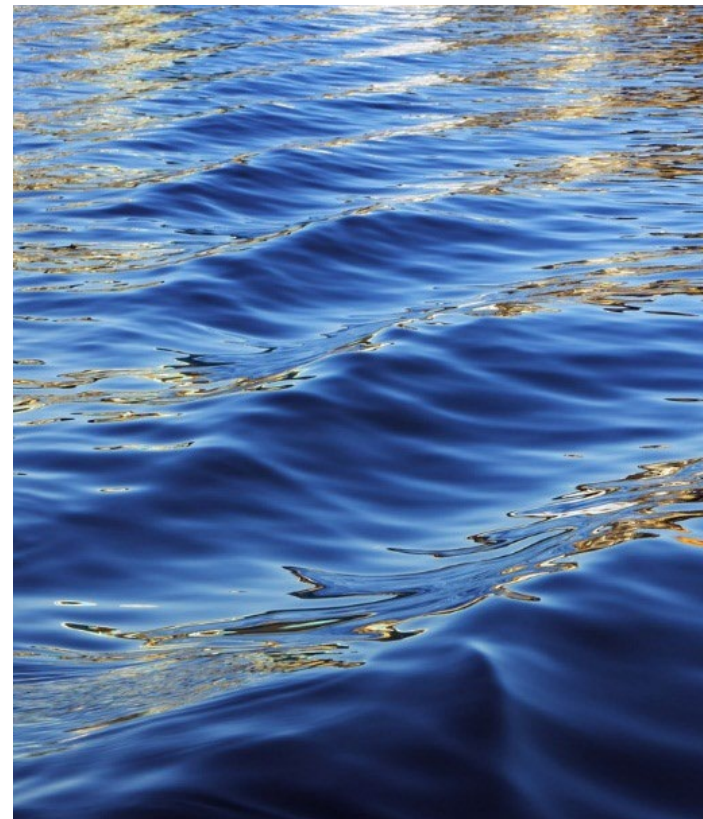


SuDS Design



Rainfall Data



- The first step in designing any Sustainable Drainage System (SuDS) is to understand the rainfall characteristics for the location of interest.
- This helps determine the intensity and volume of water the system needs to manage.

Rainfall Data



- In Sustainable Urban Drainage Systems (SUDS) design, M5-60 refers to the 60-minute rainfall depth with a return period of 5 years, based on historical rainfall records.

Rainfall Data

- It is commonly used for hydrological modelling and drainage design for the following reasons:
 - Standardised Design Storm



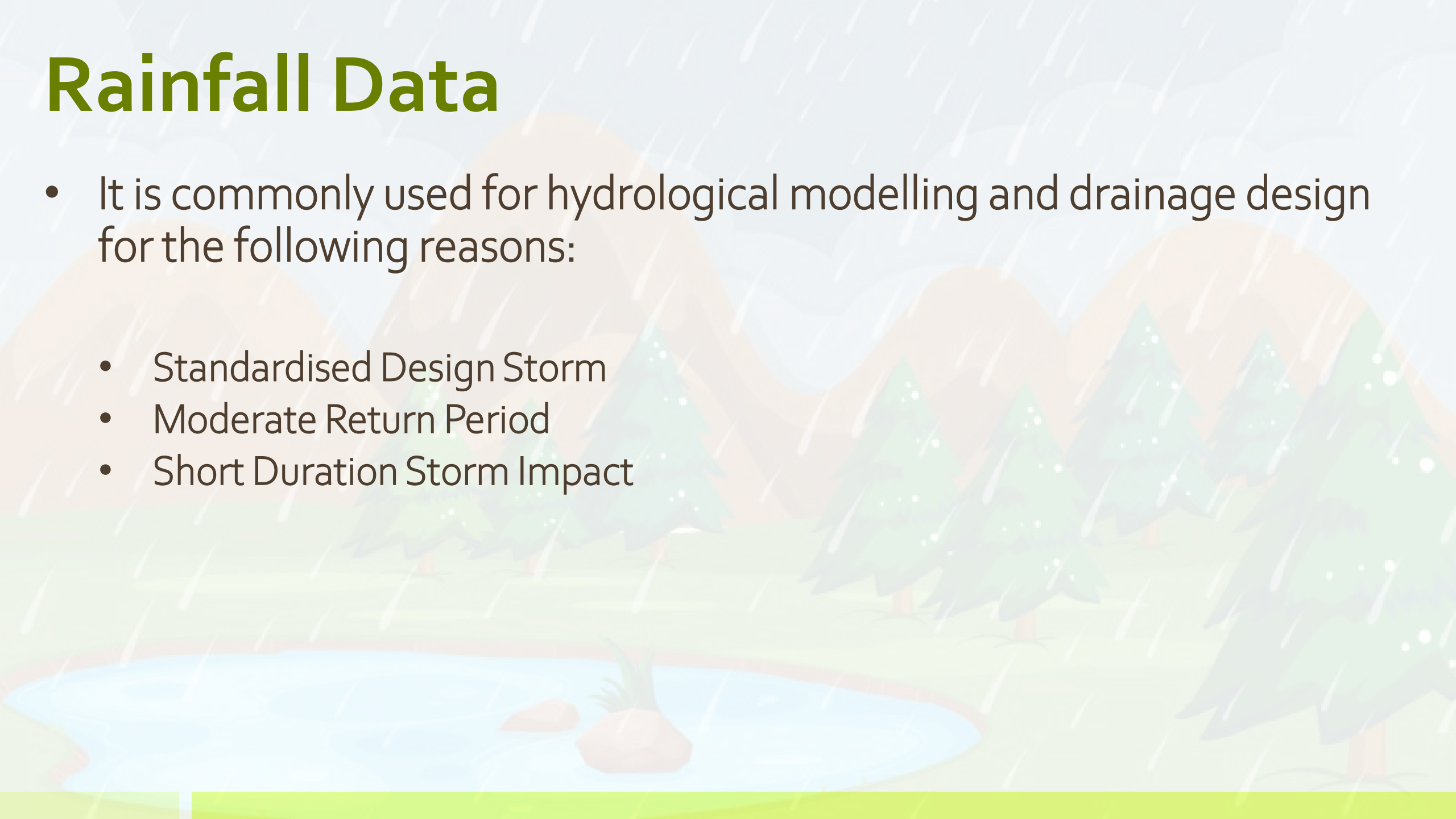
Rainfall Data

- It is commonly used for hydrological modelling and drainage design for the following reasons:
 - Standardised Design Storm
 - Moderate Return Period

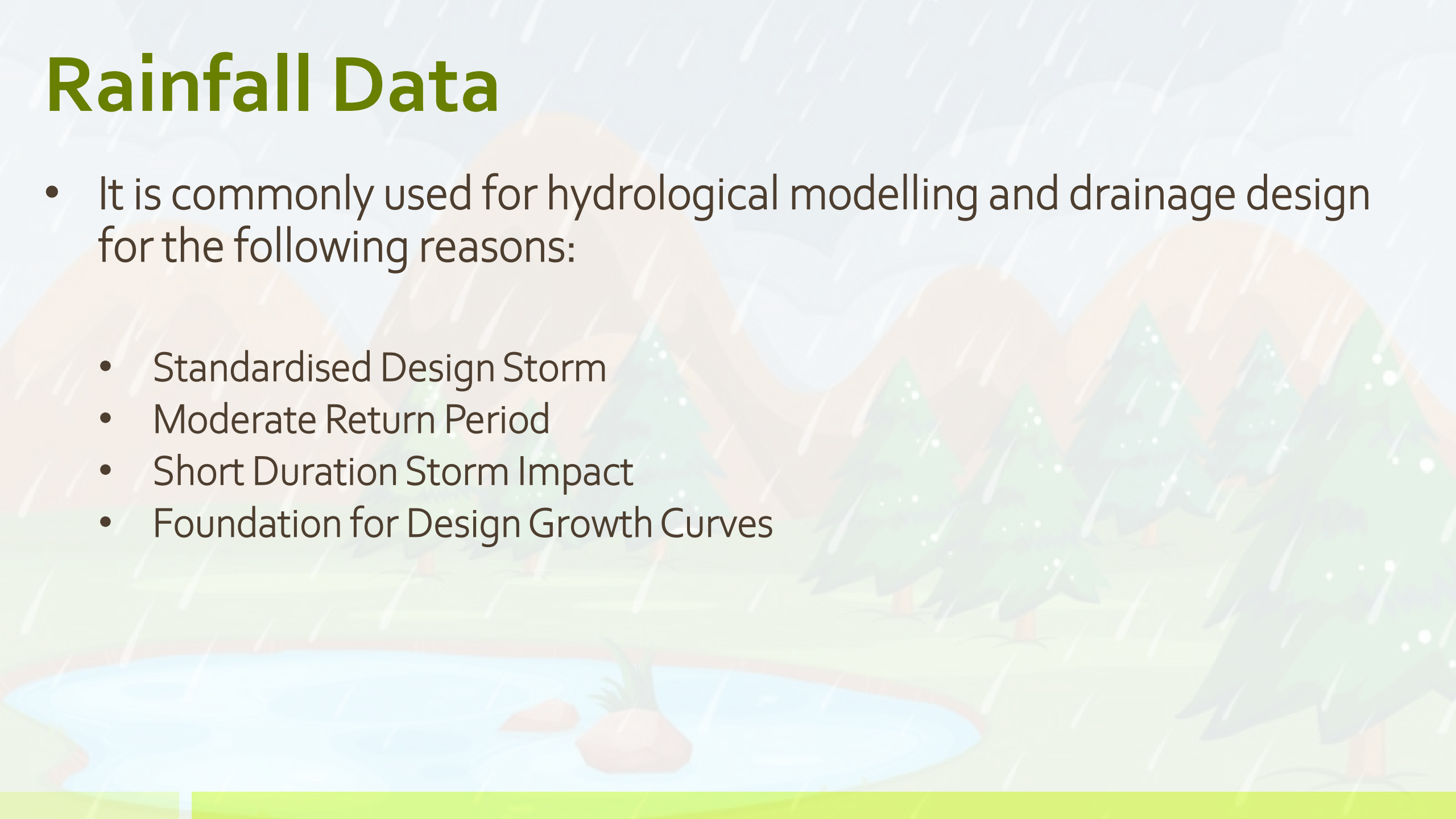


Rainfall Data

- It is commonly used for hydrological modelling and drainage design for the following reasons:
 - Standardised Design Storm
 - Moderate Return Period
 - Short Duration Storm Impact



Rainfall Data

The background of the slide is a stylized illustration of a rainy landscape. It features rolling hills in shades of orange and brown, several green coniferous trees, and a small blue pond in the foreground with some rocks. White diagonal lines represent falling rain across the entire scene.

