Blake, 2010)**	**Typical infiltration coefficients (m/s)**
Good infiltration media		
• gravel	Sandy GRAVEL	$3 \times 10^{-4} - 3 \times 10^{-2}$
• sand	Slightly silty slightly clayey SAND	$1 \times 10^{-5} - 5 \times 10^{-5}$
• loamy sand	Silty slightly clayey SAND	$1 \times 10^{-4} - 3 \times 10^{-5}$
• sandy loam	Silty clayey SAND	$1 \times 10^{-7} - 1 \times 10^{-5}$
Poor infiltration media		
• loam	Very silty clayey SAND	$1 \times 10^{-7} - 5 \times 10^{-6}$
• silt loam	Very sandy clayey SILT	$1 \times 10^{-7} - 1 \times 10^{-5}$
• chalk (structureless)	N/A	$3 \times 10^{-8} - 3 \times 10^{-6}$
• sandy clay loam	Very clayey silty SAND	$3 \times 10^{-10} - 3 \times 10^{-7}$
Very poor infiltration media	–	
• silty clay loam	–	$1 \times 10^{-8} - 1 \times 10^{-6}$
• clay	Can be any texture of soil	$< 3 \times 10^{-8}$
• till	described above	$3 \times 10^{-9} - 3 \times 10^{-6}$
Other		
• rock* (note mass infiltration capacity will depend on the type of rock and the extent and nature of discontinuities and any infill)	N/A	$3 \times 10^{-9} - 3 \times 10^{-5}$

Table 1 Infiltration coefficients

The lowest percolation rate at which a soakaway is still efficient is 1 x10^{-6} m/s.

Conservative estimates of infiltration rates were deduced for storm water drainage which are elaborated wider in this paper later. Conservative calculations have been assumed for this site due to a lack of percolation test records highlighted in the Site Investigation Record (SI records now received and available upon request).

Moreover, the infiltration rate derived from the formula below, is established as f = 1.67x10^{-5} m/sec:

$$\text{Soil infiltration rate, } f = \frac{V_{p75-25}}{a_{p50} \times t_{p75-25}}$$

V_{p75-25} = the effective storage volume of water in the trial pit between 75% and 25% effective depth

a_{p50} = the internal surface area of the trial pit up to 50% effective depth and including the base area

t_{p75-25} = the time for the water level to fall from 75% to 25% effective depth.

Figure 2 Soil Infiltration Rate Formula (Sourced: *Soakaway Design; BRE Digest 365*)

This value (f) was widely used in this assessment.

2.2 Pavement CBR

Following Site Investigation assessment study, very consistent or firm ground has been detected.

CBR (California Bearing Ratio), defining the soil strata conditions, is used to establish suitable pavement type and their required thickness. In this case pavement determination and SuDS provision for the proposed site are corelated.

And so, CBR was determined at natural moisture content in the laboratory measuring values CBR17% to CBR 24% at depths 0.10m bgl and 0.45m bgl in the SILT deposits. Hence pavement base, and foundations would be approx. 0.5m in depth. Subject to detail design to what materials will be used.

Table 2 below – delineates typical values for soil permeability and CBR values.

Soil Classification	Typical Range for Coefficient of Permeability K (m/s)	Typical Range of California Bearing Ratio (CBR) Values
Heavy Clay	10^{-10} to 10^{-8}	2 to 5
Silty Clay	10^{-9} to 10^{-8}	3 to 6
Sandy Clay	10^{-9} to 10^{-6}	5 to 20
Poorly Graded Sand	$5x10^{-7}$ to $5x10^{-6}$	10 to 40
Well Graded sand	$5x10^{-6}$ to 10^{-4}	10 to 40
Well Graded Sandy Gravel	10^{-5} to 10^{-3}	30 to 80

Table 2 Hydrosmart Permeable Clay Paving System by Blockleys Bricks Ltd, August 2008

2.3 Rainfall Data

For the purpose of this paper, the following Rainfall Return Period data (table – see below Figure 3) was used to perform detailed analysis.

Met Eireann
Return Period Rainfall Depths for sliding Durations
Irish Grid: Easting: 300852, Northing: 236011,

DURATION	Interval 6months,	1year,	Years 2,	3,	4,	5,	10,	20,	30,	50,	75,	100,	150,	200,	250,	500,
5 mins	2.3,	3.4,	4.0,	4.9,	5.6,	6.1,	7.7,	9.7,	11.0,	12.9,	14.5,	15.9,	17.9,	19.5,	20.9,	N/A ,
10 mins	3.2,	4.8,	5.6,	6.9,	7.8,	8.5,	10.8,	13.5,	15.3,	17.9,	20.3,	22.1,	25.0,	27.2,	29.1,	N/A ,
15 mins	3.8,	5.6,	6.6,	8.1,	9.1,	10.0,	12.7,	15.9,	18.0,	21.1,	23.8,	26.0,	29.4,	32.0,	34.3,	N/A ,
30 mins	5.0,	7.3,	8.5,	10.4,	11.7,	12.7,	16.1,	20.0,	22.6,	26.2,	29.6,	32.1,	36.2,	39.3,	42.0,	N/A ,
1 hours	6.6,	9.5,	11.1,	13.4,	15.0,	16.3,	20.4,	25.1,	28.2,	32.7,	36.7,	39.7,	44.5,	48.3,	51.4,	N/A ,
2 hours	8.8,	12.4,	14.3,	17.3,	19.3,	20.8,	25.9,	31.6,	35.4,	40.7,	45.5,	49.1,	54.8,	59.2,	62.9,	N/A ,
3 hours	10.3,	14.5,	16.7,	20.0,	22.3,	24.0,	29.7,	36.1,	40.3,	46.3,	51.6,	55.6,	61.9,	66.8,	70.8,	N/A ,
4 hours	11.6,	16.2,	18.6,	22.2,	24.7,	26.6,	32.8,	39.7,	44.3,	50.7,	56.4,	60.8,	67.5,	72.7,	77.0,	N/A ,
6 hours	13.7,	18.9,	21.7,	25.8,	28.6,	30.7,	37.6,	45.4,	50.5,	57.6,	63.9,	68.8,	76.2,	82.0,	86.7,	N/A ,
9 hours	16.1,	22.1,	25.2,	29.9,	33.0,	35.4,	43.2,	51.9,	57.6,	65.5,	72.5,	77.9,	86.1,	92.4,	97.6,	N/A ,
12 hours	18.1,	24.6,	28.1,	33.2,	36.6,	39.2,	47.7,	57.1,	63.3,	71.8,	79.3,	85.0,	93.8,	100.6,	106.2,	N/A ,
18 hours	21.3,	28.8,	32.7,	38.5,	42.3,	45.3,	54.8,	65.3,	72.1,	81.6,	89.9,	96.3,	106.0,	113.4,	119.6,	N/A ,
24 hours	23.9,	32.1,	36.4,	42.8,	46.9,	50.2,	60.5,	71.8,	79.2,	89.4,	98.3,	105.1,	115.5,	123.5,	130.1,	152.7,
2 days	30.0,	39.3,	44.0,	50.9,	55.4,	58.9,	69.8,	81.7,	89.2,	99.6,	108.6,	115.4,	125.8,	133.6,	140.1,	162.0,
3 days	34.9,	45.1,	50.2,	57.5,	62.3,	66.0,	77.4,	89.7,	97.6,	108.2,	117.4,	124.3,	134.8,	142.7,	149.2,	171.1,
4 days	39.3,	50.1,	55.5,	63.3,	68.3,	72.1,	84.1,	96.8,	104.9,	115.8,	125.2,	132.2,	142.8,	150.9,	157.4,	179.5,
6 days	46.9,	58.9,	64.9,	73.3,	78.8,	82.9,	95.6,	109.1,	117.6,	129.0,	138.7,	146.0,	157.0,	165.2,	171.9,	194.3,
8 days	53.7,	66.7,	73.1,	82.1,	87.9,	92.2,	105.7,	119.8,	128.6,	140.5,	150.5,	158.1,	169.3,	177.7,	184.5,	207.4,
10 days	59.9,	73.8,	80.5,	90.1,	96.1,	100.7,	114.8,	129.5,	138.6,	150.8,	161.2,	168.9,	180.4,	189.0,	196.0,	219.2,
12 days	65.8,	80.4,	87.5,	97.5,	103.8,	108.6,	123.2,	138.4,	147.8,	160.4,	171.0,	178.9,	190.7,	199.5,	206.6,	230.2,
16 days	76.6,	92.6,	100.3,	111.1,	117.9,	123.0,	138.6,	154.7,	164.6,	177.8,	188.9,	197.1,	209.4,	218.5,	225.8,	250.1,
20 days	86.7,	103.9,	112.1,	123.6,	130.8,	136.2,	152.6,	169.4,	179.8,	193.5,	205.0,	213.6,	226.2,	235.6,	243.1,	268.0,
25 days	98.5,	117.0,	125.8,	138.0,	145.7,	151.4,	168.7,	186.5,	197.3,	211.6,	223.6,	232.4,	245.5,	255.2,	262.9,	288.5,

NOTES:
N/A Data not available
These values are derived from a Depth Duration Frequency (DDF) Model
For details refer to:
'Fitzgerald D. L. (2007), Estimates of Point Rainfall Frequencies, Technical Note No. 61, Met Eireann, Dublin',
Available for download at www.met.ie/climate/dataproducts/Estimation-of-Point-Rainfall-Frequencies_TN61.pdf

Figure 3 Rainfall Data (sourced Met Eireann; *www.met.ie*)

3 CHALLENGES

Given challenges, highlighted below, and potential opportunities will be factored in to establish best available solution.

3.1 Groundwater level

Existing groundwater level will play a crucial role in determination of SuDS measures within the site extents. It will help determining whether assessed SuDS measures are feasible.

Extensive study - Site Investigation data (undertaken July 2023 and published November 2023) has been determined and can brought into this paper for reference.

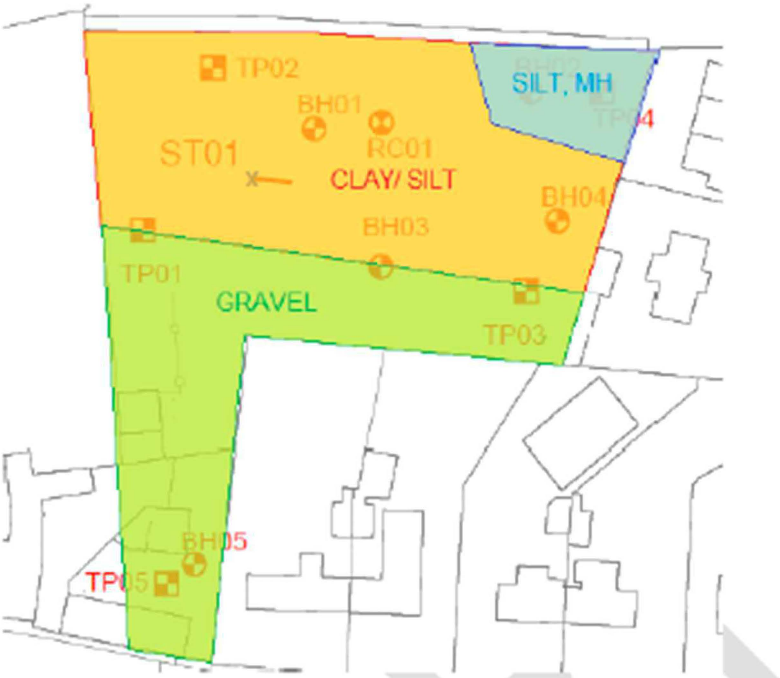

Figure 4 Site Location Map with excavation ground sampling (Sourced: Leixlip Housing Development, Site Investigation, Factual Report, November 2023)

Significant groundwater was encountered within the extent of the boreholes and trial pit excavations 1.1m bgl to 2.5m bgl.

Location	Ground level, mOD Malin	Groundwater strike		Remarks
		m bgl	mOD Malin	
TP1	26.45	1.5	24.95	Fast flow rate 1.5m.
TP2	27.98	-	-	None encountered.
TP3	26.25	1.1	25.15	Fast rate of flow 1.1m.
TP4	27.79	2.5	25.29	Steady flow rate. 2.5m
TP5	26.45	1.5	24.95	Fast flow rate 1.5m.
TP5x	26.46	-	-	None encountered.

Figure 5 Water Table Levels (Sourced: Leixlip Housing Development, Site Investigation, Factual Report, November 2023)

Groundwater table levels are discovered to be relatively high.

The following locations of TP01 and TP05 (see Figure 4 above) found groundwater strikes established at 1.5m bgl (see Figure 5). Both trial pits are in close proximity to each other. This location could also be promising to allocate suitable SuDS element.
TP02 – no groundwater table was detected, with the trial pit excavated 3.7m deep. The above information will be brought to our attention later to inform appropriate assessment.
TP03 and its vicinity confirm a groundwater strike unfavourably at 1.1m bgl, which makes it difficult to promote SuDS measure in this area.

3.2 Soil Permeability

For soil permeability information, please refer to '*Infiltration Rates*' Section 2.1 of this paper.

3.3 Overland Catchment Area (Captains Hill land to north)

Additional drainage provision through the proposed development for pre-existing overland surface water from Captain Hills to the north will be considered. This additional flow hasn't been factored in initial Drainage Design Report issued in November 2023. Kildare County Council Municipal District Engineering Office (KCC MD) is of the opinion that an impermeable retaining structure along the northern boundary will be required. On the assumption that there are no hard surfaces/roads contributing to surface water on this green area, only precipitation that falls on the area will be considered. Essentially stating that additional flow generated from this area will be minimal.

We followed an alternative approach and connected directly into the proposed stormwater network. Factoring in this additional flow into our proposal, our design has been re-calculated. This way we didn't have to introduce additional branches linking north of the site with existing Sewerage network at Mills Lane.

4 SUDS FORMS AND SUITABILITY

Runoff can be managed at or near its source by variety of means including rooftop ponding, green roofs, storage connected to downpipes and paved area ponding or other forms of paved area SuDS measures. In order to improve SuDS capabilities, the following systems will be considered. Each system will have various application, in which will be assessed in greater detail.

Each drainage systems will be determined whether it is suitable for adoption or consideration. In this chapter we will be focusing on devices which could be suitable for our site. They are introduced below.

4.1 Inlet Control

4.1.1 Green Roofs

A green roof is a planted area that has a significant storage potential, encourages evapo-transpiration and provides the added benefit of water quality improvement as stormwater travel through the soil.

This device will be looked closed and assessed in greater detail in this paper. This is already incorporated in the proposal by the appointed Architect (PLUS Architecture).

4.1.2 Storage connected to Downpipes

An alternative to detaining water on the roof structure itself is to store it at the foot of the downpipe in localised storage, either above or below ground. Small volumes (a water butt will have a capacity of about 350 l) used in large numbers, can have effects comparable with rooftop ponding.