- It is commonly used for hydrological modelling and drainage design for the following reasons:
 - Standardised Design Storm
 - Moderate Return Period
 - Short Duration Storm Impact
 - Foundation for Design Growth Curves

Rainfall Data

- It is commonly used for hydrological modelling and drainage design for the following reasons:
 - Standardised Design Storm
 - Moderate Return Period
 - Short Duration Storm Impact
 - Foundation for Design Growth Curves
 - Alignment with Industry Standards

Rainfall Data



Using the FEH web services, the estimated rainfall depths for Swansea are:

$M_{5-60}=17\text{mm}$

Peak Runoff - Example

$$Q = 2.78 \times C \times i \times A$$

Where:

Q= Peak Runoff Rate (m³/s)

C= Runoff Co-efficient (depends on land use)

i = Rainfall intensity (mm/h)

A= Catchment area in hectares

Peak Runoff - Example

Calculate the peak runoff for a 1.01 hectare site using the following values:

$$C = 0.75$$

$$i = 17\text{mm/h}$$



Peak Runoff - Example

$$Q = 2.78 \times 0.75 \times 17 \times 1.01$$

$$Q = 35.8 \text{ l/s}$$

Greenfield Runoff Rate Estimation



Greenfield runoff rate (Q_{bar}) is the natural runoff from an undeveloped site and is used as a benchmark for limiting discharge in new developments.

Greenfield Runoff Rate Estimation

$$Q_{\text{bar}} = 0.00108 \times \text{Area}^{0.89} \times \text{SAAR}^{1.17} \times \text{SOIL}^{2.17}$$

Where:

Q_{bar} = Mean Annual Flood (m^3/s)

AREA = Area of catchment in km^2

SAAR = Standard Average Annual Rainfall for the period 1941-1970 in mm

SOIL = Soil Index

Greenfield Runoff - Example

Calculate the peak runoff for our 1.01 hectare site using the following values:

AREA = 0.5

SAAR = 1136

SOIL = 0.37



Greenfield Runoff - Example

$$Q_{\text{bar}} = 0.00108 \times 0.5^{0.89} \times 1136^{1.17} \times 0.37^{2.17}$$

$$Q_{\text{bar}} = 0.2531 \text{m}^3/\text{s} \text{ (for 50 ha site)}$$

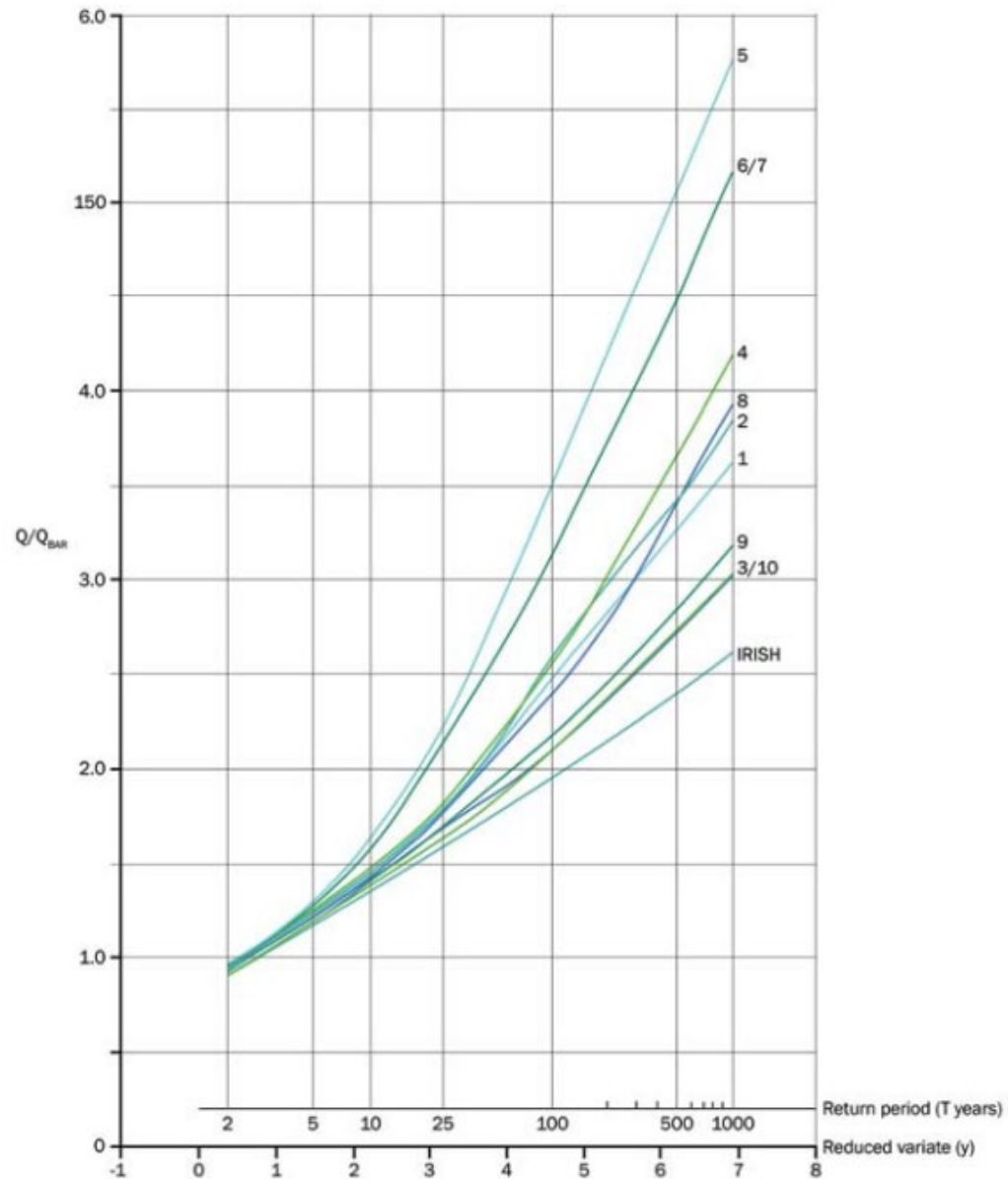
$$Q_{\text{bar}} = 253 \div 50 = 5.06 \text{l/s/ha}$$

$$Q_{\text{bar}} = 5.06 \times 1.01 = 5.11 \text{l/s}$$

Hydrological Areas



Growth Curves



Growth Curve Factors

UK and Ireland growth curve factors (after NERC, 1993)

Hydrometric area	Return period								
	1 ¹	2	5	10	25	30 ²	50	100	500
1	0.85	0.90	1.20	1.45	1.81	1.99	2.12	2.48	3.25
2	0.87	0.91	1.11	1.42	1.81	1.99	2.17	2.63	3.45
3	0.86	0.94	1.25	1.45	1.70	1.75	1.90	2.08	2.73
9	0.88	0.93	1.21	1.42	1.71	1.80	1.94	2.18	2.86
10	0.87	0.93	1.19	1.38	1.64	1.70	1.85	2.08	2.73
4	0.83	0.89	1.23	1.49	1.87	1.99	2.20	2.57	3.62
5	0.87	0.89	1.29	1.65	2.25	2.55	2.83	3.56	5.02
6/7	0.85	0.88	1.28	1.62	2.14	2.40	2.62	3.19	4.49
8	0.78	0.88	1.23	1.49	1.84	1.98	2.12	2.42	3.41
Ireland	0.83 ²	0.95	1.20	1.37	1.60	1.65	1.77	1.96	2.40

Estimating Storage Volume

$$\text{Volume} = (\text{Inflow Rate} - \text{Outflow Rate}) \times \text{Duration}$$

Where:

Inflow Rate = Peak Runoff (Q)

Outflow Rate = Greenfield Runoff (Q_{bar})

Duration = Length of Storm

Storage Volume- Example

Calculate the peak runoff for our 1.01 hectare site based on a M5-60 storm.



Estimating Storage Volume

$$\text{Volume} = (35.8 - 5.11) \times (60 \times 60)$$

$$\text{Volume} = 30.69 \times 3600$$

$$\text{Volume} = 110484 \text{ l} = 110.5 \text{ m}^3$$

Estimating Storage Volume

Media Type	SVP	VFC	SVP(1-VFC)
Sand	0.30	0.25	0.225
Soil	0.40	0.35	0.260
Gravel	0.30	0.15	0.255
Green Roof Mix	0.23	0.35	0.150
Geocellular Module	0.95	0	0.950
Sub-base	0.30	0.35	0.195
Geocomposite Layer	0.50	0.0	0.500
Void	1.00	0	1.000