A water butt is fundamentally a means of harvesting rainwater for garden use, but to be effective in providing attenuation for stormwater management it must allow some overflow to the drainage system so there is some capacity for the next rainfall. Storage connected to downpipes can also form part of a rainwater harvesting system for domestic use, typically for toilet flushing.

An alternative to providing storage at the base of the downpipe is to discharge runoff away from the building and over stable pervious areas (such as lawns, swales, porous pavements) rather than directly to the pipe system. In our case rainwater harvesting system will be incorporated into our system, it will connect into porous attenuation storage system, which will be allocated within access road \ car parks area. This in greater detail will be elaborated in 'Stormwater Network Proposal (Leixlip) – Working Example & Summary', Section 7 below.

4.2 Infiltration Devices

4.2.1 Soakaway

The two most common infiltration devices are soakaways and infiltration trenches. A soakaway is an underground structure which can be stone filled, formed with plastic mesh boxes, dry wall lined, or built with precast concrete ring units.

Below is an example of Soakaway storm water manhole – see Figure 6:

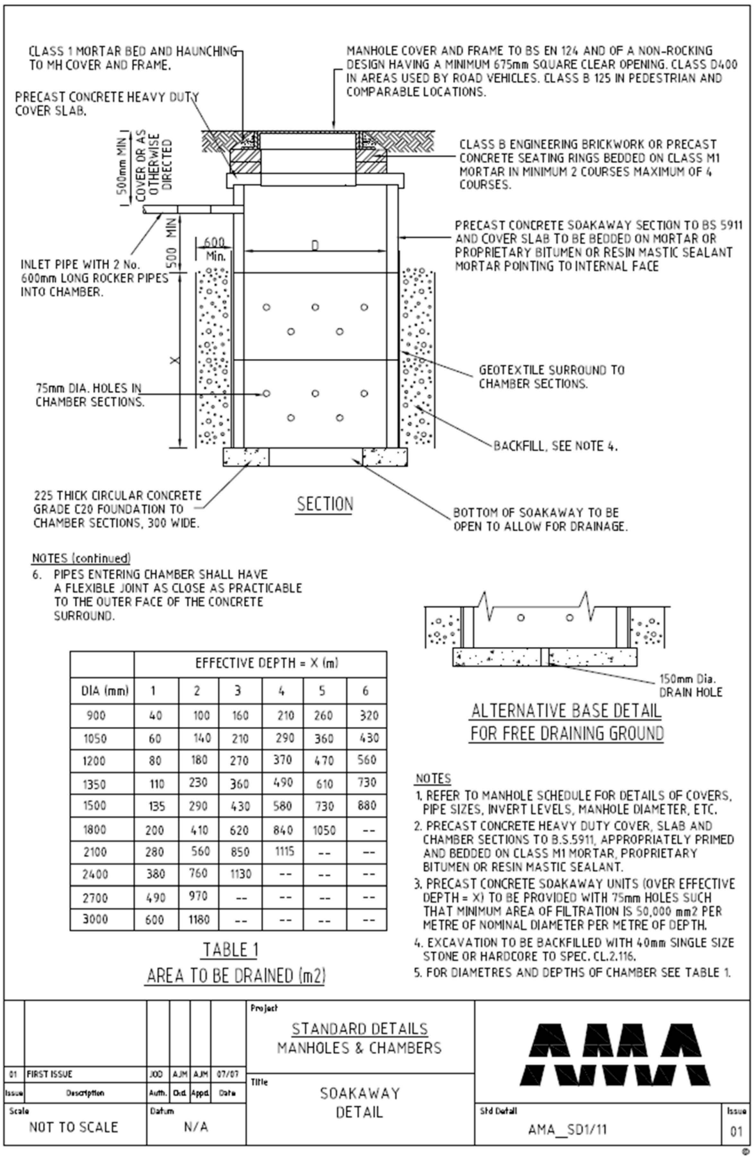

Figure 6 Soakaway Manhole storm system detail

In this example – Figure 6, X (m) delineates or refer to effective depth, which in our case, would be already submerged in the water, hence would not be efficient solution.

4.2.2 Infiltration Trench

An infiltration trench is a linear excavation lined with fabric, backfilled with stone and possibly covered with grass. Runoff is diverted to the soakaway or trench and either infiltrates into the soil or evaporates.

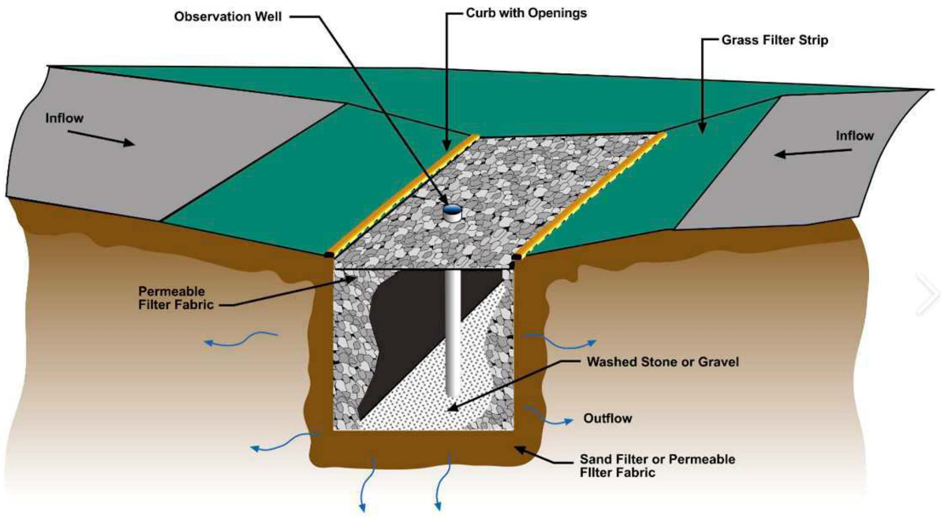

Figure 7 Infiltration Trench

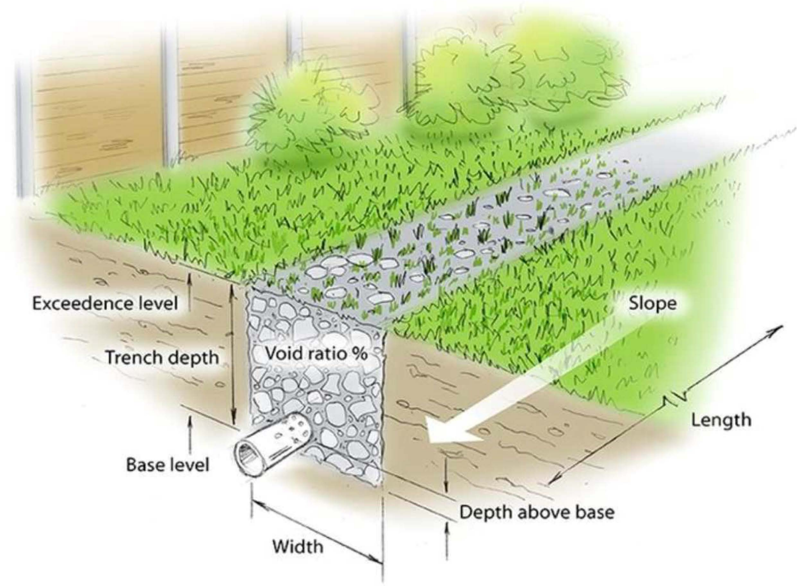

Figure 8 Infiltration Trench Alternative

Soakaways and trenches can be used in any area that has pervious subsoils such as gravel, sand, chalk and fissured rock. However, trenches installed on land gradients greater than 4% need 'flow checks' at regular intervals.

4.2.3 Filter Drains (Linear Drainage)

Filter drains are linear devices consisting of perforated or porous pipe in a trench of filter material. They have been traditionally constructed beside roads to intercept and convey runoff, but they can be used simply as a conveyance device. They may or may not allow infiltration to the ground, in the same way as pervious pavements.

Filter drains are considered to the north of the scheme proposal, will cover an area highlighted in Section 3.3 of the above report.

4.3 Vegetated Surfaces

4.3.1 Swales and Filter Strips

The main types of vegetated surfaces used in stormwater management are filter strips and grassed swales.

Swales are grassed-lined channels used for the conveyance, storage, infiltration and treatment of stormwater. Runoff enters directly from adjoining buildings or other impermeable surfaces. The runoff is stored either until infiltration takes place, or until filtered runoff is conveyed elsewhere, to the sewer system, for example.

Filter strips, also known as 'vegetative buffer strips' are gently sloping areas of ground designed to promote sheet flow of stormwater runoff.

To function well, swales require shallow slopes (<5%) and soils that drain well. Typically, they have side slopes of no greater than 1 in 3 allowing them to be easily maintained by grass cutting machinery. The bottom width is usually between 0.5m and 2m, they are 0.25-2m deep and can be readily incorporated into landscape features. Filter strips should allow a minimum flow distance of about 6m. Swales and strips delay stormwater runoff peaks and provide a reduction in runoff volume due to infiltration and evapo-transpiration. Typical velocities should be below 0.3m/s to encourage settlement.

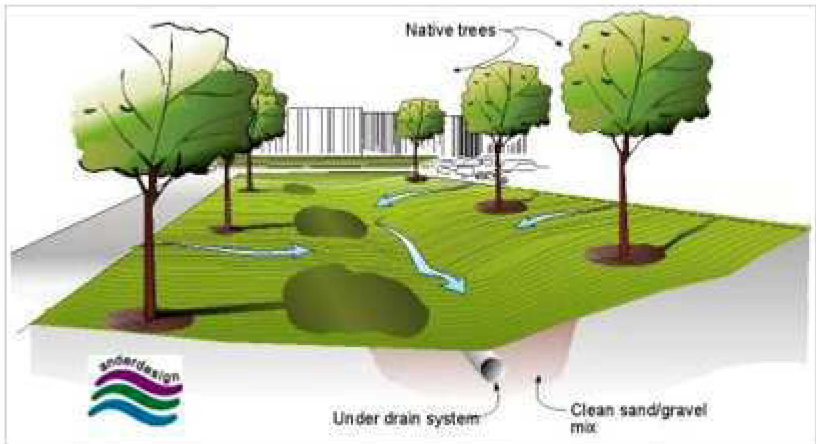

Figure 9 Swales - Permeable Conveyance Systems (courtesy of SuDS Wales; www.sudswales.com)

They are often used as a pre-treatment in combination with other control measures. Pollutants are removed by sedimentation, filtration through grass and adsorption onto it and infiltration into the soil.

4.3.2 Bioretention Areas & Rain Gardens

Bioretention areas (also referred to as bioretention cells or rain gardens) use soil, plants and microbes to treat stormwater before it is infiltrated or discharged. Bioretention areas are shallow depressions filled with sandy soil, topped with a thick layer of mulch, and planted with dense vegetation.

Stormwater runoff flows into the bioretention area, percolates through the soil (which acts as a filter) and eventually drains into the groundwater; some of the water is also absorbed by the plants. Bioretention areas are usually designed to allow ponded water and with an overflow outlet to prevent flooding during larger storm events (see Figure 11). Where soils have low permeability or where faster drainage is desired, designers may incorporate a perforated underdrain that routes to a storm drain system.

Figure 10 Rain garden (courtesy of Massachusetts Stormwater Management Standards megamanual.geosyntec.com)

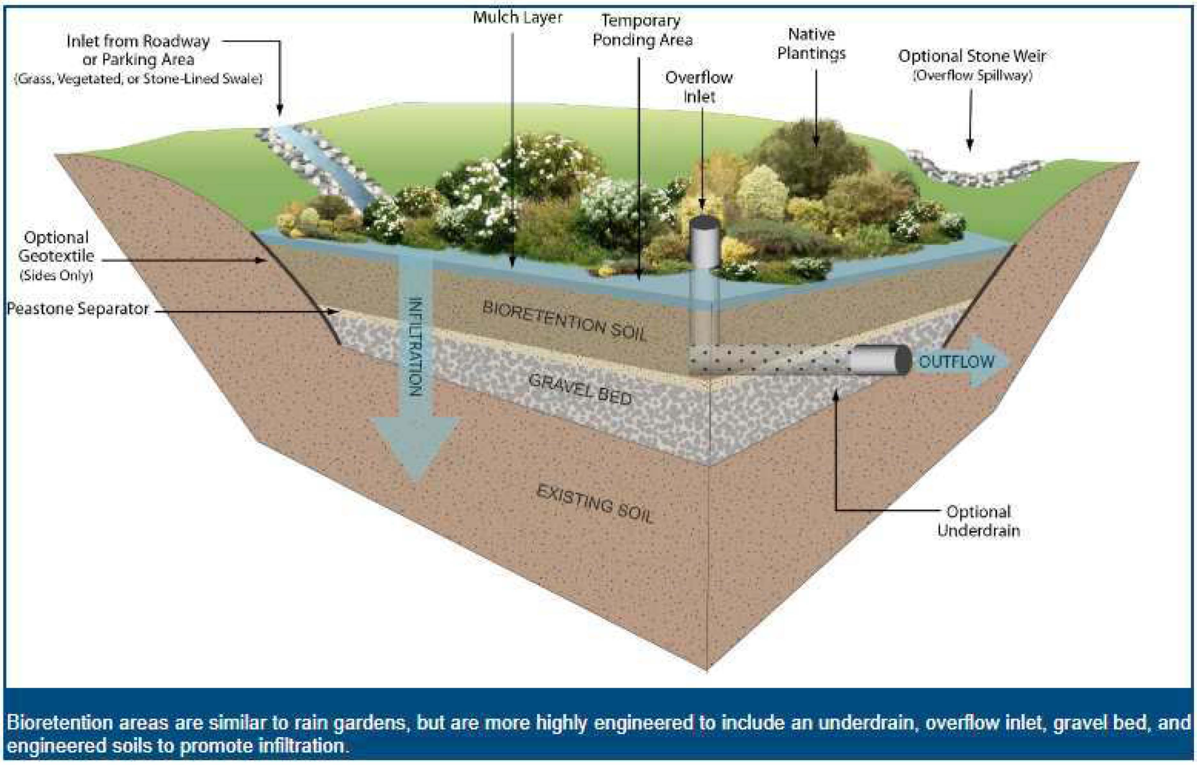

Figure 11 Bioretention area (courtesy of Massachusetts Stormwater Management Standards megamanual.geosyntec.com)

Bioretention areas can provide excellent pollutant removal and recharge for the "first flush" of stormwater runoff. Properly designed bioretention areas will remove suspended solids, metals, and nutrients. Distributed around a property, bioretention areas can enhance site aesthetics. In residential developments they are often marketed as property amenities. Routine maintenance is simple and can be handled by homeowners or conventional landscaping companies, with proper direction.

4.3.2.1 Application and Design Principles

Bioretention areas are suitable in a wide range of climatic and geologic situations. Common applications for bioretention areas include parking lot islands, median strips, and traffic islands. Bioretention is often a feasible "retrofit" that can be accomplished by replacing existing parking lot islands or by re-configuring a parking lot during resurfacing. On residential sites bioretention areas are commonly used for rooftop and driveway runoff.

4.3.3 Tree Pit SuDS system

The tree pit system operates on principles similar to those of bioretention areas and standard rain garden solutions. It can be designed as a 'classic' rain garden to capture and absorb water, or it can be a more comprehensive bioretention system. Highly engineered to include features such as an underdrain, an overflow inlet, a gravel bed, and specialized soil to enhance filtration (see Figure 12).

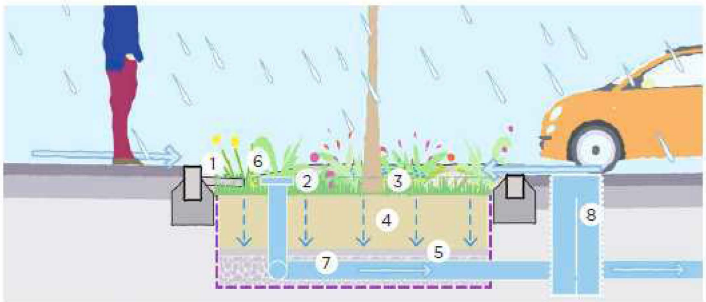

Figure 12 Tree pit (Bioretention area model)

4.4 Pavements

4.4.1 Pervious Pavements

Pervious Pavements are used mostly for car parks and can also be used for other surfaces where there is no traffic or very light traffic.

In terms of pavement structure, there are several alternatives for the surface layer – as listed below:

- Variety of types of block paving;
- Porous asphalt

Stormcell Storage System is a form of impervious pavement but, in this instance, can also adopted as pervious pavement. It can be allocated within any hardstanding. Potential application of such system, along with pervious system is currently considered and adopted at our site – north west car park area provision.

4.4.1.1 Stormcell Storage System

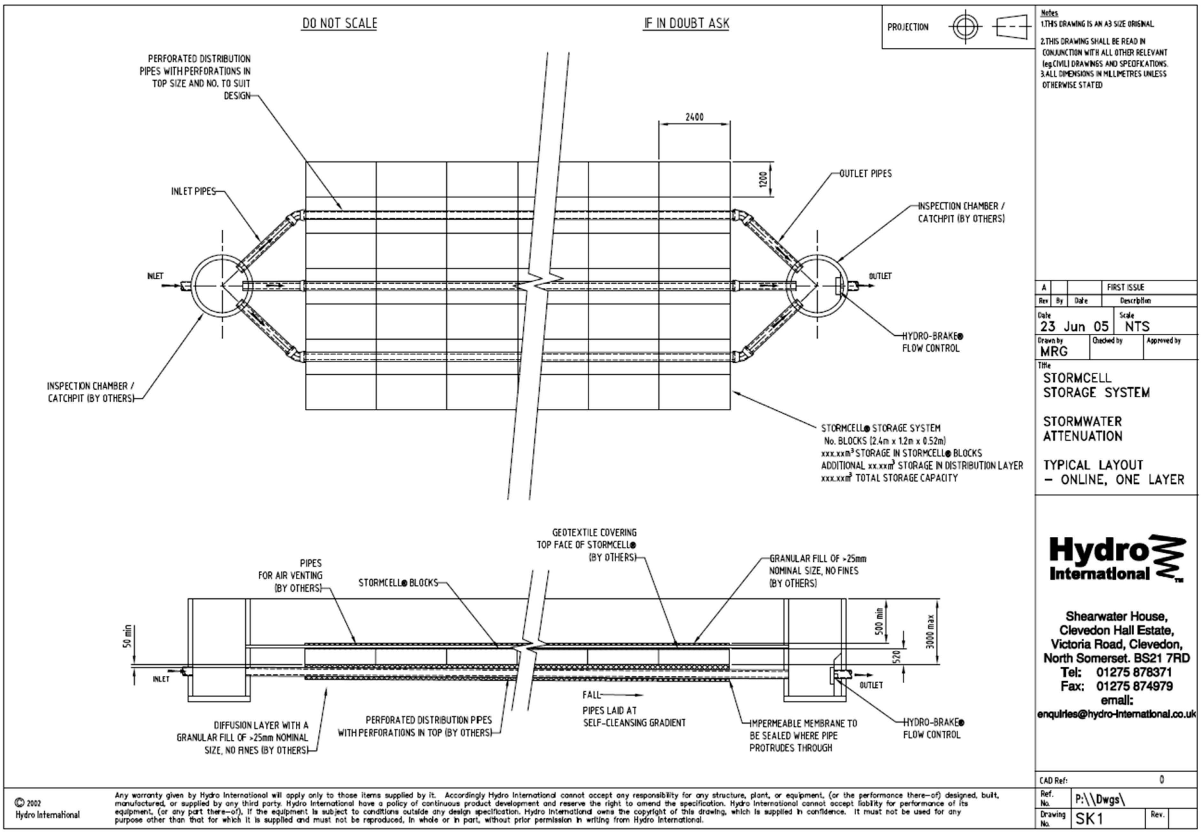

Figure 13 Stormcell Storage System (Stormwater Attenuation; courtesy of Hydro International)

The benefit of Stormcell Storage System, illustrated in Figure 13 above, is that it allows further infiltration into the ground. Following information issued by the manufacturer, Stormcell blocks offer up to 95% free void capacity. Each stormcell block is 520mm in heigh, can be stacked up to increase capacity of attenuation network (Figure 14 below). System can also be adopted beneath pavement condition subjected to vehicle loadings, such as access routes, carparks etc.

This offering will be analysed closer in this report (Stormwater Network Proposal (Leixlip) – Working Example & Summary, Section 7).

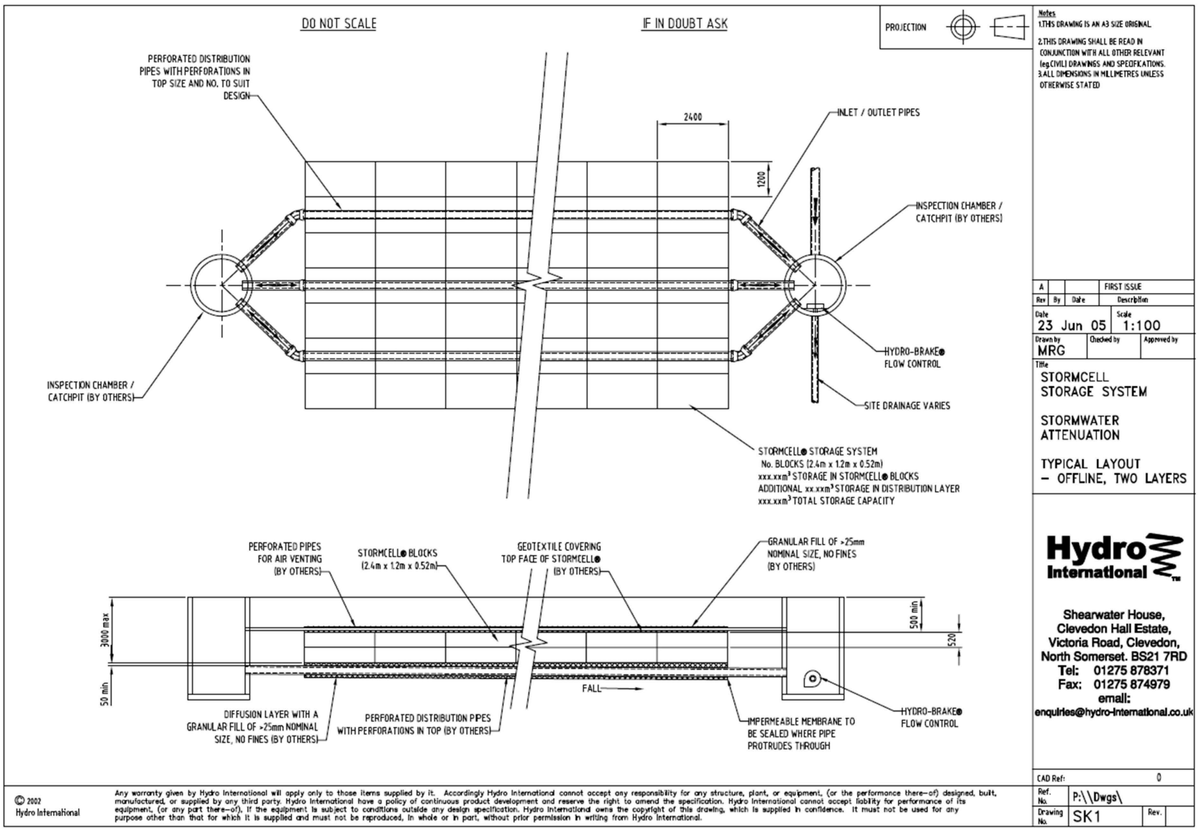

Figure 14 Stormcell Storage System (Stormwater Attenuation) - Offline, Two Layers

4.4.2 Impervious Pavements

Similarly, to previous paragraph, Stormcell Storage System (Figure 13 and Figure 14) can be adopted in conjunction with impervious pavement systems. This standard solution assumes utilisation of Stormcell Storage Attenuation System in conjunction with standard storm water '*kerb and gully system*'. Current access track proposal assumes use of both impervious black top surfacing, along with Stormcell Storage Attenuation System (two storage tanks allocated in the middle and south access track).

4.5 Limitations

Every system has its limitations. For example soakaways or infiltration trenches should not be located within 5m of the foundations or buildings.

The majority of systems highlighted within 'SuDS forms and Suitability' Section 4 of this report, are only suitable in areas where the groundwater table is low enough to allow free flow from stormwater into a subsoil at all times of the year. The base of the soakaway or trench should therefore be at least 1m above the groundwater level. Areas with no natural watercourses usually have suitable subsoils.

There was an issue with incorporation of Rainwater Harvesting system in form of water Butts mentioned in Section 4.1.2. This system is not suitable for inclusion in our scheme since rainwater down pipes are located inside the building, rather than outside at front or back building façade. Therefore, there is no space to allocate them accordingly.

4.6 Other Devices (ruled out)

4.6.1 Rooftop Ponding

Stormwater can be retained on a flat roof, thus exploiting their storage potential by using flow restrictions on the roof drains. This will induce an additional live load to be taken into account in the structural design and increase watertightness of roofing materials.

Unfortunately, flow restrictions can become blocked, leading either to overtopping or prolonged ponding.

Roof storage has little or no direct positive effect in reducing pollutant concentration.
This is seen as a positive idea but unfortunately it is not practical. This offering has been included in this report for consideration only.

4.6.2 Infiltration Basins

Infiltration basins are depressions with vegetative cover that store runoff for infiltration into the ground. They are used where there is a sufficient capacity for infiltration and where infiltration is appropriate. The bottom of the basin is flat to provide uniform infiltration. The side slopes should be no steeper than 1 in 4. They are generally used for relatively small catchments.

This system also has been ruled out on the assumption that there is a space limitation within our site to implement it. High groundwater table creates another obstruction, causing this system deemed ineffective (front garden square is the only locations where this system can be considered). Another obstacle is within slopes and depressions – not suitable for our site.

4.6.3 Detention Basins

Detention basins provide storage for stormwater with a controlled outfall to the next stage of the stormwater management or to a watercourse. They are effectively a storage facility formed out of the landscape. They are not intended to encourage infiltration to the ground and may be lined if infiltration is to be prevented completely. After a controlled outflow has taken place, the basin is commonly left dry till the next rainfall.

This is discouraged for inclusion in our scheme due to space requirements, while additionally it has the potential to be kept filled with water. This is not practical at residential locations.

4.6.4 Ponds

Ponds provide storage and treatment for stormwater within a permanent volume of water. They have aesthetic, recreational value (e.g. sailing, fishing) and environmental benefits such as returning wildlife habitats into urban areas, in addition to their flood control function. The depth of the pool is usually limited to 1.5-3.0m to avoid thermal stratification.

Similarly, to detention basins, ponds may not be a practical solution due to the confined area and residential setting.

4.6.5 Wetlands

Constructed or artificial wetlands (including reed beds, reed marshes and vegetative systems) are shallow areas or excavated land filled with earth, rock or gravel, saturated with water or covered by shallow flowing water at some time during the growing season, and planted with selected aquatic plants. The key role of plants is to transmit oxygen from the atmosphere to the root system (thus the soil) and to encourage microbial growth.

Wetlands require relatively large areas of flat areas of flat to gently sloping (less than about 5%) land. Wetlands due to their nature, won't be a suitable solution for this residential environment.

5 SUDS APPLICATION

The SUDS Manual provides guidance on how SUDS devices should be used in combination, and how they should be selected for a particular application. The use of SuDS devices in combination is an important theme in the guidance, and the result is termed a '*management train*', also referred to as '*treatment train*'. The recommended sequence of possibilities, with devices appropriate for each stage, is given in Fig. 15 & 16 below. It is preferable to find a drainage solution as close to the top of this diagram as possible, but if all drainage needs cannot be achieved at a particular stage, the designer must move further down the list. This is the way how we approach and tailor SuDS needs for our residential site.