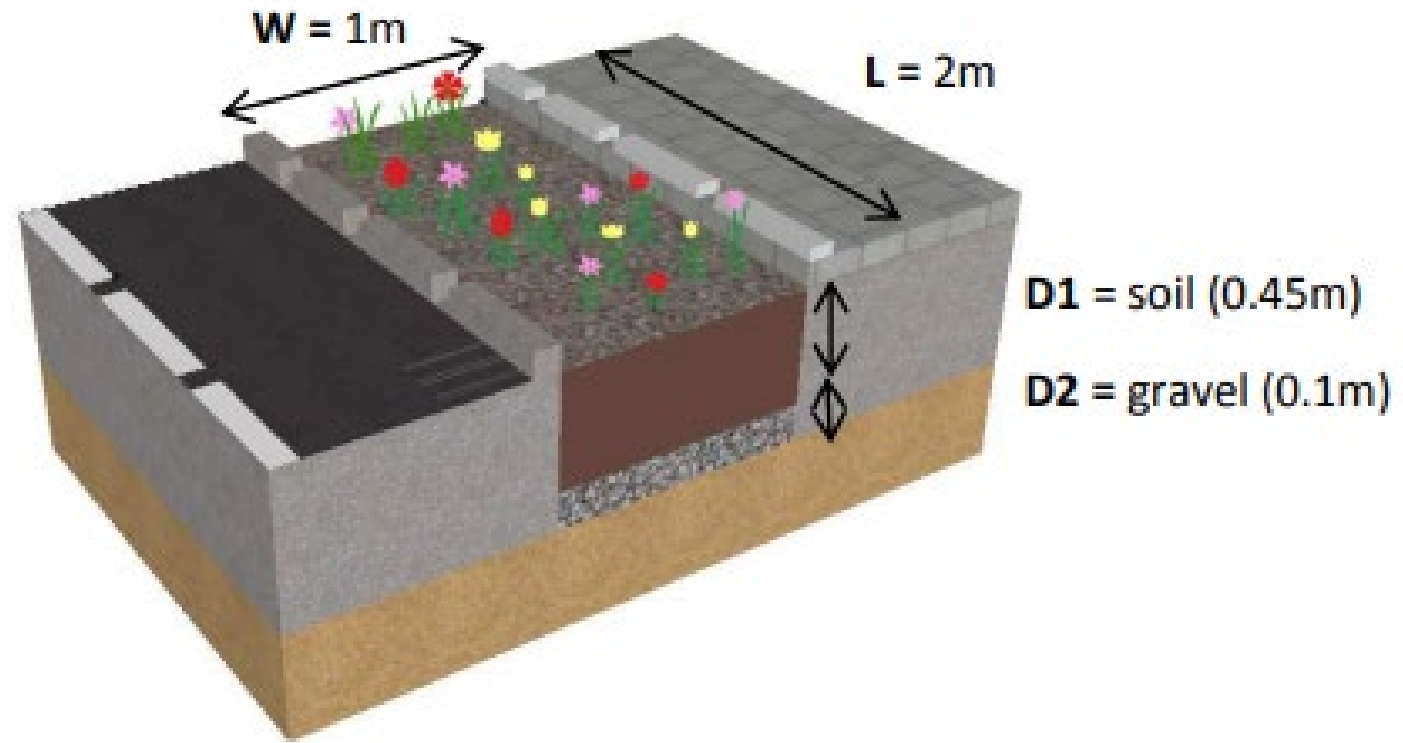
Rain Garden – Example

Calculation for estimating
volume of soil

$$V = L \times W \times D_1$$

$$V = 2.0 \times 1.0 \times 0.45$$

$$V = 0.9\text{m}^3$$



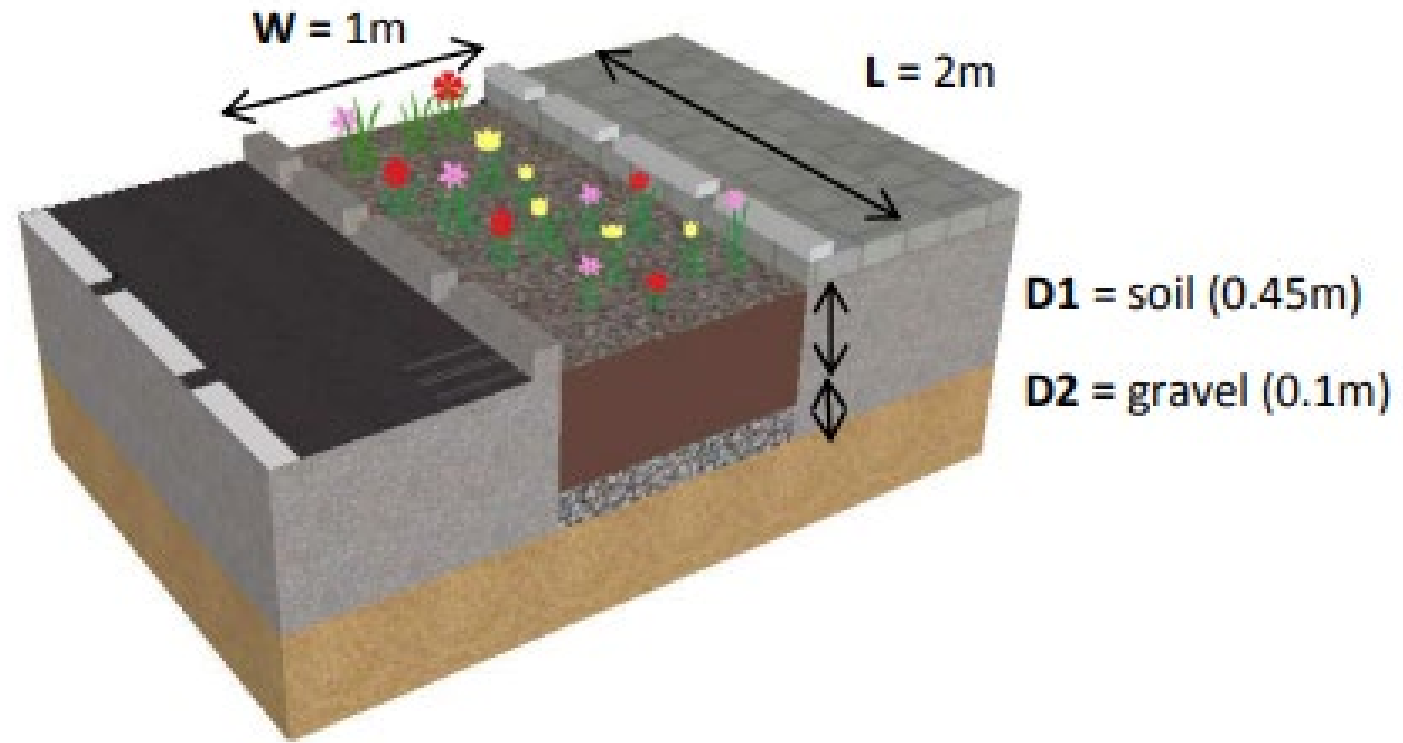
Rain Garden – Example

Calculation for estimating storage volume of soil

$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 0.9 \times 0.26$$

$$V_s = 0.234 \text{ m}^3$$