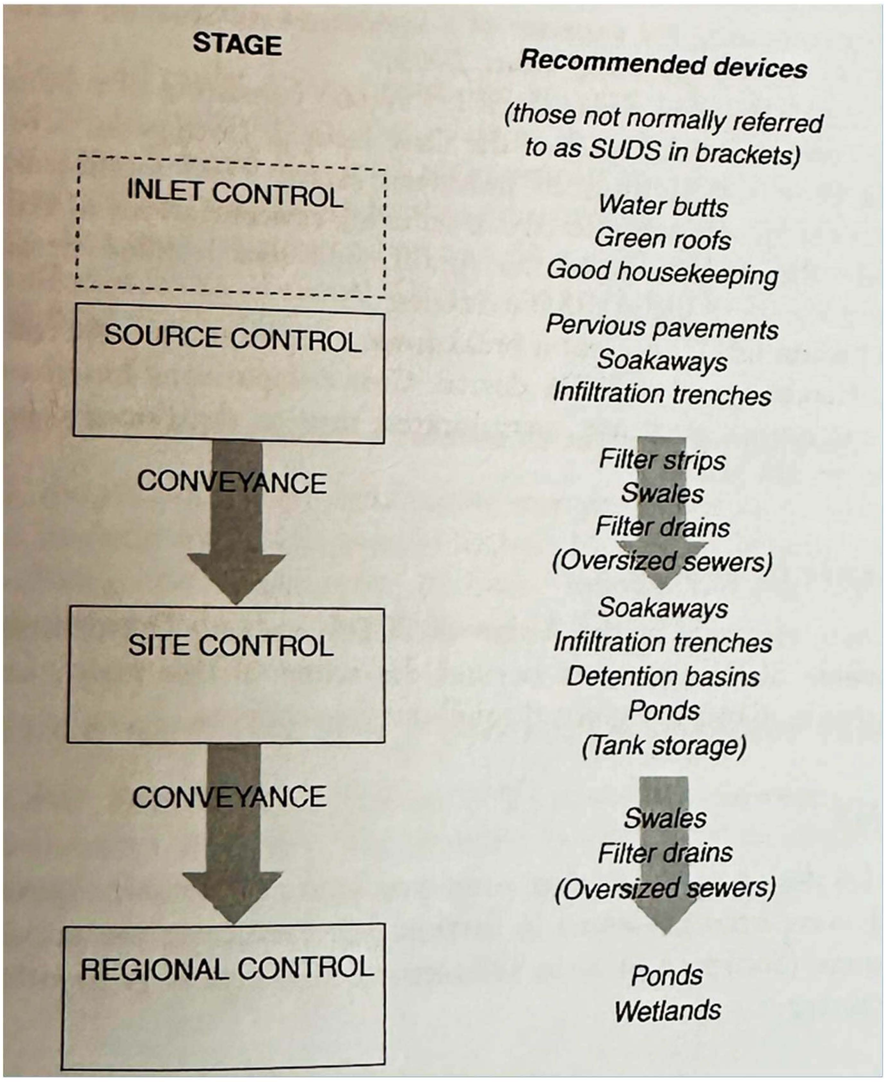

Figure 15 SuDS Management Train

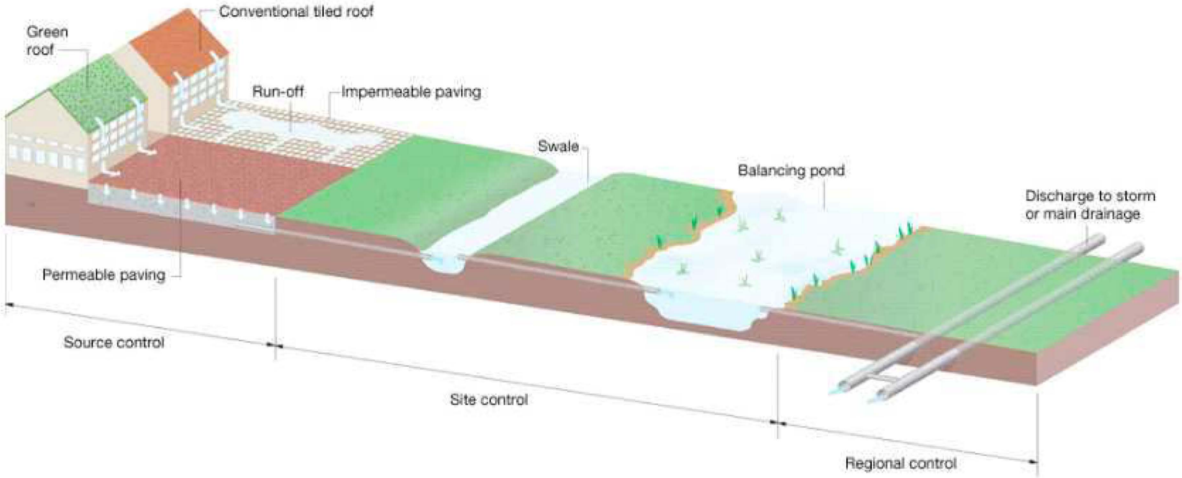

Figure 16 SuDS Management Train (variation no. 2)

6 SUDS MAINTENANCE REGIME

The SuDS Manual recommends that owners of developments with SuDS should be provided with an owner's manual, and gives details of what it should contain. Model agreements for SuDS – legal documents that can be used as the basis of arrangements for maintenance – have been published in CIRIA (Shaffer et al., 2004).

Many SuDS devices promote sedimentation, and therefore sediment removal can be an important element in maintenance. Sediment removal operations and subsequent disposal of waste are considered in The SuDS Manual (Woods-Ballard et al., 2007a).

The cost of SuDS schemes is generally considered to be comparable to the cost of conventional piped drainage. Relative cost is not generally identified as an over-riding advantage or disadvantage of SuDS. Operation and maintenance costs must be taken into account in addition to construction costs. The SuDS Manual recommends and presents a whole life cost approach, and provides some typical costs.

7 STORMWATER NETWORK PROPOSAL (LEIXLIP) – WORKING EXAMPLE & SUMMARY

An initial design was introduced in November 2023, incorporating impermeable attenuation storage system located in the main Public Open Space, outside the entrance to residential housing.

Following consultation with Kildare County Council Drainage Department and the Design Team's Landscape Architect, we were encouraged to further develop our stormwater drainage proposal with further inclusion of SuDS elements.

Multiple options were considered and are detailed in the 'SuDS Forms and Suitability' Section 4 of this report. Each device has been evaluated accordingly, assessed as to whether it could be implemented. Unfavourable options were also listed.

Following feedback from the Client and KCC MD, it was also encouraged that additional flow generated from a land to the north could have been connected into the existing stormwater network along Mills Lane. Consent from the Council was granted for this proposal. Our proposal allows for a connection of this additional flow into our stormwater network. For more information please also refer to 'Overland Catchment Area (Captains Hill land to north)' Section 3.3 of the above report.

The previous drainage assessment carried out, forming part of Drainage Design Report, was undertaken using excel spreadsheets. For the purpose of this report, we utilised computerised software Flow Causeway – providing improvements relating to simulations regime, providing more reliable assessment. Please refer to Appendix A for Design Output.

7.1 Revised Network Proposal

The new network proposal differs from the original Drainage Design. We no longer promote an impermeable attenuation storage tank. Nor do we provide storage within Public Open Space following Landscape Architects comments, pointing out that previous offering conflicted with growing trees or vegetation in this area. Instead of the above, we encourage utilisation of a pavement provision, equipped with underground permeable storage attenuation tanks. Permeable system will work on the assumption that the bottom of the proposed storage cells would be at least 0.5m above worst-case scenario groundwater table (for groundwater table depths and their respective location please refer to Figure 4 and 5). This allows for suitable infiltration further and therefore reduces the needs of storage capacity. Moreover, permeable pavement SuDS provision will be supported by green roofs provision. Optional rainwater harvesting system based on water butts being now discarded (see Section 4.5 for more information). Similar impermeable structures will require an additional circa 10-20% of storage volume (this has been determined on conservative soil infiltration rates). Pre-development discharge rates have not changed in comparison with original figures from the Drainage Design Report at 2.39 l/s (figure based on 1 in 100 years Return Period with 30% Climate Change factor). To maintain this level a flow control device is incorporated. Both the flow control device and petrol interceptor are located on the exit line flowing into the public network. For more network parameters \ assumptions, please refer to Appendix A – Surface Water Design Outputs.

Linear drainage in the form of filter drains will be positioned along the northern perimeter of the site, as indicated in Section 3.3 of this report. Filter drains as described in Section 4.2.3 joining MH on the west corner of a site. Filter drain at this location will be sufficient given the evidence of catchment area to the north with no history of flooding with subject to precipitation generated flow only.

Two forms of pavement being incorporated into our proposal – permeable and impermeable, both supported by permeable Stormcell Storage Attenuation System, as highlighted in Section 4.4. Permeable paving allowing for initial treatment and conveyance of storm water.

Additional SuDS measures have now been incorporated to enhance our current sustainable drainage offering, with the submission dated January 2024. These measures reflect the latest discussions with the client and the feedback received in August 2024. We have now allocated rain gardens, tree pits, and swales within the main Public Open Space, outside the entrance to residential housing. These enhancements optimize the drainage proposal model and reduce the required attenuation storage capacity for the scheme, taking into account soil characteristics, rainfall data, and other relevant factors. This adjustment is based on the provision of permeable SuDS. Previously estimated at 365 m^3, we have successfully reduced this requirement to approx. 320 m^3.

Other SuDS devices were also considered, such as Soakaways, infiltration basins, detention basins, ponds and wetland. Unfortunately, they were not deemed to be suitable for our site. Soakaways, for example to be efficient required deep manholes. This could have been achieved when groundwater levels are low. In our cases, this requirement was not met.

Basins, ponds and wetlands as mentioned in previous paragraphs although promoting sustainable solutions, require substantial amount of space. To accommodate these, area fenced off or positioned away from busy residential environment would be anticipated.

Regardless, we feel a sustainable improved solution for such a busy residential development has been provided.

8 REFERENCES

- BRE 1991 Soakaway design Digest 365, BRE, Garston
- CIRIA C697 The SUDS Manual, Section 10
- Woods-Ballard, B., Kellagher, R., Martin, P., Jefferies, C., Bray, R. and Shaffer, P. (2007b) Site Handbook for the Construction of SUDS, CIRIA C698
- Shaffer P, Elliott C, Reed J, Holmes J and Ward M (2004) Model agreements for sustainable water management systems. Model agreements for SUDS C625, CIRIA, London
- Greater Dublin Regional Code of Practice V6.0, Section 16.3

- Institute of Hydrology Report No. 124, Section 7.2, Eqn 7.1. CIRIA C697 The SUDS Manual, Table 4.2 states that the Institute of Hydrology Report No. 124 is to be used to determine QBAR.
- MET Eireann Annual Average Rainfall Grid
- MET Eireann Online Data - Rainfall Return Period Table
- An allowance of 30% has been included for climate change as per Table 6.2 of GDSDS Vol. 2

Appendix 1 – Design Outputs

Design Settings

Rainfall Methodology	FSR	Maximum Time of Concentration (mins)	30.00
Return Period (years)	5	Maximum Rainfall (mm/hr)	50.0
Additional Flow (%)	10	Minimum Velocity (m/s)	1.00
FSR Region	Scotland and Ireland	Connection Type	Level Soffits
M5-60 (mm)	16.300	Minimum Backdrop Height (m)	0.200
Ratio-R	0.277	Preferred Cover Depth (m)	1.200
CV	0.750	Include Intermediate Ground	✓
Time of Entry (mins)	5.00	Enforce best practice design rules	✓

Adoptable Manhole Type

Max Width (mm)	Diameter (mm)	Max Width (mm)	Diameter (mm)	Max Width (mm)	Diameter (mm)	Max Width (mm)	Diameter (mm)
374	1200	499	1350	749	1500	900	1800

>900 Link+900 mm

Max Depth (m)	Diameter (mm)	Max Depth (m)	Diameter (mm)
1.500	1050	99.999	1200

Circular Link Type

Shape	Circular	Barrels	1	Auto Increment (mm)	75	Follow Ground	x

Available Diameters (mm)

100	150

1:3 Swale (model 1) Link Type

Shape	Trapezoidal	Side Slope (1:X)	3.0	Steep Slope (1:X)	500	ks (mm) / n	0.030
Barrels	1	Auto Increment (mm)	10	Follow Ground	✓		
Width (mm)	1000	Preferred Cover (m)	0.010	Velocity	Manning		

Available Diameters (mm)

400

1:3 Swale (model 2) Link Type

Shape	Trapezoidal	Side Slope (1:X)	3.0	Steep Slope (1:X)	500	ks (mm) / n	0.030
Barrels	1	Auto Increment (mm)	10	Follow Ground	✓		
Width (mm)	1000	Preferred Cover (m)	0.010	Velocity	Manning		

Available Diameters (mm)

600

Nodes

Name	Area (ha)	T of E (mins)	Cover Level (m)	Diameter (mm)	Easting (m)	Northing (m)	Depth (m)
1	0.000	5.00	27.060	1200	700827.230	736071.421	1.000
2	0.045	5.00	26.980	1200	700808.370	736072.532	1.238
3	0.082	5.00	26.690	1200	700775.440	736073.734	1.485
4	0.031	5.00	26.690	1200	700774.876	736055.958	1.590
5	0.017	5.00	27.040	1200	700797.137	736055.184	2.220
6	0.012	5.00	26.700	1350	700796.859	736049.143	2.120
7	0.000	5.00	26.460	2000	700779.255	736048.421	1.950
8	0.064	5.00	26.650	1350	700782.905	736004.612	2.323
9	0.023	5.00	26.580	1350	700777.560	735976.015	2.374
OUTFALL MH			26.200	1350	700775.599	735966.229	2.056
Rainwater Garden 2	0.015	5.00	27.000		700822.119	736047.035	1.600
10	0.025	5.00	27.170	1200	700816.460	736054.498	1.300
17		5.00	26.500	1200	700770.057	736073.611	0.890
19	0.027	5.00	26.560	1200	700772.055	736034.639	1.273
Swale 1 (Entry)	0.005	5.00	26.700	1500	700784.155	736011.241	0.410
24	0.015	5.00	26.500	1200	700764.864	736073.833	0.900
25	0.040	5.00	26.550	1200	700767.999	736037.040	1.231
Swale 2 (Entry)	0.006	5.00	26.760	1500	700839.529	736035.189	0.410
12	0.011	5.00	26.500	1200	700773.906	735976.239	0.570
13	0.020	5.00	26.590	1200	700779.538	736004.819	0.984
14			26.450	1200	700776.979	736034.900	1.232
15			26.680	1200	700786.108	736043.204	1.674
16	0.071	5.00	26.700	1200	700796.601	736042.176	2.004
Rainwater Garden 1	0.006	5.00	26.660		700789.948	736025.901	1.110
20			26.630	1200	700834.938	736020.684	0.730
21	0.046	5.00	26.720	1500	700784.811	736025.370	1.328
11	0.005	5.00	26.700	1200	700799.401	736051.161	0.610
Swale 5 (Exit)			27.020	1200	700847.435	736059.835	1.300
23	0.026	5.00	26.780	1200	700840.915	736038.107	1.514
18	0.005	5.00	26.700	1200	700799.267	736044.305	0.610
26			26.580	1200	700790.026	736052.085	1.000
Swale 3 (Entry)	0.005	5.00	26.900	1500	700818.279	736042.257	0.610
27			26.650	1200	700780.515	735995.177	1.000
Swale 3 (Exit)			26.800	1500	700807.060	736043.325	0.533

Nodes

Name	Area (ha)	T of E (mins)	Cover Level (m)	Diameter (mm)	Easting (m)	Northing (m)	Depth (m)
Swale 4 (Entry)	0.003	5.00	27.000	1500	700824.911	736050.315	0.610
Swale MULTI (Exit)			26.700	1200	700799.815	736048.815	1.427
Swale 5 (Entry)	0.006	5.00	27.040	1500	700833.214	736071.223	0.410
Swale 5 (Mid)			27.040	1500	700849.386	736070.271	0.442

Links

Name	US Node	DS Node	Length (m)	ks (mm) / n	US IL (m)	DS IL (m)	Fall (m)	Slope (1:X)	Dia (mm)	T of C (mins)	Rain (mm/hr)
8.000	1	2	18.893	0.600	26.060	25.742	0.318	59.4	100	5.31	50.0
8.001	2	3	32.952	0.600	25.742	25.330	0.412	80.0	100	5.95	50.0
8.002	3	4	17.785	0.600	25.205	25.100	0.105	169.4	225	6.25	50.0
8.003	4	5	22.274	0.600	25.100	24.914	0.186	120.0	225	6.56	50.0
8.004	5	6	6.048	0.600	24.820	24.770	0.050	121.0	225	6.64	50.0
1.005	6	7	17.603	0.600	24.580	24.510	0.070	251.5	375	7.53	50.0
1.006	7	8	43.961	0.600	24.510	24.327	0.183	240.0	375	8.15	50.0
1.007	8	9	29.092	0.600	24.327	24.206	0.121	240.0	375	8.57	49.2
1.008	9	OUTFALL MH	9.981	0.600	24.206	24.144	0.062	160.0	375	8.69	48.9
Swale 1 (Link)	Swale 1 (Entry)	21	14.144	0.030	26.290	26.262	0.028	500.0	400	5.40	50.0
9.000	10	5	19.335	0.600	25.870	25.387	0.483	40.0	100	5.26	50.0
Swale 2 (Link)	Swale 2 (Entry)	20	15.214	0.030	26.350	26.320	0.030	500.0	400	5.43	50.0
5.000	12	13	29.130	0.600	25.930	25.606	0.324	90.0	100	5.60	50.0
5.001	13	14	30.190	0.600	25.606	25.271	0.335	90.0	100	6.22	50.0
5.002	14	15	12.341	0.600	25.218	25.081	0.137	90.1	150	6.41	50.0
2.003	15	16	10.543	0.600	25.006	24.889	0.117	90.0	225	7.04	50.0
1.004	16	6	6.971	0.600	24.696	24.655	0.041	170.0	300	7.27	50.0
Rainwater Gargen 1 (Link)	Rainwater Garden 1	21	5.164	0.600	25.550	25.442	0.108	47.8	100	5.08	50.0
7.000_1	17	19	39.023	0.600	25.610	25.331	0.279	140.0	100	6.00	50.0
6.002	19	14	4.891	0.600	25.287	25.218	0.069	70.9	150	6.18	50.0
Swale 3 (link)	Swale 3 (Entry)	Swale 3 (Exit)	11.270	0.030	26.290	26.267	0.023	500.0	600	5.25	50.0
6.000	20	21	50.346	0.600	25.900	25.442	0.458	109.9	100	6.57	50.0
6.001	21	15	17.881	0.600	25.392	25.254	0.138	129.6	150	6.91	50.0
7.000	Swale 5 (Exit)	23	22.685	0.600	25.720	25.266	0.454	50.0	100	6.11	50.0
1.003	23	16	44.500	0.600	25.266	24.895	0.371	120.0	100	7.17	50.0
6.000_1	24	25	36.926	0.600	25.600	25.369	0.231	160.0	100	6.02	50.0
6.001_1	25	19	4.714	0.600	25.319	25.287	0.032	147.3	150	6.11	50.0
Rainwater Garden 2 (link)	Rainwater Garden 2	Swale MULTI (Exit)	25.364	0.600	25.400	25.273	0.127	199.7	150	5.69	50.0
Swale 4 (Link)	Swale 4 (Entry)	Rainwater Garden 2	4.307	0.030	26.390	26.381	0.009	478.6	600	5.09	50.0

Name	Vel (m/s)	Cap (l/s)	Flow (l/s)	US Depth (m)	DS Depth (m)	Σ Area (ha)	Σ Add Inflow (l/s)	Pro Depth (mm)	Pro Velocity (m/s)
8.000	1.001	7.9	0.0	0.900	1.138	0.000	0.0	0	0.000
8.001	0.861	6.8	6.7	1.138	1.260	0.045	0.0	82	0.981
8.002	1.001	39.8	18.9	1.260	1.365	0.127	0.0	109	0.990
8.003	1.192	47.4	23.6	1.365	1.901	0.158	0.0	112	1.190
8.004	1.187	47.2	29.8	1.995	1.705	0.200	0.0	130	1.253
1.005	1.138	125.7	78.0	1.745	1.575	0.524	0.0	214	1.196
1.006	1.165	128.7	78.0	1.575	1.948	0.524	0.0	211	1.219
1.007	1.165	128.7	86.2	1.948	1.999	0.588	0.0	225	1.245
1.008	1.430	157.9	89.0	1.999	1.681	0.611	0.0	202	1.471
Swale 1 (Link)	0.590	519.6	0.7	0.010	0.058	0.005	0.0	11	0.070
9.000	1.223	9.6	3.7	1.200	1.553	0.025	0.0	43	1.147
Swale 2 (Link)	0.590	519.6	0.9	0.010	-0.090	0.006	0.0	11	0.073
5.000	0.811	6.4	1.6	0.470	0.884	0.011	0.0	35	0.681
5.001	0.811	6.4	4.6	0.884	1.079	0.031	0.0	63	0.883
5.002	1.059	18.7	16.8	1.082	1.449	0.113	0.0	112	1.196
2.003	1.379	54.8	26.2	1.449	1.586	0.176	0.0	109	1.363
1.004	1.203	85.0	41.6	1.704	1.745	0.279	0.0	148	1.196
Rainwater Gargen 1 (Link)	1.117	8.8	0.9	1.010	1.178	0.006	0.0	21	0.713
7.000_1	0.648	5.1	0.0	0.790	1.129	0.000	0.0	0	0.000
6.002	1.196	21.1	12.2	1.123	1.082	0.082	0.0	82	1.237
Swale 3 (link)	0.741	1244.7	0.7	0.010	-0.067	0.005	0.0	10	0.069
6.000	0.733	5.8	0.9	0.630	1.178	0.006	0.0	27	0.534
6.001	0.881	15.6	9.4	1.178	1.276	0.063	0.0	84	0.922
7.000	1.093	8.6	0.9	1.200	1.414	0.006	0.0	21	0.698
1.003	0.701	5.5	4.8	1.414	1.705	0.032	0.0	72	0.789
6.000_1	0.605	4.8	2.2	0.800	1.081	0.015	0.0	48	0.595
6.001_1	0.826	14.6	8.2	1.081	1.123	0.055	0.0	81	0.850
Rainwater Garden 2 (link)	0.707	12.5	2.6	1.450	1.277	0.018	0.0	47	0.560
Swale 4 (Link)	0.757	1272.2	0.4	0.010	0.019	0.003	0.0	7	0.054

Links

Name	US Node	DS Node	Length (m)	ks (mm) / n	US IL (m)	DS IL (m)	Fall (m)	Slope (1:X)	Dia (mm)	T of C (mins)	Rain (mm/hr)
10.002	Swale MULTI (Exit)	6	2.974	0.600	25.273	25.243	0.030	99.1	150	5.80	50.0
13.000	11	Swale MULTI (Exit)	2.382	0.030	26.090	26.085	0.005	500.0	600	5.05	50.0
12.000	18	Swale MULTI (Exit)	4.543	0.030	26.090	26.081	0.009	500.0	600	5.10	50.0
11.001	Swale 3 (Exit)	Swale MULTI (Exit)	9.090	0.030	26.267	26.206	0.061	150.0	150	5.75	50.0
Swale 5 (link)	Swale 5 (Entry)	Swale 5 (Mid)	16.200	0.030	26.630	26.598	0.032	500.0	400	5.46	50.0
Swale 5 (link2)	Swale 5 (Mid)	Swale 5 (Exit)	10.617	0.030	26.598	26.578	0.020	530.8	400	5.77	50.0

Name	Vel (m/s)	Cap (l/s)	Flow (l/s)	US Depth (m)	DS Depth (m)	Σ Area (ha)	Σ Add Inflow (l/s)	Pro Depth (mm)	Pro Velocity (m/s)
10.002	1.009	17.8	4.8	1.277	1.307	0.033	0.0	54	0.862
13.000	0.741	1244.7	0.7	0.010	0.015	0.005	0.0	10	0.069
12.000	0.741	1244.7	0.7	0.010	0.019	0.005	0.0	10	0.069
11.001	0.305	5.4	0.7	0.383	0.344	0.005	0.0	38	0.215
Swale 5 (link)	0.590	519.6	0.9	0.010	0.042	0.006	0.0	11	0.073
Swale 5 (link2)	0.573	504.3	0.9	0.042	0.042	0.006	0.0	12	0.074

Pipeline Schedule

Link	Length (m)	Slope (1:X)	Dia (mm)	Link Type	US CL (m)	US IL (m)	US Depth (m)	DS CL (m)	DS IL (m)	DS Depth (m)
8.000	18.893	59.4	100	Circular	27.060	26.060	0.900	26.980	25.742	1.138
8.001	32.952	80.0	100	Circular	26.980	25.742	1.138	26.690	25.330	1.260
8.002	17.785	169.4	225	Circular	26.690	25.205	1.260	26.690	25.100	1.365
8.003	22.274	120.0	225	Circular	26.690	25.100	1.365	27.040	24.914	1.901
8.004	6.048	121.0	225	Circular	27.040	24.820	1.995	26.700	24.770	1.705
1.005	17.603	251.5	375	Circular	26.700	24.580	1.745	26.460	24.510	1.575
1.006	43.961	240.0	375	Circular	26.460	24.510	1.575	26.650	24.327	1.948
1.007	29.092	240.0	375	Circular	26.650	24.327	1.948	26.580	24.206	1.999
1.008	9.981	160.0	375	Circular	26.580	24.206	1.999	26.200	24.144	1.681
Swale 1 (Link)	14.144	500.0	400	1:3 Swale (model 1)	26.700	26.290	0.010	26.720	26.262	0.058
9.000	19.335	40.0	100	Circular	27.170	25.870	1.200	27.040	25.387	1.553
Swale 2 (Link)	15.214	500.0	400	1:3 Swale (model 1)	26.760	26.350	0.010	26.630	26.320	-0.090
5.000	29.130	90.0	100	Circular	26.500	25.930	0.470	26.590	25.606	0.884
5.001	30.190	90.0	100	Circular	26.590	25.606	0.884	26.450	25.271	1.079
5.002	12.341	90.1	150	Circular	26.450	25.218	1.082	26.680	25.081	1.449
2.003	10.543	90.0	225	Circular	26.680	25.006	1.449	26.700	24.889	1.586
1.004	6.971	170.0	300	Circular	26.700	24.696	1.704	26.700	24.655	1.745
Rainwater Gargen 1 (Link)	5.164	47.8	100	Circular	26.660	25.550	1.010	26.720	25.442	1.178
7.000_1	39.023	140.0	100	Circular	26.500	25.610	0.790	26.560	25.331	1.129
6.002	4.891	70.9	150	Circular	26.560	25.287	1.123	26.450	25.218	1.082
Swale 3 (link)	11.270	500.0	600	1:3 Swale (model 2)	26.900	26.290	0.010	26.800	26.267	-0.067
6.000	50.346	109.9	100	Circular	26.630	25.900	0.630	26.720	25.442	1.178
6.001	17.881	129.6	150	Circular	26.720	25.392	1.178	26.680	25.254	1.276
7.000	22.685	50.0	100	Circular	27.020	25.720	1.200	26.780	25.266	1.414
1.003	44.500	120.0	100	Circular	26.780	25.266	1.414	26.700	24.895	1.705

Link	US Node	Dia (mm)	Node Type	MH Type	DS Node	Dia (mm)	Node Type	MH Type
8.000	1	1200	Manhole	Adoptable	2	1200	Manhole	Adoptable
8.001	2	1200	Manhole	Adoptable	3	1200	Manhole	Adoptable
8.002	3	1200	Manhole	Adoptable	4	1200	Manhole	Adoptable
8.003	4	1200	Manhole	Adoptable	5	1200	Manhole	Adoptable
8.004	5	1200	Manhole	Adoptable	6	1350	Manhole	Adoptable
1.005	6	1350	Manhole	Adoptable	7	2000	Manhole	Adoptable
1.006	7	2000	Manhole	Adoptable	8	1350	Manhole	Adoptable
1.007	8	1350	Manhole	Adoptable	9	1350	Manhole	Adoptable
1.008	9	1350	Manhole	Adoptable	OUTFALL MH	1350	Manhole	Adoptable
Swale 1 (Link)	Swale 1 (Entry)	1500	Manhole	Adoptable	21	1500	Manhole	Adoptable
9.000	10	1200	Manhole	Adoptable	5	1200	Manhole	Adoptable
Swale 2 (Link)	Swale 2 (Entry)	1500	Manhole	Adoptable	20	1200	Manhole	Adoptable
5.000	12	1200	Manhole	Adoptable	13	1200	Manhole	Adoptable
5.001	13	1200	Manhole	Adoptable	14	1200	Manhole	Adoptable
5.002	14	1200	Manhole	Adoptable	15	1200	Manhole	Adoptable
2.003	15	1200	Manhole	Adoptable	16	1200	Manhole	Adoptable
1.004	16	1200	Manhole	Adoptable	6	1350	Manhole	Adoptable
Rainwater Gargen 1 (Link)	Rainwater Garden 1		Junction		21	1500	Manhole	Adoptable
7.000_1	17	1200	Manhole	Adoptable	19	1200	Manhole	Adoptable
6.002	19	1200	Manhole	Adoptable	14	1200	Manhole	Adoptable
Swale 3 (link)	Swale 3 (Entry)	1500	Manhole	Adoptable	Swale 3 (Exit)	1500	Manhole	Adoptable
6.000	20	1200	Manhole	Adoptable	21	1500	Manhole	Adoptable
6.001	21	1500	Manhole	Adoptable	15	1200	Manhole	Adoptable
7.000	Swale 5 (Exit)	1200	Manhole	Adoptable	23	1200	Manhole	Adoptable
1.003	23	1200	Manhole	Adoptable	16	1200	Manhole	Adoptable

Pipeline Schedule

Link	Length (m)	Slope (1:X)	Dia (mm)	Link Type	US CL (m)	US IL (m)	US Depth (m)	DS CL (m)	DS IL (m)	DS Depth (m)
6.000_1	36.926	160.0	100	Circular	26.500	25.600	0.800	26.550	25.369	1.081
6.001_1	4.714	147.3	150	Circular	26.550	25.319	1.081	26.560	25.287	1.123
Rainwater Garden 2 (link)	25.364	199.7	150	Circular	27.000	25.400	1.450	26.700	25.273	1.277
Swale 4 (Link)	4.307	478.6	600	1:3 Swale (model 2)	27.000	26.390	0.010	27.000	26.381	0.019
10.002	2.974	99.1	150	Circular	26.700	25.273	1.277	26.700	25.243	1.307
13.000	2.382	500.0	600	1:3 Swale (model 2)	26.700	26.090	0.010	26.700	26.085	0.015
12.000	4.543	500.0	600	1:3 Swale (model 2)	26.700	26.090	0.010	26.700	26.081	0.019
11.001	9.090	150.0	150	Circular	26.800	26.267	0.383	26.700	26.206	0.344
Swale 5 (link)	16.200	500.0	400	1:3 Swale (model 1)	27.040	26.630	0.010	27.040	26.598	0.042
Swale 5 (link2)	10.617	530.8	400	1:3 Swale (model 1)	27.040	26.598	0.042	27.020	26.578	0.042