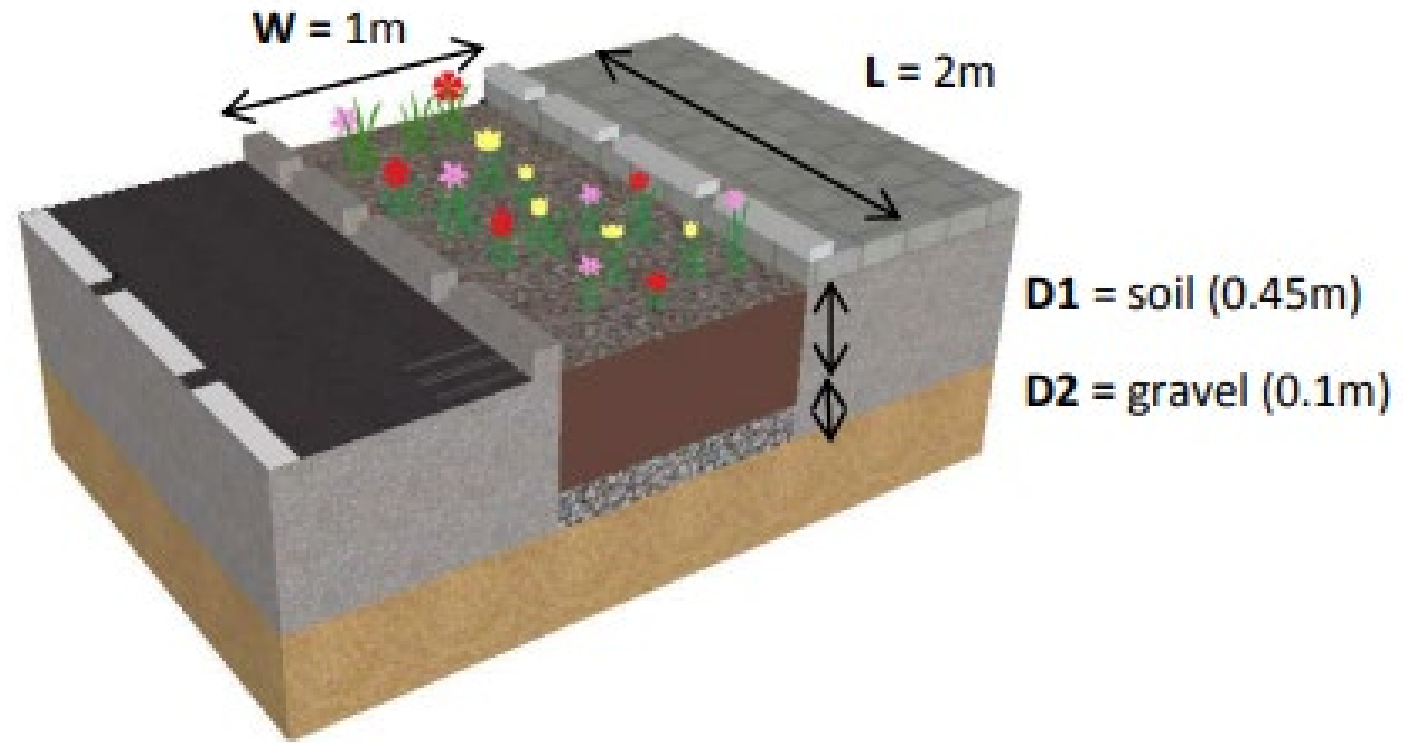
Rain Garden – Example

Calculation for estimating
volume of gravel

$$V = L \times W \times D_1$$

$$V = 2.0 \times 1.0 \times 0.1$$

$$V = 0.2 \text{ m}^3$$



Rain Garden – Example

Calculation for estimating storage volume of gravel

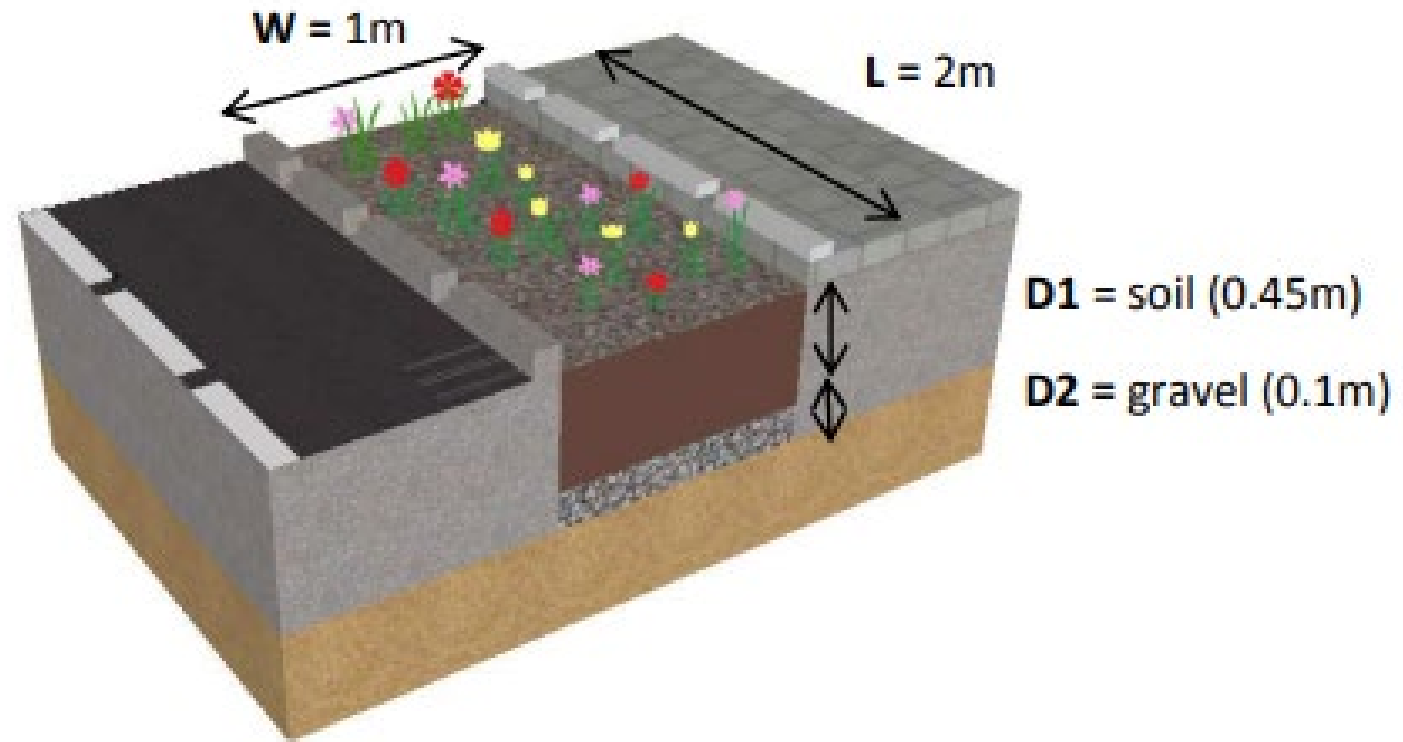
$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 0.2 \times 0.255$$