Link	US Node	Dia (mm)	Node Type	MH Type	DS Node	Dia (mm)	Node Type	MH Type
6.000_1	24	1200	Manhole	Adoptable	25	1200	Manhole	Adoptable
6.001_1	25	1200	Manhole	Adoptable	19	1200	Manhole	Adoptable
Rainwater Garden 2 (link)	Rainwater Garden 2		Junction		Swale MULTI (Exit)	1200	Manhole	Adoptable
Swale 4 (Link)	Swale 4 (Entry)	1500	Manhole	Adoptable	Rainwater Garden 2		Junction	
10.002	Swale MULTI (Exit)	1200	Manhole	Adoptable	6	1350	Manhole	Adoptable
13.000	11	1200	Manhole	Adoptable	Swale MULTI (Exit)	1200	Manhole	Adoptable
12.000	18	1200	Manhole	Adoptable	Swale MULTI (Exit)	1200	Manhole	Adoptable
11.001	Swale 3 (Exit)	1500	Manhole	Adoptable	Swale MULTI (Exit)	1200	Manhole	Adoptable
Swale 5 (link)	Swale 5 (Entry)	1500	Manhole	Adoptable	Swale 5 (Mid)	1500	Manhole	Adoptable
Swale 5 (link2)	Swale 5 (Mid)	1500	Manhole	Adoptable	Swale 5 (Exit)	1200	Manhole	Adoptable

Manhole Schedule

Node	Easting (m)	Northing (m)	CL (m)	Depth (m)	Dia (mm)	Connections	Link	IL (m)	Dia (mm)
1	700827.230	736071.421	27.060	1.000	1200	0	8.000	26.060	100
2	700808.370	736072.532	26.980	1.238	1200	1	8.000	25.742	100
						0	8.001	25.742	100
3	700775.440	736073.734	26.690	1.485	1200	1	8.001	25.330	100
						0	8.002	25.205	225
4	700774.876	736055.958	26.690	1.590	1200	1	8.002	25.100	225
						0	8.003	25.100	225
5	700797.137	736055.184	27.040	2.220	1200	1	9.000	25.387	100
						2	8.003	24.914	225
						0	8.004	24.820	225
6	700796.859	736049.143	26.700	2.120	1350	1	10.002	25.243	150
						2	8.004	24.770	225
						3	1.004	24.655	300
						0	1.005	24.580	375
7	700779.255	736048.421	26.460	1.950	2000	1	1.005	24.510	375
						0	1.006	24.510	375
8	700782.905	736004.612	26.650	2.323	1350	1	1.006	24.327	375
						0	1.007	24.327	375
9	700777.560	735976.015	26.580	2.374	1350	1	1.007	24.206	375
						0	1.008	24.206	375
OUTFALL MH	700775.599	735966.229	26.200	2.056	1350	1	1.008	24.144	375
Rainwater Garden 2	700822.119	736047.035	27.000	1.600		1	Swale 4 (Link)	26.381	600
						0	Rainwater Garden 2 (link)	25.400	150

Manhole Schedule

Node	Easting (m)	Northing (m)	CL (m)	Depth (m)	Dia (mm)	Connections	Link	IL (m)	Dia (mm)
10	700816.460	736054.498	27.170	1.300	1200	0	9.000	25.870	100
17	700770.057	736073.611	26.500	0.890	1200	0	7.000_1	25.610	100
19	700772.055	736034.639	26.560	1.273	1200	1	7.000_1	25.331	100
						2	6.001_1	25.287	150
						0	6.002	25.287	150
Swale 1 (Entry)	700784.155	736011.241	26.700	0.410	1500	0	Swale 1 (Link)	26.290	400
24	700764.864	736073.833	26.500	0.900	1200	0	6.000_1	25.600	100
25	700767.999	736037.040	26.550	1.231	1200	1	6.000_1	25.369	100
						0	6.001_1	25.319	150
Swale 2 (Entry)	700839.529	736035.189	26.760	0.410	1500	0	Swale 2 (Link)	26.350	400
12	700773.906	735976.239	26.500	0.570	1200	0	5.000	25.930	100
13	700779.538	736004.819	26.590	0.984	1200	1	5.000	25.606	100
						0	5.001	25.606	100
14	700776.979	736034.900	26.450	1.232	1200	1	6.002	25.218	150
						2	5.001	25.271	100
						0	5.002	25.218	150
15	700786.108	736043.204	26.680	1.674	1200	1	5.002	25.081	150
						2	6.001	25.254	150
						0	2.003	25.006	225
16	700796.601	736042.176	26.700	2.004	1200	1	2.003	24.889	225
						2	1.003	24.895	100
						0	1.004	24.696	300
Rainwater Garden 1	700789.948	736025.901	26.660	1.110		0	Rainwater Gargen 1 (Link)	25.550	100
20	700834.938	736020.684	26.630	0.730	1200	1	Swale 2 (Link)	26.320	400
						0	6.000	25.900	100
21	700784.811	736025.370	26.720	1.328	1500	1	Rainwater Gargen 1 (Link)	25.442	100
						2	Swale 1 (Link)	26.262	400
						3	6.000	25.442	100
						0	6.001	25.392	150
11	700799.401	736051.161	26.700	0.610	1200	0	13.000	26.090	600
Swale 5 (Exit)	700847.435	736059.835	27.020	1.300	1200	1	Swale 5 (link2)	26.578	400
						0	7.000	25.720	100
23	700840.915	736038.107	26.780	1.514	1200	1	7.000	25.266	100
						0	1.003	25.266	100
18	700799.267	736044.305	26.700	0.610	1200	0	12.000	26.090	600
26	700790.026	736052.085	26.580	1.000	1200				

Manhole Schedule

Node	Easting (m)	Northing (m)	CL (m)	Depth (m)	Dia (mm)	Connections	Link	IL (m)	Dia (mm)
Swale 3 (Entry)	700818.279	736042.257	26.900	0.610	1500	0	Swale 3 (link)	26.290	600
27	700780.515	735995.177	26.650	1.000	1200				
Swale 3 (Exit)	700807.060	736043.325	26.800	0.533	1500	1	Swale 3 (link)	26.267	600
						0	11.001	26.267	150
Swale 4 (Entry)	700824.911	736050.315	27.000	0.610	1500	0	Swale 4 (Link)	26.390	600
Swale MULTI (Exit)	700799.815	736048.815	26.700	1.427	1200	1	13.000	26.085	600
						2	12.000	26.081	600
						3	11.001	26.206	150
						4	Rainwater Garden 2 (link)	25.273	150
						0	10.002	25.273	150
Swale 5 (Entry)	700833.214	736071.223	27.040	0.410	1500	0	Swale 5 (link)	26.630	400
Swale 5 (Mid)	700849.386	736070.271	27.040	0.442	1500	1	Swale 5 (link)	26.598	400
						0	Swale 5 (link2)	26.598	400

Simulation Settings

Rainfall Methodology	FSR	Winter CV	0.840	Check Discharge Rate(s)	x
FSR Region	Scotland and Ireland	Analysis Speed	Normal	Check Discharge Volume	✓
M5-60 (mm)	16.300	Skip Steady State	x	100 year 360 minute (m³)	
Ratio-R	0.277	Drain Down Time (mins)	240		
Summer CV	0.750	Additional Storage (m³/ha)	20.0		

Storm Durations

15	60	180	360	600	960	2160	4320	7200	10080
30	120	240	480	720	1440	2880	5760	8640	

Return Period (years)	Climate Change (CC %)	Additional Area (A %)	Additional Flow (Q %)	Return Period (years)	Climate Change (CC %)	Additional Area (A %)	Additional Flow (Q %)
1	0	0	0	100	30	0	0
30	0	0	0				

Pre-development Discharge Volume

Site Makeup	Greenfield	Soil Index	1	Return Period (years)	100	Betterment (%)	0
Greenfield Method	FSR/FEH	SPR	0.10	Climate Change (%)	0	PR	
Positively Drained Area (ha)		CWI		Storm Duration (mins)	360	Runoff Volume (m³)	

Node 9 Online Orifice Control

Flap Valve	x	Invert Level (m)	24.206	Design Flow (l/s)	2.4	Discharge Coefficient	0.600
Replaces Downstream Link	✓	Design Depth (m)	1.400	Diameter (m)	0.031		

Node 7 Online Weir Control

Flap Valve	x	Invert Level (m)	26.300	Discharge Coefficient	0.590
Replaces Downstream Link	✓	Width (m)	8.000		

Node 7 Offline Weir Control

Flap Valve	x	Loop to Node	26	Invert Level (m)	26.300	Width (m)	8.000	Discharge Coefficient	0.590

Node 26 Offline Hydro-Brake® Control

Flap Valve	✓	Design Flow (l/s)	0.6	Min Outlet Diameter (m)	0.075
Loop to Node	7	Objective	(HE) Minimise upstream storage	Min Node Diameter (mm)	1200
Invert Level (m)	25.580	Sump Available	✓		
Design Depth (m)	1.000	Product Number	CTL-SHE-0036-6000-1000-6000		

Node 9 Online Weir Control

Flap Valve	x	Invert Level (m)	26.300	Discharge Coefficient	0.590
Replaces Downstream Link	✓	Width (m)	5.000		

Node 9 Offline Weir Control

Flap Valve	x	Loop to Node	27	Invert Level (m)	26.300	Width (m)	6.000	Discharge Coefficient	0.590

Node 27 Offline Hydro-Brake® Control

Flap Valve	✓	Design Flow (l/s)	0.6	Min Outlet Diameter (m)	0.075
Loop to Node	9	Objective	(HE) Minimise upstream storage	Min Node Diameter (mm)	1200
Invert Level (m)	25.650	Sump Available	✓		
Design Depth (m)	0.800	Product Number	CTL-SHE-0038-6000-0800-6000		

Node 26 Carpark Storage Structure

BRE-365: Volume (m³)	1.090	Base Inf Coefficient (m/hr)	0.00000	Invert Level (m)	25.580	Slope (1:X)	500.0
BRE-365: Area (m²)	5.970	Side Inf Coefficient (m/hr)	0.00000	Time to half empty (mins)		Depth (m)	0.800
BRE-365: Time (hrs)	182.000	Safety Factor	2.0	Width (m)	8.000	Inf Depth (m)	
BRE-365: Inf Coef (m/hr)	0.00100	Porosity	0.30	Length (m)	10.000		

Node 25 Depth/Area Storage Structure

Base Inf Coefficient (m/hr)	0.00100	Safety Factor	2.0	Invert Level (m)	25.319
Side Inf Coefficient (m/hr)	0.00100	Porosity	1.00	Time to half empty (mins)	

Depth (m)	Area (m²)	Inf Area (m²)	Depth (m)	Area (m²)	Inf Area (m²)	Depth (m)	Area (m²)	Inf Area (m²)
0.000	180.0	180.0	0.750	180.0	180.0	0.755	0.5	180.0

Node 27 Carpark Storage Structure

Base Inf Coefficient (m/hr)	0.00000	Porosity	0.30	Width (m)	5.000	Depth (m)	0.600
Side Inf Coefficient (m/hr)	0.00000	Invert Level (m)	25.650	Length (m)	5.000	Inf Depth (m)	
Safety Factor	2.0	Time to half empty (mins)	360	Slope (1:X)	500.0		

Node Rainwater Garden 1 Depth/Area Storage Structure

Base Inf Coefficient (m/hr)	0.00000	Safety Factor	2.0	Invert Level (m)	25.550
Side Inf Coefficient (m/hr)	0.00000	Porosity	0.20	Time to half empty (mins)	

Depth (m)	Area (m²)	Inf Area (m²)	Depth (m)	Area (m²)	Inf Area (m²)	Depth (m)	Area (m²)	Inf Area (m²)
0.000	60.0	60.0	0.500	60.0	60.0	1.000	60.0	60.0

Node Rainwater Garden 2 Depth/Area Storage Structure

Base Inf Coefficient (m/hr)	0.00000	Safety Factor	2.0	Invert Level (m)	25.400
Side Inf Coefficient (m/hr)	0.00000	Porosity	0.20	Time to half empty (mins)	

Depth (m)	Area (m²)	Inf Area (m²)	Depth (m)	Area (m²)	Inf Area (m²)
0.000	100.0	100.0	1.000	100.0	100.0

Other (defaults)

Entry Loss (manhole)	0.250	Entry Loss (junction)	0.000	Apply Recommended Losses	x
Exit Loss (manhole)	0.250	Exit Loss (junction)	0.000	Flood Risk (m)	0.300

Flood Risk Overrides

Node	Flood Risk (m)
25	0.300
9	0.300
7	0.300

Approval Settings

Node Size	✓	Maximum Cover Depth (m)	3.000	Surcharged Depth	✓
Node Losses	✓	Backdrops	✓	Return Period (years)	
Link Size	✓	Minimum Backdrop Height (m)		Maximum Surcharged Depth (m)	0.100
Minimum Diameter (mm)	150	Maximum Backdrop Height (m)	1.500	Flooding	✓
Link Length	✓	Full Bore Velocity	✓	Return Period (years)	30
Maximum Length (m)	100.000	Minimum Full Bore Velocity (m/s)		Time to Half Empty	x
Coordinates	✓	Maximum Full Bore Velocity (m/s)	3.000	Discharge Rates	✓
Accuracy (m)	1.000	Proportional Velocity	✓	Discharge Volume	✓
Crossings	✓	Return Period (years)		100 year 360 minute (m³)	
Cover Depth	✓	Minimum Proportional Velocity (m/s)	0.750		
Minimum Cover Depth (m)		Maximum Proportional Velocity (m/s)	3.000		

Rainfall

Event	Peak Intensity (mm/hr)	Average Intensity (mm/hr)	Event	Peak Intensity (mm/hr)	Average Intensity (mm/hr)
1 year 15 minute summer	87.529	24.768	1 year 180 minute summer	22.254	5.727
1 year 15 minute winter	61.424	24.768	1 year 180 minute winter	14.466	5.727
1 year 30 minute summer	60.044	16.991	1 year 240 minute summer	18.096	4.782
1 year 30 minute winter	42.136	16.991	1 year 240 minute winter	12.022	4.782
1 year 60 minute summer	42.719	11.289	1 year 360 minute summer	14.400	3.706
1 year 60 minute winter	28.382	11.289	1 year 360 minute winter	9.361	3.706
1 year 120 minute summer	27.907	7.375	1 year 480 minute summer	11.682	3.087
1 year 120 minute winter	18.541	7.375	1 year 480 minute winter	7.761	3.087

Rainfall

Event	Peak Intensity (mm/hr)	Average Intensity (mm/hr)	Event	Peak Intensity (mm/hr)	Average Intensity (mm/hr)
1 year 600 minute summer	9.797	2.680	30 year 2880 minute winter	4.456	1.777
1 year 600 minute winter	6.694	2.680	30 year 4320 minute summer	5.124	1.340
1 year 720 minute summer	8.907	2.387	30 year 4320 minute winter	3.374	1.340
1 year 720 minute winter	5.986	2.387	30 year 5760 minute summer	4.281	1.096
1 year 960 minute summer	7.593	1.999	30 year 5760 minute winter	2.771	1.096
1 year 960 minute winter	5.029	1.999	30 year 7200 minute summer	3.675	0.937
1 year 1440 minute summer	5.752	1.542	30 year 7200 minute winter	2.372	0.937
1 year 1440 minute winter	3.866	1.542	30 year 8640 minute summer	3.235	0.825
1 year 2160 minute summer	4.298	1.188	30 year 8640 minute winter	2.088	0.825
1 year 2160 minute winter	2.961	1.188	30 year 10080 minute summer	2.904	0.741
1 year 2880 minute summer	3.684	0.987	30 year 10080 minute winter	1.874	0.741
1 year 2880 minute winter	2.476	0.987	100 year +30% CC 15 minute summer	327.527	92.679
1 year 4320 minute summer	2.914	0.762	100 year +30% CC 15 minute winter	229.844	92.679
1 year 4320 minute winter	1.919	0.762	100 year +30% CC 30 minute summer	226.573	64.112
1 year 5760 minute summer	2.473	0.633	100 year +30% CC 30 minute winter	158.999	64.112
1 year 5760 minute winter	1.600	0.633	100 year +30% CC 60 minute summer	157.663	41.666
1 year 7200 minute summer	2.146	0.548	100 year +30% CC 60 minute winter	104.748	41.666
1 year 7200 minute winter	1.385	0.548	100 year +30% CC 120 minute summer	99.533	26.304
1 year 8640 minute summer	1.907	0.486	100 year +30% CC 120 minute winter	66.127	26.304
1 year 8640 minute winter	1.231	0.486	100 year +30% CC 180 minute summer	77.429	19.925
1 year 10080 minute summer	1.726	0.440	100 year +30% CC 180 minute winter	50.331	19.925
1 year 10080 minute winter	1.114	0.440	100 year +30% CC 240 minute summer	61.799	16.332
30 year 15 minute summer	194.379	55.003	100 year +30% CC 240 minute winter	41.058	16.332
30 year 15 minute winter	136.406	55.003	100 year +30% CC 360 minute summer	47.810	12.303
30 year 30 minute summer	133.530	37.785	100 year +30% CC 360 minute winter	31.077	12.303
30 year 30 minute winter	93.706	37.785	100 year +30% CC 480 minute summer	38.027	10.049
30 year 60 minute summer	93.310	24.659	100 year +30% CC 480 minute winter	25.264	10.049
30 year 60 minute winter	61.993	24.659	100 year +30% CC 600 minute summer	31.385	8.585
30 year 120 minute summer	59.381	15.693	100 year +30% CC 600 minute winter	21.444	8.585
30 year 120 minute winter	39.452	15.693	100 year +30% CC 720 minute summer	28.153	7.545
30 year 180 minute summer	46.475	11.960	100 year +30% CC 720 minute winter	18.921	7.545
30 year 180 minute winter	30.210	11.960	100 year +30% CC 960 minute summer	23.367	6.153
30 year 240 minute summer	37.258	9.846	100 year +30% CC 960 minute winter	15.479	6.153
30 year 240 minute winter	24.753	9.846	100 year +30% CC 1440 minute summer	17.217	4.614
30 year 360 minute summer	29.021	7.468	100 year +30% CC 1440 minute winter	11.571	4.614
30 year 360 minute winter	18.865	7.468	100 year +30% CC 2160 minute summer	12.515	3.459
30 year 480 minute summer	23.200	6.131	100 year +30% CC 2160 minute winter	8.623	3.459
30 year 480 minute winter	15.414	6.131	100 year +30% CC 2880 minute summer	10.508	2.816
30 year 600 minute summer	19.226	5.259	100 year +30% CC 2880 minute winter	7.062	2.816
30 year 600 minute winter	13.136	5.259	100 year +30% CC 4320 minute summer	8.052	2.105
30 year 720 minute summer	17.304	4.638	100 year +30% CC 4320 minute winter	5.302	2.105
30 year 720 minute winter	11.629	4.638	100 year +30% CC 5760 minute summer	6.684	1.711
30 year 960 minute summer	14.440	3.802	100 year +30% CC 5760 minute winter	4.326	1.711
30 year 960 minute winter	9.565	3.802	100 year +30% CC 7200 minute summer	5.710	1.457
30 year 1440 minute summer	10.720	2.873	100 year +30% CC 7200 minute winter	3.685	1.457
30 year 1440 minute winter	7.204	2.873	100 year +30% CC 8640 minute summer	5.005	1.277
30 year 2160 minute summer	7.851	2.170	100 year +30% CC 8640 minute winter	3.230	1.277
30 year 2160 minute winter	5.410	2.170	100 year +30% CC 10080 minute summer	4.477	1.142
30 year 2880 minute summer	6.630	1.777	100 year +30% CC 10080 minute winter	2.889	1.142

Results for 1 year Critical Storm Duration. Lowest mass balance: 70.03%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
5760 minute winter	1	5340	26.063	0.003	0.0	0.0034	0.0000	OK
5760 minute winter	2	5340	26.063	0.321	0.2	0.5963	0.0000	SURCHARGED
5760 minute winter	3	5400	26.063	0.858	0.5	1.9174	0.0000	SURCHARGED
5760 minute winter	4	5340	26.063	0.963	0.7	1.4646	0.0000	SURCHARGED
5760 minute winter	5	5400	26.063	1.243	1.0	1.5959	0.0000	SURCHARGED
5760 minute winter	6	5340	26.063	1.483	1.1	2.2907	0.0000	SURCHARGED
5760 minute winter	7	5400	26.063	1.553	0.5	4.8784	0.0000	SURCHARGED
120 minute winter	8	86	24.815	0.488	2.7	0.9680	0.0000	SURCHARGED
120 minute winter	9	84	24.815	0.609	2.7	0.9900	0.0000	SURCHARGED
15 minute summer	OUTFALL MH	1	24.144	0.000	1.1	0.0000	0.0000	OK
5760 minute winter	Rainwater Garden 2	5400	26.063	0.663	0.3	13.3772	0.0000	SURCHARGED
5760 minute winter	10	5400	26.062	0.192	0.1	0.2915	0.0000	SURCHARGED
5760 minute winter	17	5400	26.063	0.453	0.0	0.5121	0.0000	SURCHARGED
5760 minute winter	19	5400	26.062	0.775	1.3	1.2058	0.0000	SURCHARGED
30 minute summer	Swale 1 (Entry)	21	26.300	0.010	0.5	0.0196	0.0000	OK
5760 minute winter	24	5400	26.063	0.463	0.1	0.6774	0.0000	SURCHARGED
5760 minute winter	25	5400	26.063	0.744	1.5	135.1609	0.0000	SURCHARGED
30 minute winter	Swale 2 (Entry)	21	26.361	0.011	0.5	0.0219	0.0000	OK
5760 minute winter	12	5460	26.062	0.132	0.0	0.2006	0.0000	SURCHARGED
5760 minute winter	13	5460	26.062	0.456	0.1	0.7013	0.0000	SURCHARGED
5760 minute winter	14	5400	26.063	0.844	1.3	0.9551	0.0000	SURCHARGED
5760 minute winter	15	5400	26.063	1.057	1.1	1.1951	0.0000	SURCHARGED
5760 minute winter	16	5400	26.063	1.367	1.7	2.5147	0.0000	SURCHARGED
5760 minute winter	Rainwater Garden 1	5400	26.063	0.513	0.2	6.2078	0.0000	SURCHARGED
10080 minute winter	20	7680	26.063	0.163	0.0	0.1841	0.0000	SURCHARGED
5760 minute winter	21	5400	26.063	0.671	0.2	1.6501	0.0000	SURCHARGED
15 minute winter	11	10	26.100	0.010	0.6	0.0132	0.0000	OK
5760 minute winter	Swale 5 (Exit)	5460	26.063	0.343	0.1	0.3878	0.0000	SURCHARGED
5760 minute winter	23	5460	26.063	0.797	0.2	1.1747	0.0000	SURCHARGED
15 minute winter	18	11	26.101	0.011	0.6	0.0142	0.0000	OK
15 minute summer	26	1	25.580	0.000	0.0	0.0000	0.0000	OK
15 minute winter	Swale 3 (Entry)	10	26.299	0.009	0.6	0.0176	0.0000	OK
15 minute summer	27	1	25.650	0.000	0.0	0.0000	0.0000	OK
60 minute winter	Swale 3 (Exit)	41	26.294	0.027	0.3	0.0474	0.0000	OK

Link Event (Outflow)	US Node	Link	DS Node	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
5760 minute winter	1	8.000	2	0.0	-0.004	-0.002	0.0745	
15 minute winter	2	8.001	3	4.9	0.930	0.720	0.2082	
15 minute summer	3	8.002	4	14.0	0.855	0.352	0.7073	
15 minute summer	4	8.003	5	16.4	0.984	0.346	0.8859	
15 minute winter	5	8.004	6	16.8	0.943	0.356	0.2405	
15 minute summer	6	1.005	7	14.1	0.566	0.112	1.9416	
15 minute summer	7	Weir	8	0.0				
15 minute summer	7	Weir	26	0.0				0.0
15 minute summer	8	1.007	9	7.1	0.283	0.055	2.3440	
120 minute winter	9	Orifice	OUTFALL MH	1.5				10.8
15 minute summer	9	Weir	OUTFALL MH	0.0				0.0
15 minute summer	9	Weir	27	0.0				0.0
60 minute summer	Rainwater Garden 2	Rainwater Garden 2 (link)	Swale MULTI (Exit)	-9.1	-0.565	-0.726	0.4465	
15 minute winter	10	9.000	5	2.7	1.043	0.286	0.0941	
600 minute winter	17	7.000_1	19	-0.1	-0.020	-0.018	0.3053	
60 minute winter	19	6.002	14	-14.2	-0.809	-0.674	0.0861	
30 minute summer	Swale 1 (Entry)	Swale 1 (Link)	21	0.3	0.054	0.001	0.0867	
15 minute winter	24	6.000_1	25	1.6	0.544	0.331	0.1068	
60 minute winter	25	6.001_1	19	-15.4	-1.139	-1.057	0.0830	
15 minute summer	25	Infiltration		0.0				
30 minute winter	Swale 2 (Entry)	Swale 2 (Link)	20	0.4	0.057	0.001	0.1018	
15 minute winter	12	5.000	13	1.2	0.414	0.188	0.0874	
15 minute winter	13	5.001	14	3.3	0.795	0.516	0.1764	
60 minute winter	14	5.002	15	-13.0	-0.736	-0.692	0.2173	
60 minute winter	15	2.003	16	-11.3	0.652	-0.206	0.4193	
15 minute summer	16	1.004	6	15.0	0.679	0.176	0.4909	
60 minute winter	Rainwater Garden 1	Rainwater Gargen 1 (Link)	21	1.5	0.483	0.166	0.0324	
30 minute winter	20	6.000	21	0.4	0.327	0.063	0.2191	
15 minute winter	21	6.001	15	5.8	0.779	0.373	0.3043	
15 minute winter	11	13.000	Swale MULTI (Exit)	0.5	0.080	0.000	0.0162	
30 minute winter	Swale 5 (Exit)	7.000	23	0.3	0.064	0.038	0.0958	
15 minute winter	23	1.003	16	2.7	0.589	0.484	0.3482	
15 minute winter	18	12.000	Swale MULTI (Exit)	0.5	0.072	0.000	0.0326	
15 minute summer	26	Hydro-Brake®	7	0.0				0.0
15 minute winter	Swale 3 (Entry)	Swale 3 (link)	Swale 3 (Exit)	0.6	0.062	0.000	0.1574	
15 minute summer	27	Hydro-Brake®	9	0.0				0.0
60 minute winter	Swale 3 (Exit)	11.001	Swale MULTI (Exit)	0.2	0.158	0.041	0.0131	

Results for 1 year Critical Storm Duration. Lowest mass balance: 70.03%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
15 minute winter	Swale 4 (Entry)	11	26.397	0.007	0.3	0.0138	0.0000	OK
5760 minute winter	Swale MULTI (Exit)	5400	26.063	0.790	0.4	0.8934	0.0000	SURCHARGED
15 minute winter	Swale 5 (Entry)	12	26.642	0.012	0.7	0.0252	0.0000	OK
30 minute winter	Swale 5 (Mid)	24	26.608	0.010	0.6	0.0171	0.0000	OK

Link Event (Outflow)	US Node	Link	DS Node	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute winter	Swale 4 (Entry)	Swale 4 (Link)	Rainwater Garden 2	0.2	0.053	0.000	0.0203	
60 minute summer	Swale MULTI (Exit)	10.002	6	-8.5	-0.484	-0.478	0.0524	
30 minute summer	Swale 5 (Entry)	Swale 5 (link)	Swale 5 (Mid)	0.6	0.066	0.001	0.1470	
30 minute winter	Swale 5 (Mid)	Swale 5 (link2)	Swale 5 (Exit)	0.3	0.054	0.001	0.0647	