$$V_s = 0.051\text{m}^3$$

$$\text{Total storage} = 0.235 + 0.051$$

$$\text{Total storage} = 0.285\text{m}^3$$



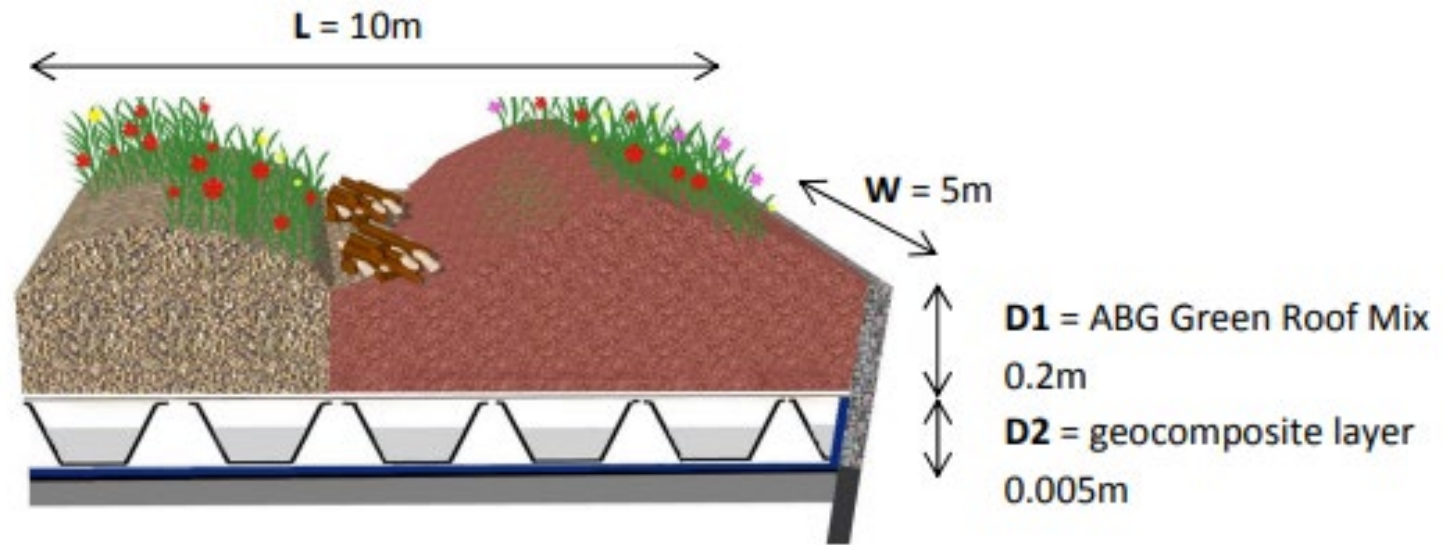
Green Roof – Example

Calculation for estimating
volume of Green Roof Mix

$$V = L \times W \times D_1$$

$$V = 10.0 \times 5 \times 0.2$$

$$V = 10.0 \text{ m}^3$$



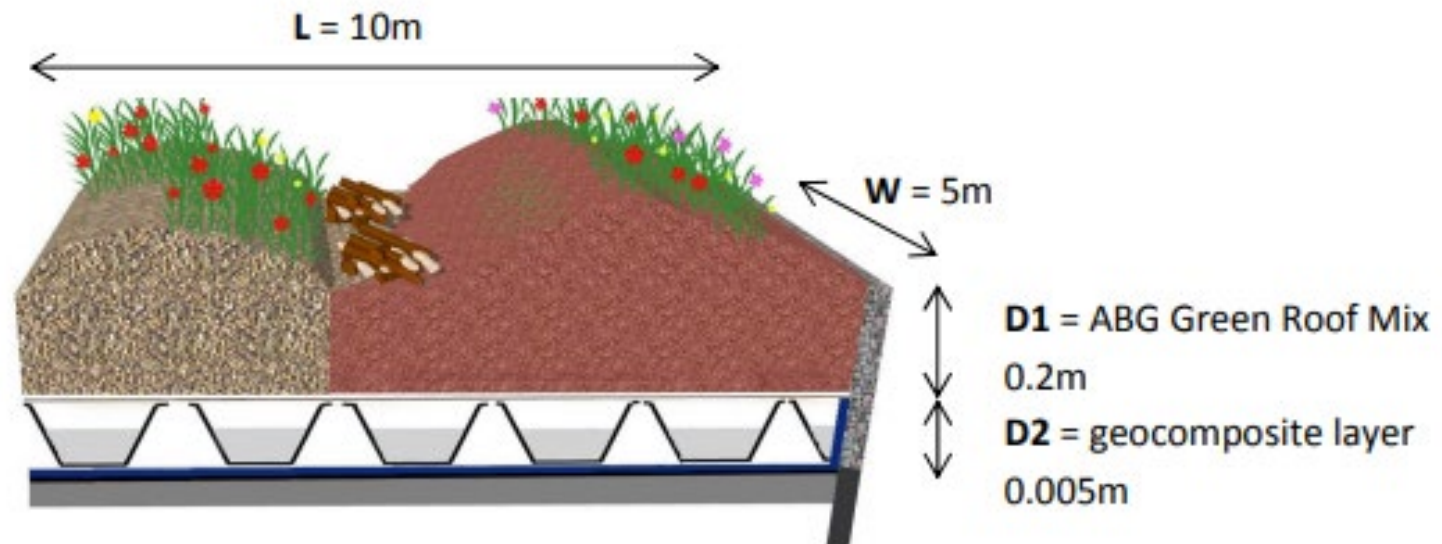
Green Roof – Example

Calculation for estimating
storage volume of Green
Roof Mix

$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 10 \times 0.15$$

$$V_s = 1.5 \text{m}^3$$



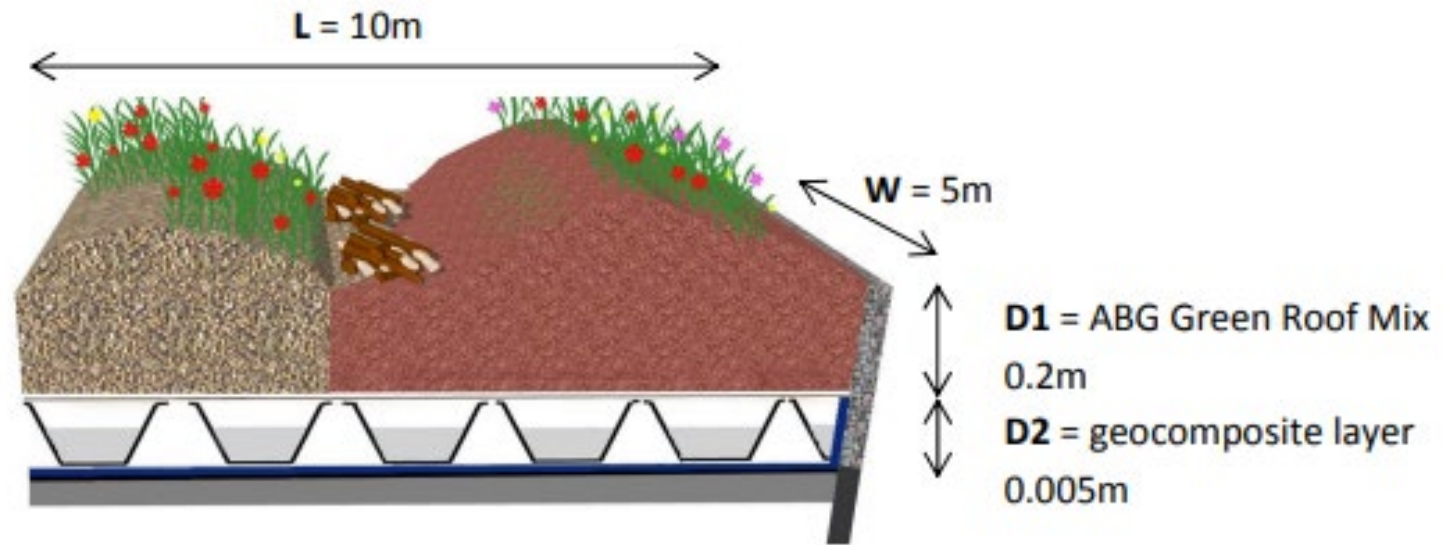
Green Roof – Example

Calculation for estimating
volume of Geocomposite
Layer

$$V = L \times W \times D_1$$

$$V = 10.0 \times 5 \times 0.005$$

$$V = 0.25\text{m}^3$$



Green Roof – Example

Calculation for estimating
storage volume of
Geocomposite Layer

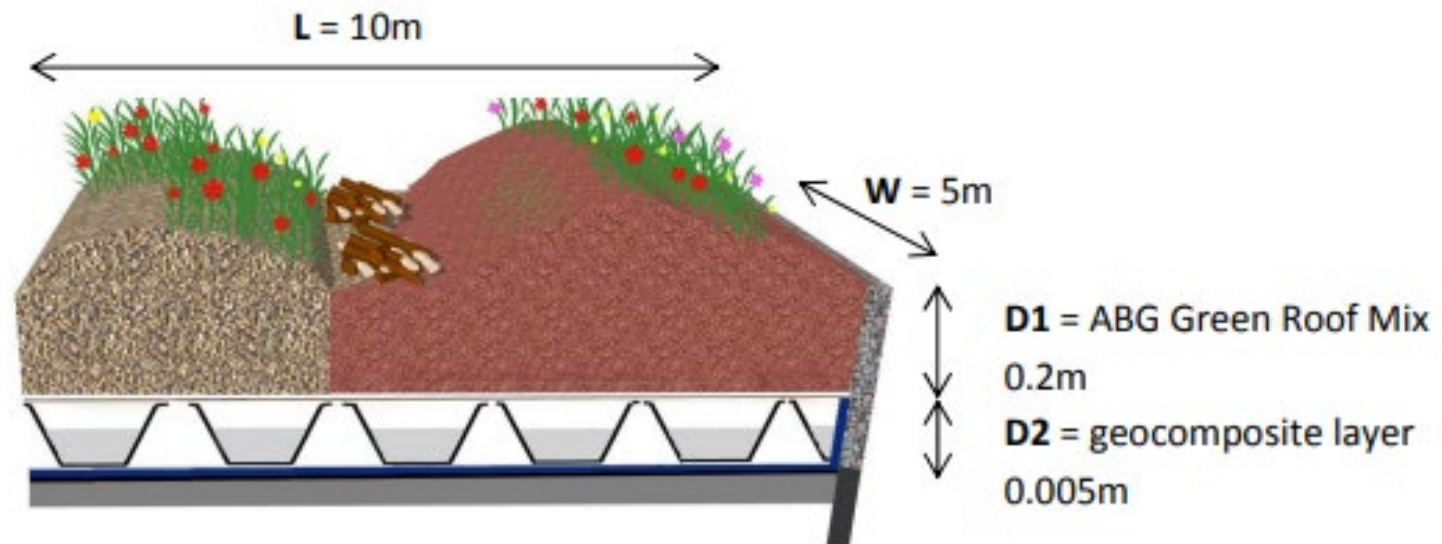
$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 0.25 \times 0.50$$

$$V_s = 0.125\text{m}^3$$

$$\text{Total storage} = 1.5 + 0.125$$

$$\text{Total storage} = 1.625\text{m}^3$$



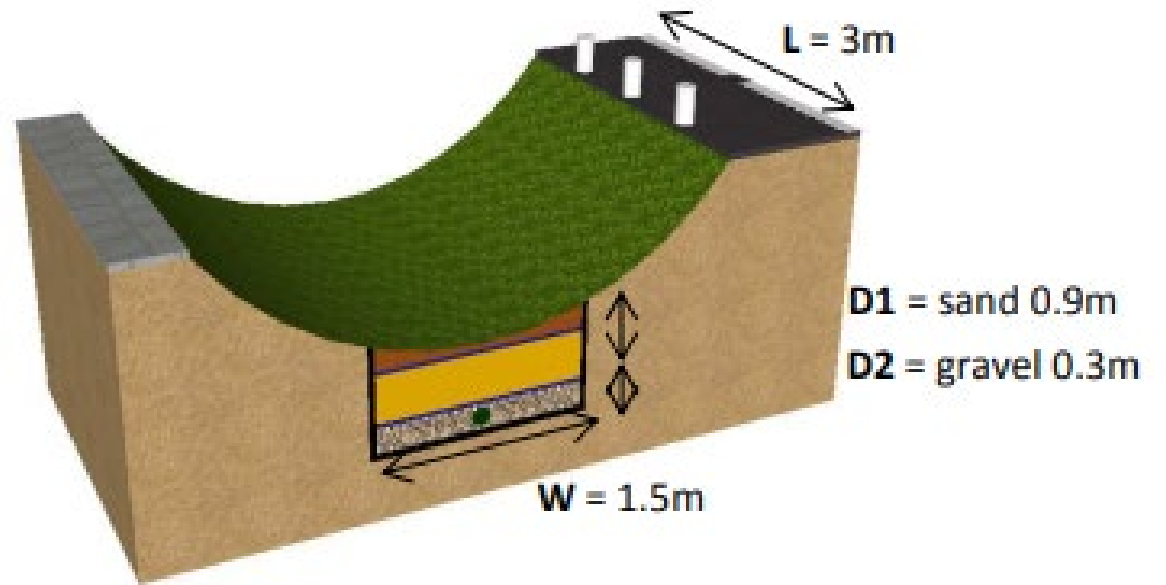
Swale – Example

Calculation for estimating
volume of Sand

$$V = L \times W \times D_1$$

$$V = 3.0 \times 1.5 \times 0.9$$

$$V = 4.05\text{m}^3$$



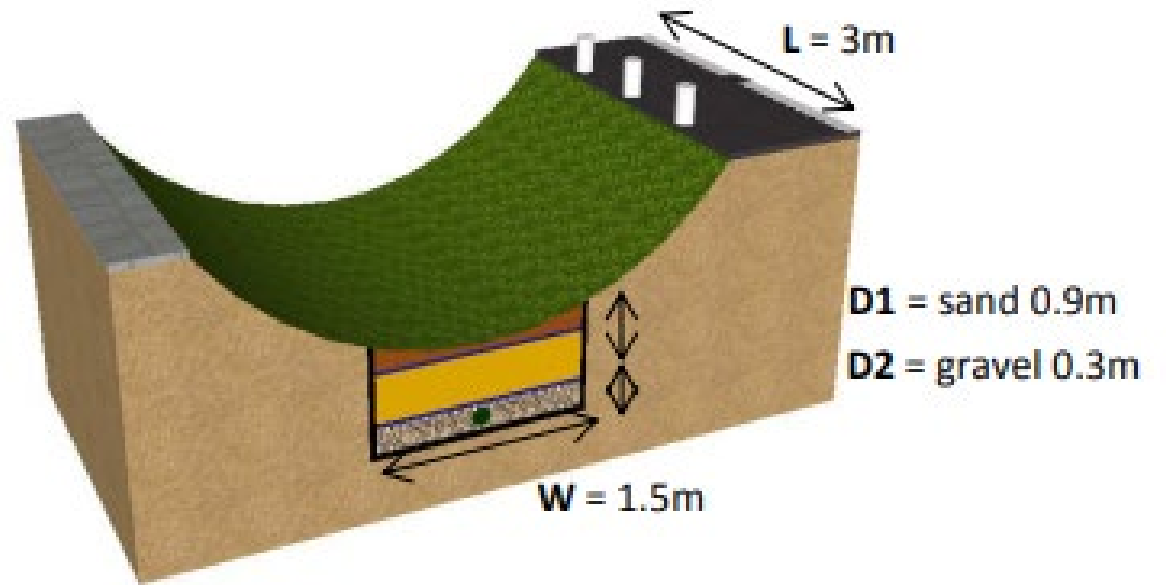
Swale – Example

Calculation for estimating storage volume of Sand

$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 4.05 \times 0.225$$

$$V_s = 0.911\text{m}^3$$



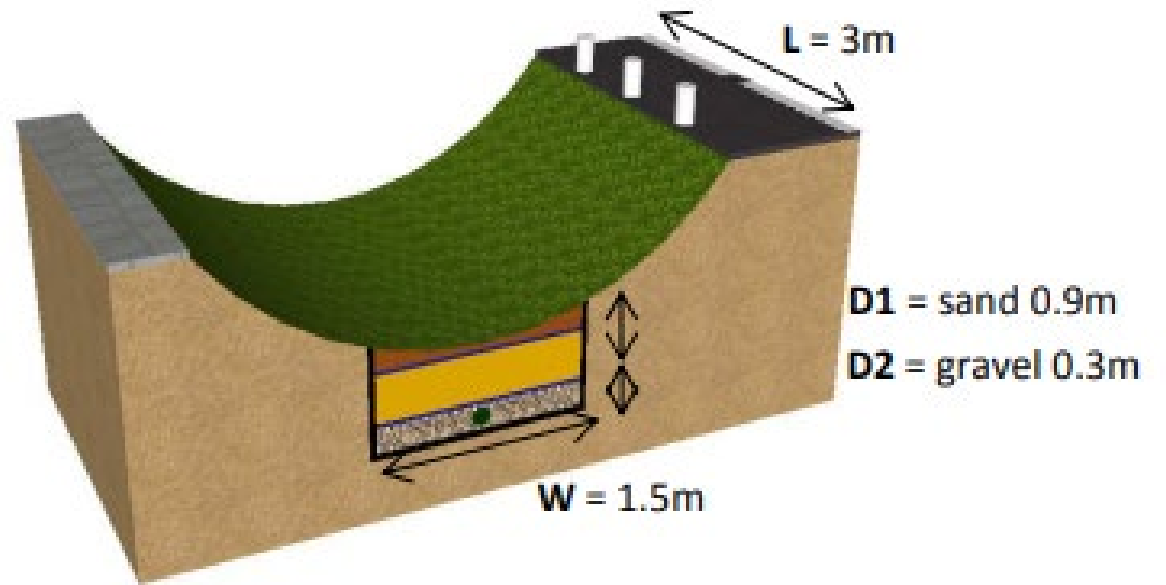
Swale – Example

Calculation for estimating
volume of Gravel

$$V = L \times W \times D_1$$

$$V = 3.0 \times 1.5 \times 0.3$$

$$V = 1.35\text{m}^3$$



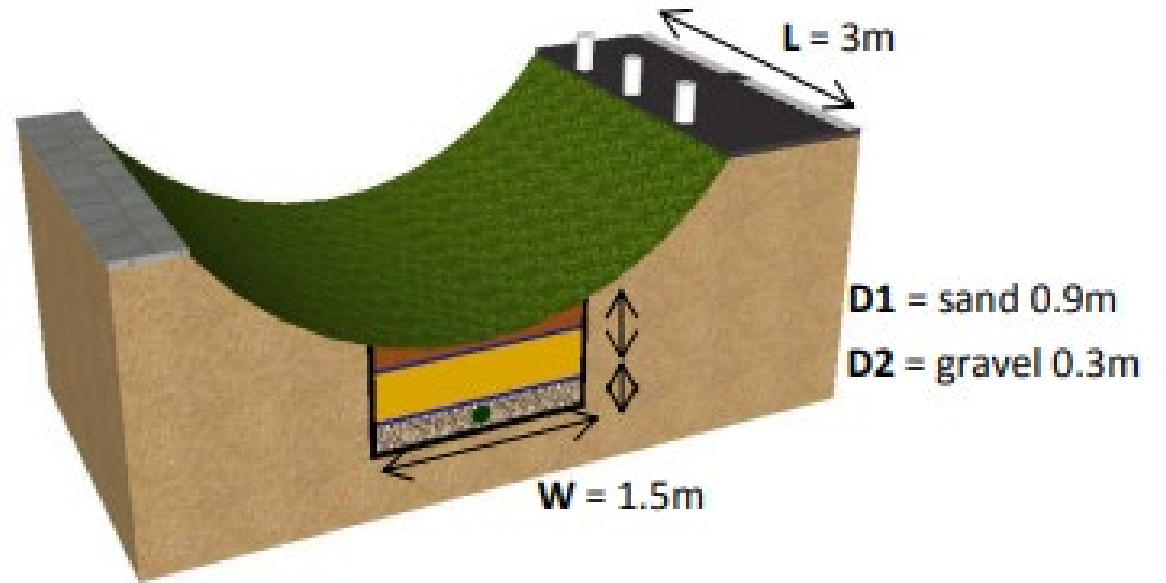
Swale – Example

Calculation for estimating
storage volume of Gravel

$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 1.35 \times 0.255$$

$$V_s = 0.344 \text{ m}^3$$



Swale – Example

Calculation for estimating
(storage) volume of swale

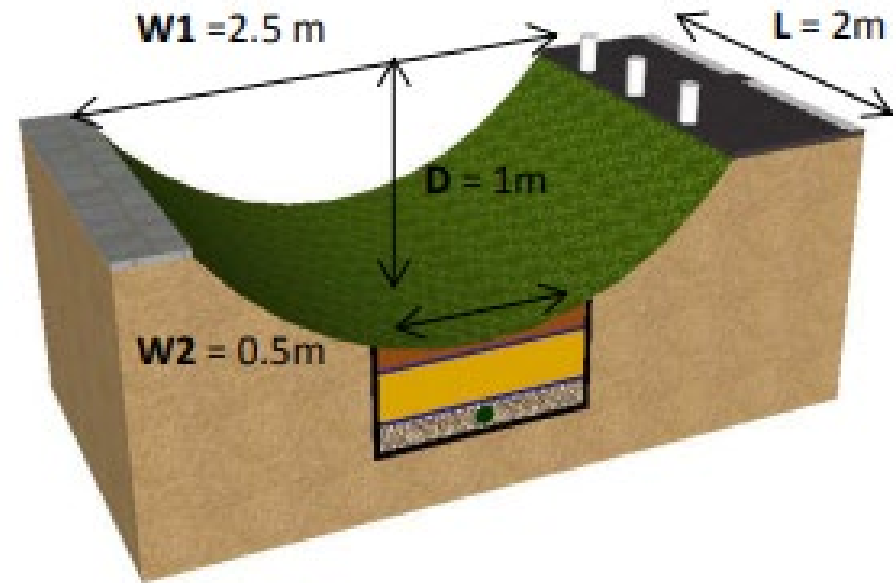
$$V = 0.5 \times D \times (W_1 + W_2) \times L$$