Results for 30 year Critical Storm Duration. Lowest mass balance: 70.03%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
30 minute winter	1	22	26.371	0.311	2.5	0.3519	0.0000	SURCHARGED
30 minute winter	2	22	26.369	0.627	9.1	1.1647	0.0000	SURCHARGED
2880 minute winter	3	1860	26.307	1.102	1.3	2.4629	0.0000	SURCHARGED
2880 minute winter	4	1860	26.307	1.207	1.6	1.8361	0.0000	SURCHARGED
2880 minute winter	5	1860	26.307	1.487	2.1	1.9094	0.0000	SURCHARGED
2880 minute winter	6	1860	26.306	1.726	4.7	2.6666	0.0000	SURCHARGED
2880 minute winter	7	1860	26.308	1.798	5.2	5.6484	0.0000	FLOOD RISK
2160 minute winter	8	1440	26.304	1.977	5.4	3.9190	0.0000	SURCHARGED
2160 minute winter	9	1440	26.304	2.098	5.8	3.4086	0.0000	FLOOD RISK
15 minute summer	OUTFALL MH	1	24.144	0.000	2.3	0.0000	0.0000	OK
2880 minute winter	Rainwater Garden 2	1860	26.312	0.912	1.3	18.4055	0.0000	SURCHARGED
2880 minute winter	10	1800	26.308	0.438	0.3	0.6643	0.0000	SURCHARGED
4320 minute winter	17	2580	26.307	0.697	0.1	0.7888	0.0000	FLOOD RISK
2880 minute winter	19	1860	26.307	1.020	3.9	1.5868	0.0000	FLOOD RISK
4320 minute winter	Swale 1 (Entry)	2580	26.307	0.017	0.1	0.0343	0.0000	OK
2160 minute winter	24	1380	26.309	0.709	0.2	1.0385	0.0000	FLOOD RISK
2880 minute winter	25	1860	26.308	0.989	4.4	137.3285	0.0000	FLOOD RISK
15 minute winter	Swale 2 (Entry)	13	26.368	0.018	1.5	0.0374	0.0000	OK
2160 minute winter	12	1380	26.309	0.379	0.1	0.5744	0.0000	FLOOD RISK
2160 minute winter	13	1380	26.308	0.702	0.4	1.0791	0.0000	FLOOD RISK
2880 minute winter	14	1860	26.307	1.089	3.6	1.2321	0.0000	FLOOD RISK
2880 minute winter	15	1860	26.307	1.301	3.3	1.4718	0.0000	SURCHARGED
2880 minute winter	16	1860	26.307	1.611	3.0	2.9645	0.0000	SURCHARGED
2880 minute winter	Rainwater Garden 1	1860	26.307	0.757	0.8	9.1677	0.0000	SURCHARGED
2880 minute winter	20	1860	26.308	0.408	0.1	0.4611	0.0000	SURCHARGED
2880 minute winter	21	1860	26.307	0.915	0.9	2.2514	0.0000	SURCHARGED
4320 minute winter	11	2520	26.324	0.234	0.0	0.3032	0.0000	OK
2160 minute winter	Swale 5 (Exit)	1380	26.308	0.588	0.1	0.6653	0.0000	SURCHARGED
2160 minute winter	23	1380	26.308	1.042	0.4	1.5358	0.0000	SURCHARGED
2160 minute winter	18	1440	26.314	0.224	6.1	0.2906	0.0000	OK
2160 minute winter	26	1380	26.307	0.727	2.6	18.0195	0.0000	OK
2160 minute winter	Swale 3 (Entry)	1440	26.310	0.020	0.1	0.0395	0.0000	OK
2160 minute winter	27	1560	26.304	0.654	1.5	5.2066	0.0000	OK
2160 minute winter	Swale 3 (Exit)	1440	26.311	0.044	0.1	0.0769	0.0000	OK

Link Event (Outflow)	US Node	Link	DS Node	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute summer	1	8.000	2	-2.9	-0.401	-0.371	0.1478	
15 minute summer	2	8.001	3	7.1	0.945	1.044	0.2578	
15 minute winter	3	8.002	4	21.1	0.901	0.530	0.7073	
15 minute winter	4	8.003	5	23.4	1.047	0.494	0.8859	
15 minute winter	5	8.004	6	29.4	0.955	0.622	0.2405	
15 minute winter	6	1.005	7	20.8	0.617	0.166	1.9416	
4320 minute winter	7	Weir	8	5.4				
1440 minute winter	7	Weir	26	3.2				18.7
15 minute winter	8	1.007	9	9.1	0.351	0.070	3.2088	
2160 minute winter	9	Orifice	OUTFALL MH	2.9				171.8
2160 minute winter	9	Weir	OUTFALL MH	2.0				17.1
60 minute winter	9	Weir	27	1.6				0.5
15 minute winter	Rainwater Garden 2	Rainwater Garden 2 (link)	Swale MULTI (Exit)	-17.6	-1.029	-1.408	0.4465	
15 minute summer	10	9.000	5	5.9	1.227	0.618	0.1422	
15 minute winter	17	7.000_1	19	-1.1	-0.198	-0.209	0.2150	
30 minute winter	19	6.002	14	-25.7	-1.460	-1.216	0.0861	
15 minute winter	Swale 1 (Entry)	Swale 1 (Link)	21	0.9	0.081	0.002	0.1514	
15 minute winter	24	6.000_1	25	3.5	0.676	0.742	0.1926	
30 minute winter	25	6.001_1	19	-29.4	-1.885	-2.013	0.0830	
15 minute summer	25	Infiltration		0.0				
15 minute winter	Swale 2 (Entry)	Swale 2 (Link)	20	1.0	0.087	0.002	0.1822	
15 minute winter	12	5.000	13	2.7	0.482	0.423	0.1642	
15 minute winter	13	5.001	14	5.9	0.855	0.921	0.2362	
60 minute winter	14	5.002	15	-21.9	-1.246	-1.172	0.2173	
30 minute winter	15	2.003	16	-24.5	0.815	-0.446	0.4193	
15 minute summer	16	1.004	6	17.1	0.687	0.201	0.4909	
15 minute winter	Rainwater Garden 1	Rainwater Gargen 1 (Link)	21	-10.5	-1.382	-1.191	0.0404	
30 minute summer	20	6.000	21	1.5	0.259	0.256	0.3530	
15 minute summer	21	6.001	15	10.0	0.818	0.644	0.3148	
4320 minute summer	11	13.000	Swale MULTI (Exit)	9.0	0.047	0.007	0.8873	
15 minute summer	Swale 5 (Exit)	7.000	23	-2.9	-0.383	-0.340	0.1775	
15 minute summer	23	1.003	16	3.4	0.621	0.615	0.3482	
7200 minute winter	18	12.000	Swale MULTI (Exit)	10.3	0.028	0.008	1.6798	
4320 minute winter	26	Hydro-Brake®	7	0.0				0.2
15 minute winter	Swale 3 (Entry)	Swale 3 (link)	Swale 3 (Exit)	1.2	0.082	0.001	0.3129	
2160 minute winter	27	Hydro-Brake®	9	0.5				5.2
30 minute winter	Swale 3 (Exit)	11.001	Swale MULTI (Exit)	0.5	0.207	0.095	0.0232	

Results for 30 year Critical Storm Duration. Lowest mass balance: 70.03%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
15 minute winter	Swale 4 (Entry)	11	26.401	0.011	0.6	0.0211	0.0000	OK
7200 minute winter	Swale MULTI (Exit)	4020	26.313	1.040	15.1	1.1762	0.0000	SURCHARGED
15 minute winter	Swale 5 (Entry)	11	26.650	0.020	1.5	0.0402	0.0000	OK
30 minute winter	Swale 5 (Mid)	22	26.615	0.017	1.3	0.0298	0.0000	OK

Link Event (Outflow)	US Node	Link	DS Node	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute winter	Swale 4 (Entry)	Swale 4 (Link)	Rainwater Garden 2	0.6	0.077	0.000	0.0324	
15 minute winter	Swale MULTI (Exit)	10.002	6	-17.5	-0.997	-0.984	0.0524	
15 minute winter	Swale 5 (Entry)	Swale 5 (link)	Swale 5 (Mid)	1.6	0.097	0.003	0.2641	
30 minute winter	Swale 5 (Mid)	Swale 5 (link2)	Swale 5 (Exit)	0.9	0.086	0.002	0.1179	

Results for 100 year +30% CC Critical Storm Duration. Lowest mass balance: 70.03%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
30 minute summer	1	20	26.998	0.938	4.9	1.0610	0.0000	FLOOD RISK
30 minute winter	2	19	26.980	1.238	15.5	2.3002	1.4079	FLOOD
30 minute summer	3	19	26.690	1.485	35.5	3.3190	0.1744	FLOOD
30 minute summer	4	19	26.612	1.512	41.4	2.2992	0.0000	FLOOD RISK
30 minute summer	5	19	26.435	1.615	52.9	2.0743	0.0000	SURCHARGED
240 minute winter	6	184	26.358	1.778	29.7	2.7475	0.0000	SURCHARGED
480 minute winter	7	312	26.400	1.890	50.0	5.9384	0.0000	FLOOD RISK
600 minute summer	8	360	26.413	2.086	71.0	4.1350	0.0000	FLOOD RISK
960 minute winter	9	555	26.327	2.121	21.2	3.4471	0.0000	FLOOD RISK
15 minute summer	OUTFALL MH	1	24.144	0.000	2.9	0.0000	0.0000	OK
600 minute winter	Rainwater Garden 2	390	26.352	0.952	2.5	19.2169	0.0000	SURCHARGED
30 minute winter	10	20	26.712	0.842	8.6	1.2770	0.0000	SURCHARGED
600 minute winter	17	390	26.361	0.751	0.2	0.8489	0.0000	FLOOD RISK
600 minute winter	19	390	26.361	1.074	16.1	1.6707	0.0000	FLOOD RISK
600 minute winter	Swale 1 (Entry)	390	26.354	0.064	0.8	0.1289	0.0000	OK
360 minute winter	24	240	26.367	0.767	1.1	1.1227	0.0000	FLOOD RISK
600 minute winter	25	390	26.364	1.045	18.4	137.4563	0.0000	FLOOD RISK
15 minute winter	Swale 2 (Entry)	12	26.376	0.026	2.5	0.0527	0.0000	OK
30 minute winter	12	22	26.464	0.534	3.8	0.8103	0.0000	FLOOD RISK
30 minute winter	13	22	26.416	0.810	8.8	1.2451	0.0000	FLOOD RISK
600 minute winter	14	390	26.360	1.142	14.8	1.2921	0.0000	FLOOD RISK
600 minute winter	15	390	26.354	1.348	13.6	1.5249	0.0000	SURCHARGED
480 minute winter	16	312	26.354	1.658	14.7	3.0507	0.0000	SURCHARGED
600 minute summer	Rainwater Garden 1	360	26.356	0.806	2.4	9.7558	0.0000	SURCHARGED
360 minute winter	20	232	26.352	0.452	0.6	0.5115	0.0000	FLOOD RISK
600 minute winter	21	390	26.354	0.962	4.0	2.3674	0.0000	SURCHARGED
480 minute winter	11	312	26.363	0.273	14.6	0.3534	0.0000	OK
30 minute winter	Swale 5 (Exit)	24	26.641	0.921	3.6	1.0417	0.0000	SURCHARGED
30 minute winter	23	20	26.657	1.391	9.0	2.0504	0.0000	FLOOD RISK
960 minute winter	18	585	26.362	0.272	23.4	0.3528	0.0000	OK
720 minute winter	26	435	26.362	0.782	14.9	19.4198	0.0000	OK
600 minute winter	Swale 3 (Entry)	390	26.347	0.057	0.5	0.1097	0.0000	OK
600 minute winter	27	360	26.337	0.687	14.4	5.2433	0.0000	OK
600 minute winter	Swale 3 (Exit)	390	26.347	0.080	1.3	0.1415	0.0000	OK

Link Event (Outflow)	US Node	Link	DS Node	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute winter	1	8.000	2	-5.5	-0.697	-0.694	0.1478	
30 minute summer	2	8.001	3	7.3	0.931	1.077	0.2578	
30 minute winter	3	8.002	4	31.0	0.810	0.779	0.7073	
15 minute winter	4	8.003	5	41.2	1.083	0.869	0.8859	
15 minute winter	5	8.004	6	52.5	1.320	1.112	0.2405	
360 minute winter	6	1.005	7	51.8	0.470	0.413	1.9416	
960 minute winter	7	Weir	8	187.5				
600 minute winter	7	Weir	26	92.0				109.4
360 minute winter	8	1.007	9	41.1	0.373	0.319	3.2088	
240 minute winter	9	Orifice	OUTFALL MH	2.9				51.1
720 minute winter	9	Weir	OUTFALL MH	58.0				151.2
480 minute winter	9	Weir	27	43.3				34.3
15 minute summer	Rainwater Garden 2	Rainwater Garden 2 (link)	Swale MULTI (Exit)	-23.0	-1.306	-1.839	0.4465	
15 minute winter	10	9.000	5	7.3	1.224	0.757	0.1513	
15 minute summer	17	7.000_1	19	-3.0	-0.415	-0.598	0.3053	
15 minute winter	19	6.002	14	-31.2	-1.772	-1.477	0.0861	
360 minute winter	Swale 1 (Entry)	Swale 1 (Link)	21	6.0	0.077	0.012	1.1597	
15 minute winter	24	6.000_1	25	5.4	0.719	1.134	0.2743	
30 minute summer	25	6.001_1	19	-39.1	-2.380	-2.679	0.0830	
15 minute summer	25	Infiltration		0.0				
15 minute winter	Swale 2 (Entry)	Swale 2 (Link)	20	2.7	0.115	0.005	0.3554	
15 minute summer	12	5.000	13	3.9	0.557	0.608	0.2279	
30 minute winter	13	5.001	14	6.6	0.840	1.032	0.2362	
60 minute summer	14	5.002	15	-26.1	-1.485	-1.397	0.2173	
15 minute winter	15	2.003	16	-32.5	0.916	-0.593	0.4193	
360 minute winter	16	1.004	6	16.6	0.410	0.195	0.4909	
15 minute winter	Rainwater Garden 1	Rainwater Gargen 1 (Link)	21	-15.9	-2.033	-1.812	0.0404	
15 minute winter	20	6.000	21	-3.2	-0.406	-0.552	0.3939	
360 minute winter	21	6.001	15	15.0	0.854	0.965	0.3148	
960 minute winter	11	13.000	Swale MULTI (Exit)	155.1	0.344	0.125	1.0769	
15 minute summer	Swale 5 (Exit)	7.000	23	-5.3	-0.683	-0.617	0.1775	
30 minute winter	23	1.003	16	4.9	0.632	0.898	0.3482	
720 minute winter	18	12.000	Swale MULTI (Exit)	26.0	0.067	0.021	1.9490	
30 minute winter	26	Hydro-Brake®	7	0.4				5.7
15 minute winter	Swale 3 (Entry)	Swale 3 (link)	Swale 3 (Exit)	2.0	0.088	0.002	0.4832	
30 minute winter	27	Hydro-Brake®	9	0.5				5.2
360 minute winter	Swale 3 (Exit)	11.001	Swale MULTI (Exit)	2.3	0.240	0.427	0.1007	

Results for 100 year +30% CC Critical Storm Duration. Lowest mass balance: 70.03%

Node Event	US Node	Peak (mins)	Level (m)	Depth (m)	Inflow (l/s)	Node Vol (m³)	Flood (m³)	Status
15 minute winter	Swale 4 (Entry)	11	26.405	0.015	1.1	0.0283	0.0000	OK
240 minute winter	Swale MULTI (Exit)	184	26.361	1.088	61.9	1.2309	0.0000	SURCHARGED
15 minute winter	Swale 5 (Entry)	10	26.655	0.025	2.5	0.0523	0.0000	OK
30 minute winter	Swale 5 (Mid)	24	26.642	0.044	2.3	0.0770	0.0000	OK

Link Event (Outflow)	US Node	Link	DS Node	Outflow (l/s)	Velocity (m/s)	Flow/Cap	Link Vol (m³)	Discharge Vol (m³)
15 minute winter	Swale 4 (Entry)	Swale 4 (Link)	Rainwater Garden 2	1.0	0.099	0.001	0.0447	
30 minute winter	Swale MULTI (Exit)	10.002	6	-30.3	-1.720	-1.698	0.0524	
15 minute winter	Swale 5 (Entry)	Swale 5 (link)	Swale 5 (Mid)	2.7	0.119	0.005	0.3780	
30 minute summer	Swale 5 (Mid)	Swale 5 (link2)	Swale 5 (Exit)	2.6	0.105	0.005	0.4807	