$$V = 0.5 \times 1 \times (2.5 + 0.5) \times 2$$

$$V = 3.0 \text{ m}^3$$

$$\text{Total storage} = 0.911 + 0.344 + 3.0$$

$$\text{Total storage} = 4.255 \text{ m}^3$$



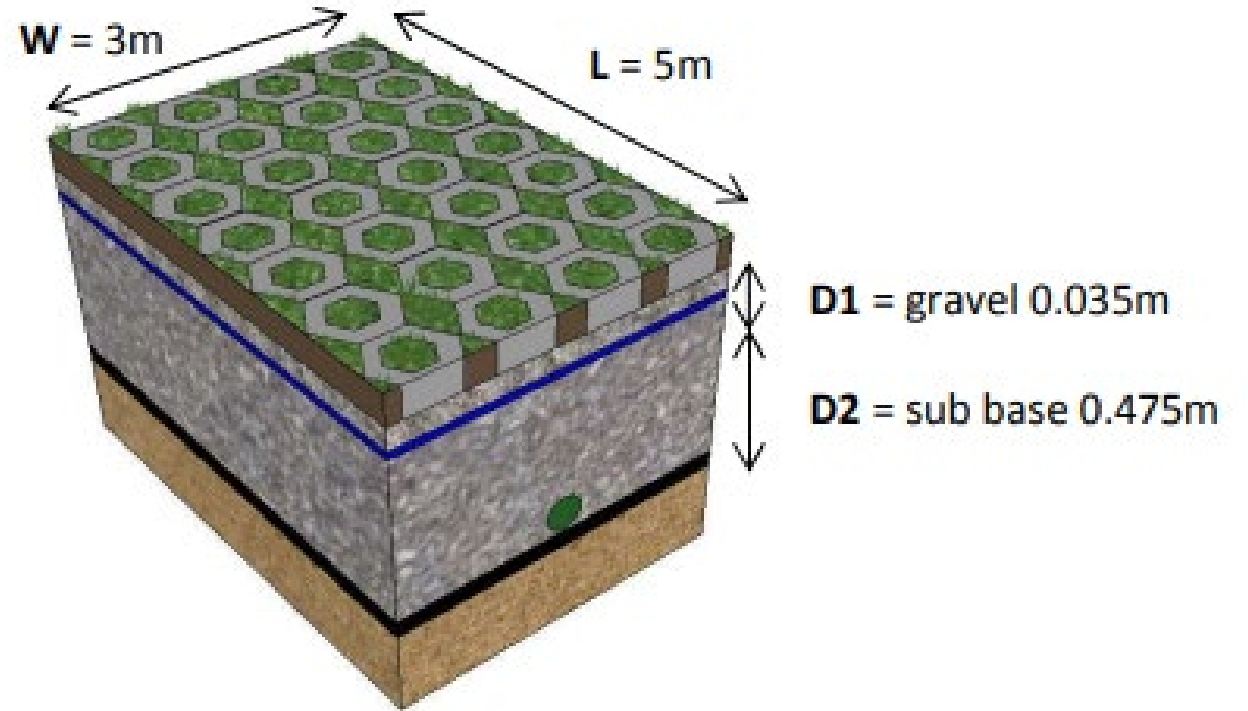
Permeable Paving – Example

Calculation for estimating
volume of gravel

$$V = L \times W \times D_1$$

$$V_s = 5 \times 3 \times 0.035$$

$$V_s = 0.525 \text{m}^3$$



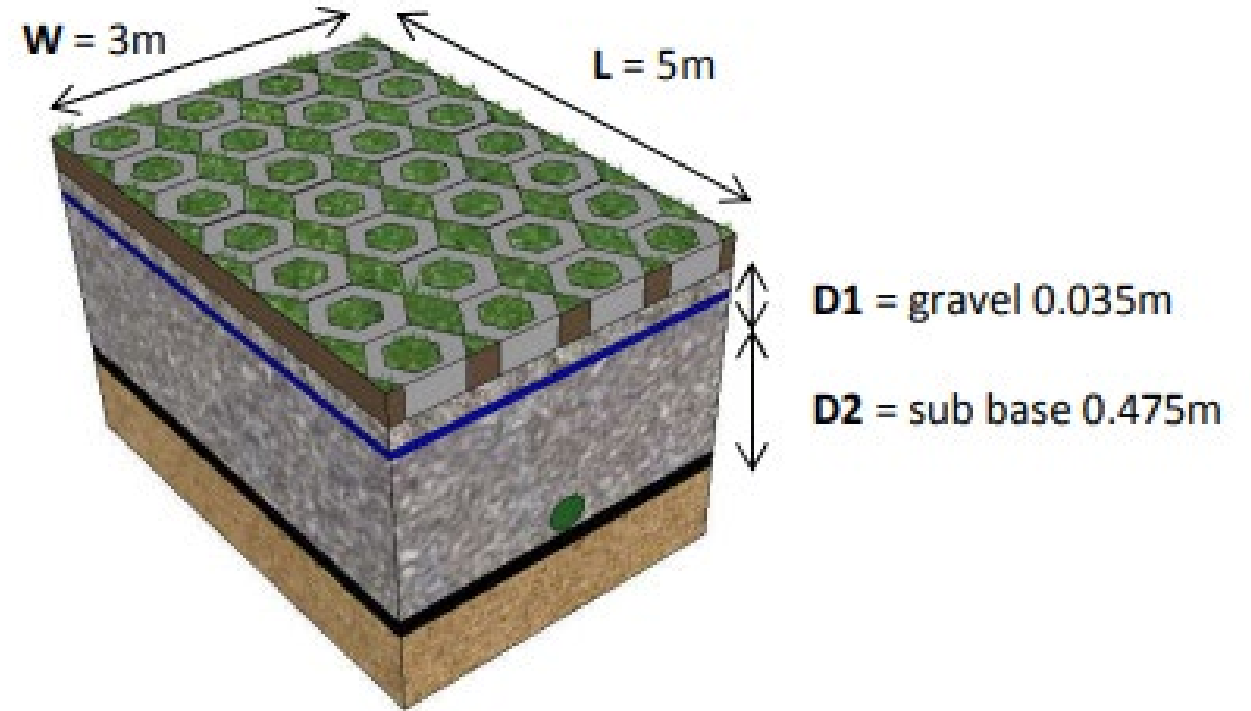
Permeable Paving – Example

Calculation for estimating storage volume of gravel

$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 0.525 \times 0.255$$

$$V_s = 0.134 \text{ m}^3$$



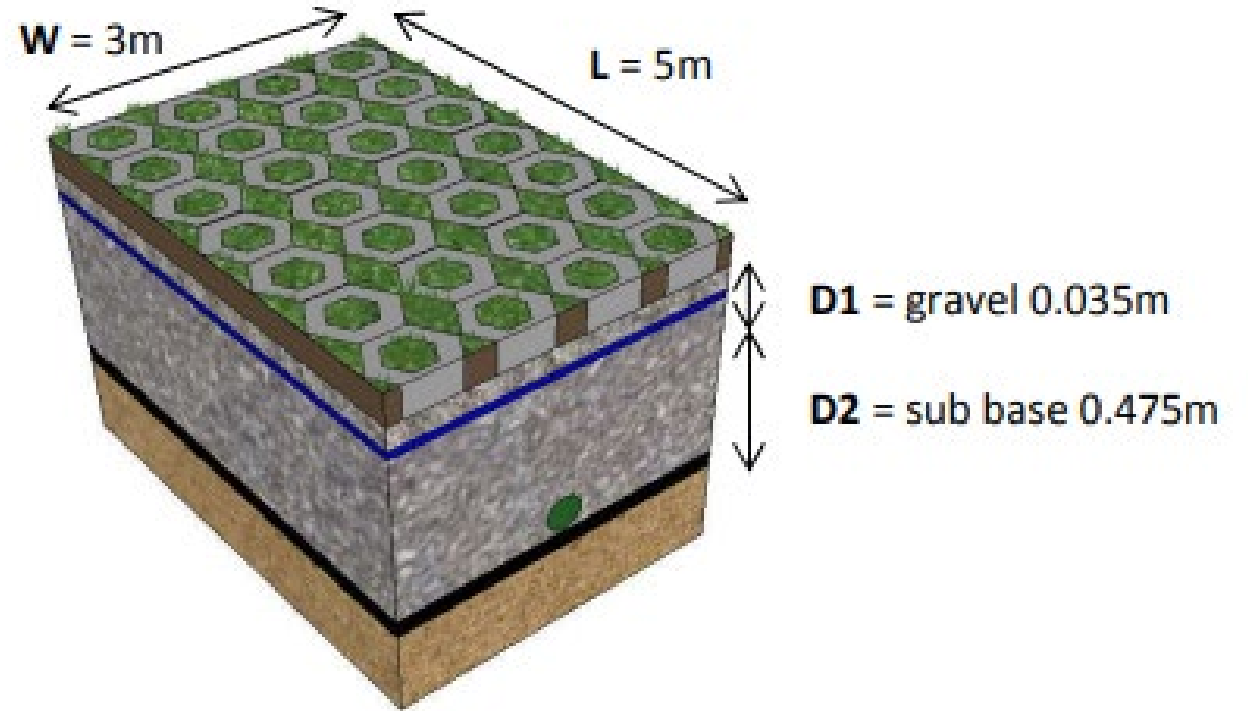
Permeable Paving – Example

Calculation for estimating
volume of sub base

$$V = L \times W \times D_1$$

$$V_s = 5 \times 3 \times 0.475$$

$$V_s = 7.125\text{m}^3$$



Permeable Paving – Example

Calculation for estimating storage volume of gravel

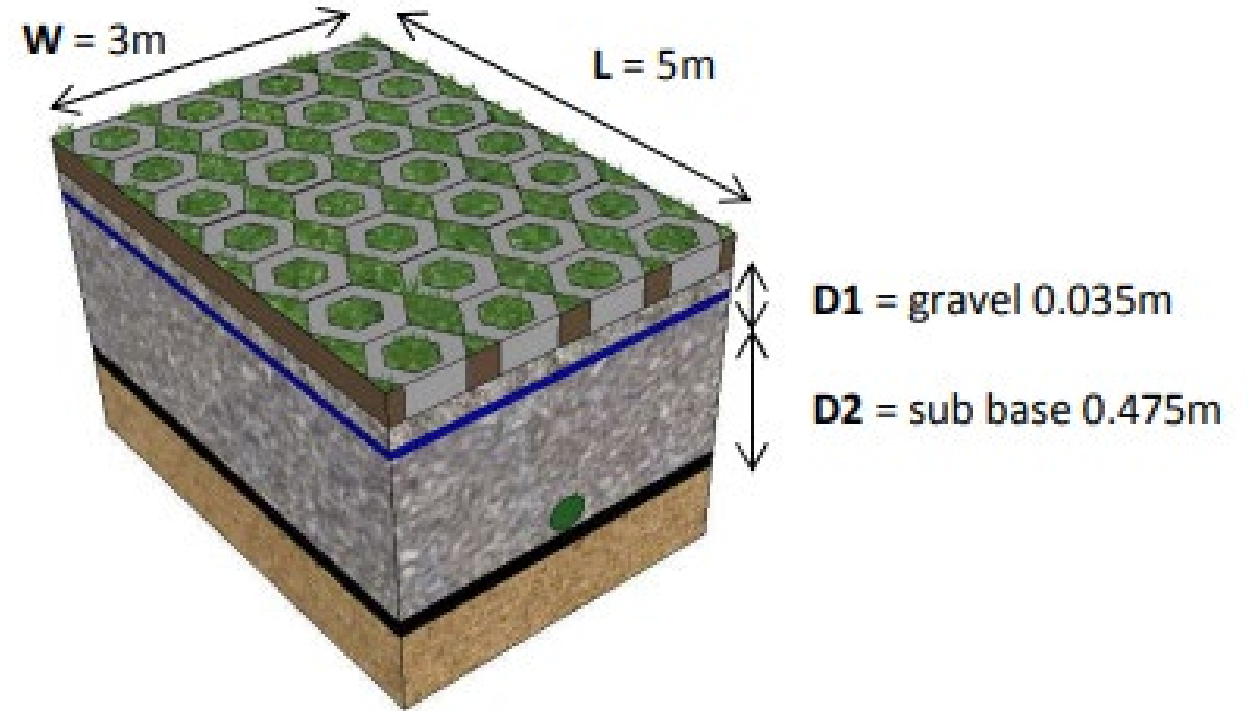
$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 7.125 \times 0.195$$

$$V_s = 1.40 \text{ m}^3$$

$$\text{Total storage} = 0.134 + 1.40$$

$$\text{Total storage} = 1.52 \text{ m}^3$$



Permeable Paving – Example

Calculation for estimating storage volume of gravel

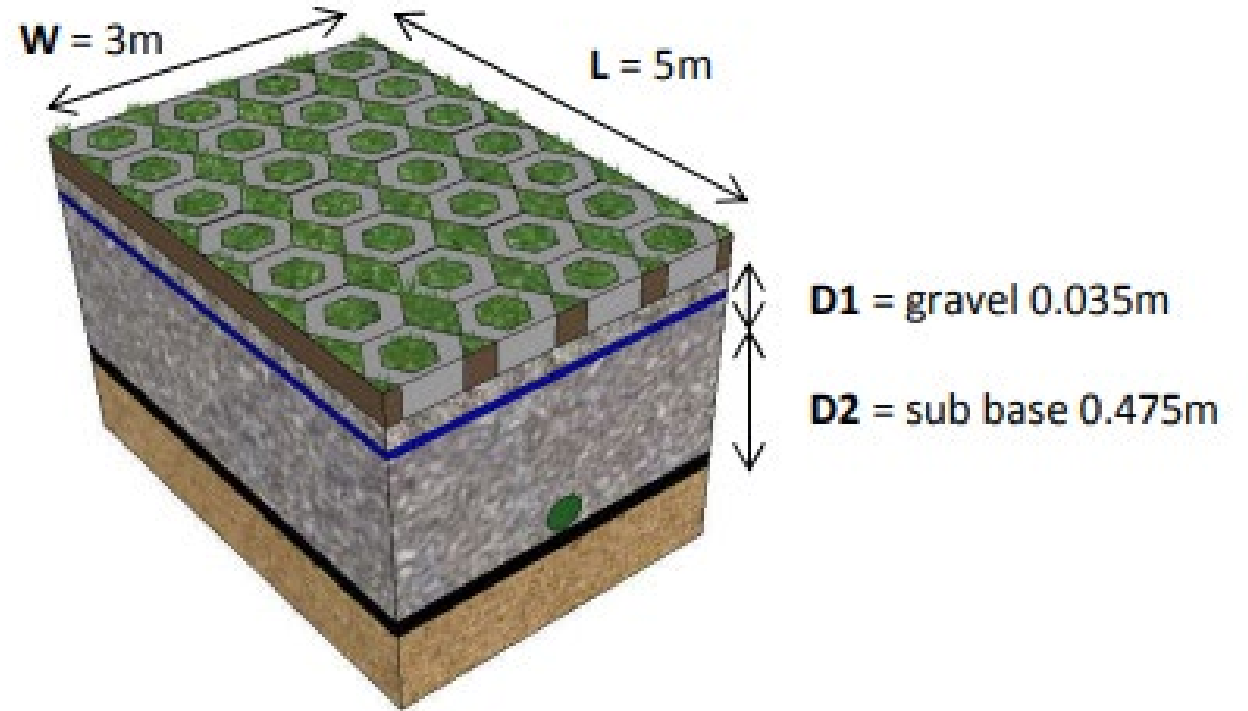
$$V_s = V \times SVP(1 - VFC)$$

$$V_s = 7.125 \times 0.195$$

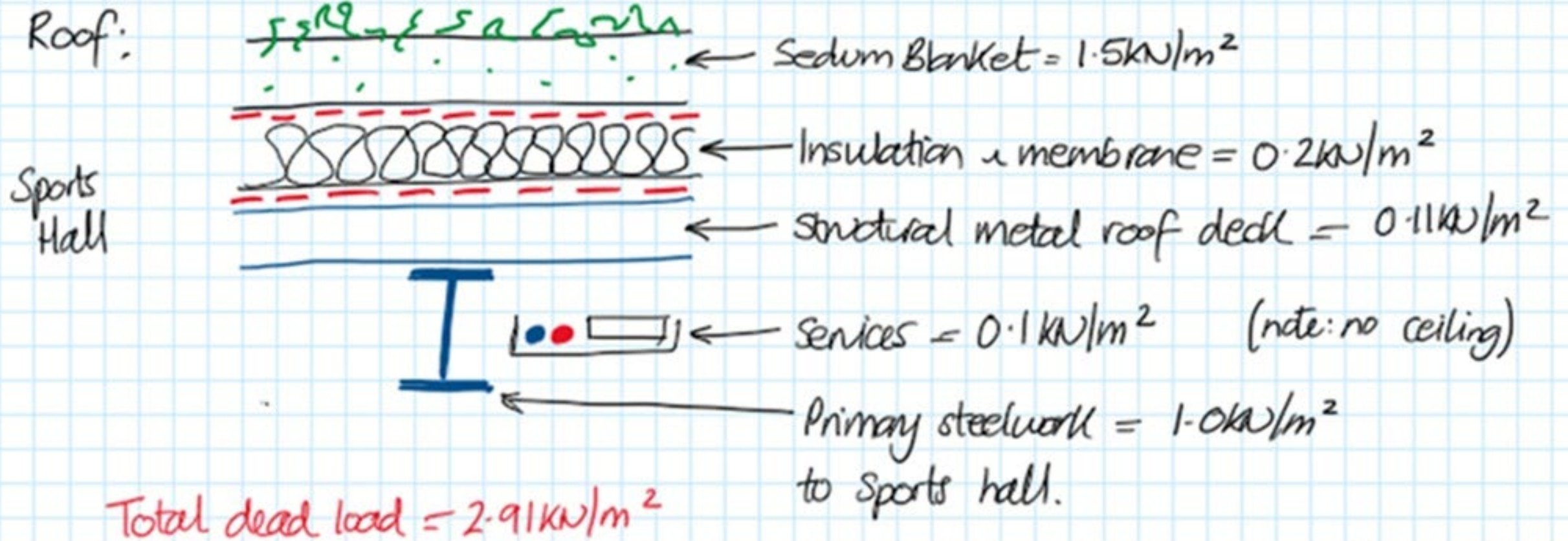
$$V_s = 1.40 \text{m}^3$$

$$\text{Total storage} = 0.134 + 1.40$$

$$\text{Total storage} = 1.52 \text{m}^3$$



Green Roof – Loading Example



Rainwater Harvesting – Example

Estimation of yield (runoff from roof)

$$Y_R = A \times e \times AAR \times \eta \times 0.05$$

Where:

Y_R = Runoff Volume (Yield) (l)

A = Collecting Runoff Area (m²)

e = Runoff (yield) coefficient

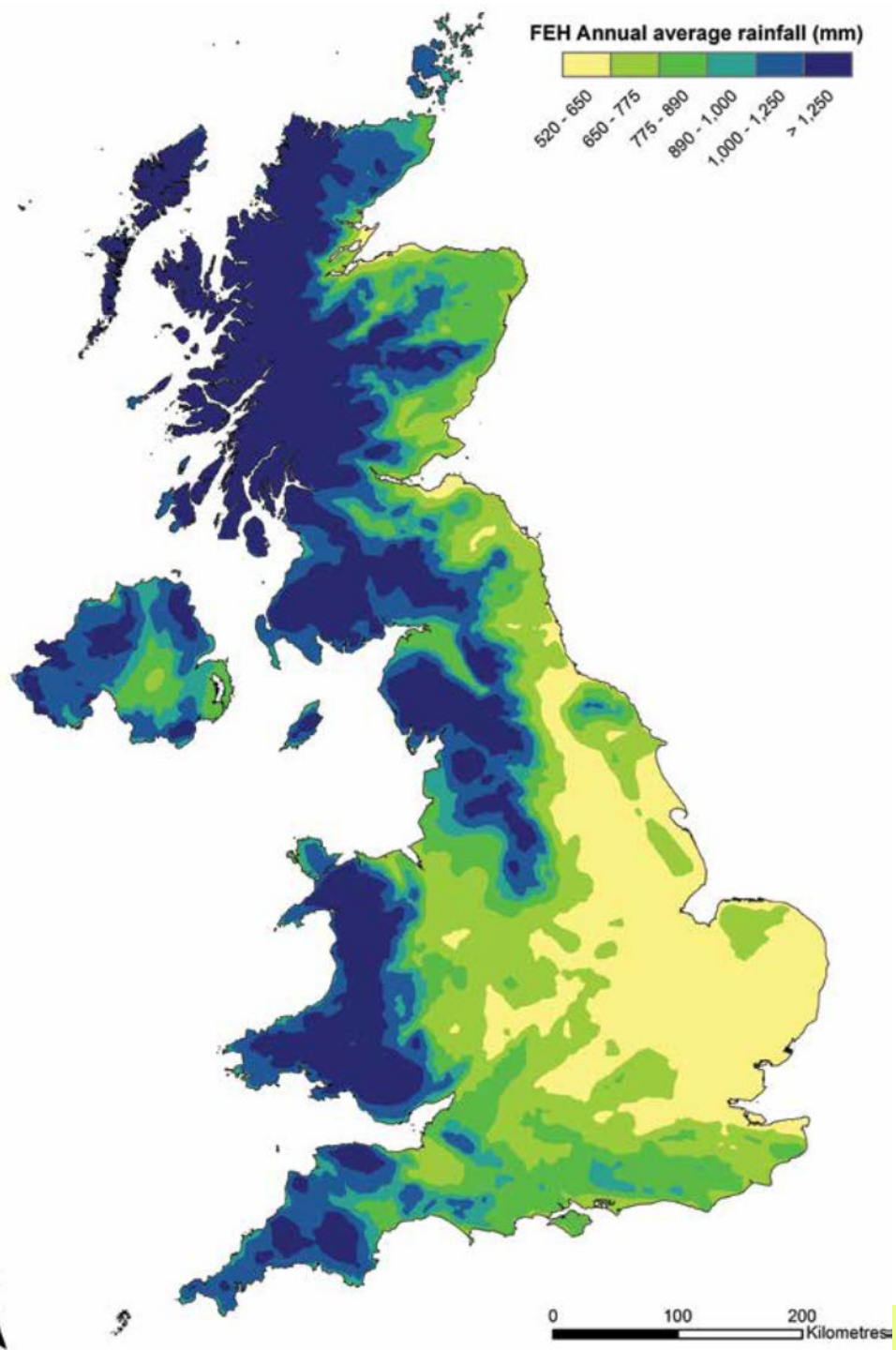
AAR = Average Annual Rainfall Depth (mm)

η = Hydraulic Filter Efficiency

Rainwater Harvesting - Example

Calculate the yield (runoff from roof) of the proposed building with flat roof area of 3250m^2





Average Annual Rainfall

(CIRIA, 2015)

Rainwater Harvesting - Example

Surface type	Runoff coefficient
Pitched roof with profiled metal sheeting	0.95
Pitched roof with tiles	0.90
Flat roof without gravel	0.80
Flat roof with gravel	0.60
Green roof, intensive ¹	0.30
Green roof, extensive ¹	0.60
Permeable pavement (concrete blocks) ²	0.60
Road/pavement	0.75

Rainwater Harvesting – Example

Estimation of yield (runoff from roof)

$$Y_R = A \times e \times AAR \times \eta$$

$$Y_R = 3250 \times 0.8 \times (1250/1000) \times 0.9$$

$$Y_R = 2925\text{m}^3 = 2925000\text{l}$$

Rainwater Harvesting - Example

Assume there are 800 students using the building in a day, with 10% of them using the toilet 1 time. Calculate the approximate demand for water for toilet flushing.



Rainwater Harvesting – Example

Estimation of non potable water demand

$$D_n = (800 \times 0.1) \times 4.5 \times 365$$

$$D_n = 131400\text{l}$$

Rainwater Harvesting – Example

Yield Demand Ratio YR/Dn needs to be <0.95 for effective surface water management. Therefore, the maximum area of roof from which runoff can be harvested is:

$$=(0.95 \times 131400)/(1.250 \times 0.80 \times 0.9 \times 1000)$$

$$= 124830 / 900$$

$$= 138\text{m}^2$$

Costs

Table 1-2: Indicative costs for SUDS options

Option	Unit cost	Source
Green roofs	£90/m ² - covered roof with sedum mat £80/m ² - biodiverse roof (varied covering of plants, growing medium and aggregates) Variable costs for Sedum blanket , turf and growing medium roof options	Bamfield, 2005. Bamfield, 2005. Rawlinson, 2006
Simple rainwater harvesting (water butts)	£100 - £243 per property (includes installation and connection pipe)	Stovin & Swan 2007
Advanced rainwater harvesting	£2,100 - £2,400 per residential property £2,500 - £6,000 per residential property £2,600 - £3,700 per residential property £6,300 - £21,000 per commercial / industrial property £45 per m ² for residential properties £9 per m ² for non residential properties	Woking Borough Council EA, 2007 RainCycle, 2005 RainCycle, 2005 EA, 2007 EA, 2007
Greywater re-use	£1,900 - £3,500 per residential property £3,000 per property	Woking Borough Council EA, 2007
Permeable paving	£30-£40 per m ² of permeable	CIRIA, 2007

	surface £27 per m ² of replacement surface £54 per m ²	Stovin & Swan 2007 EA, 2007
Filter drain / perforated pipes	£100 - £140 per m ³ stored volume £61 per m £120 per m ²	CIRIA, 2007 Stovin & Swan 2007 Environment Agency, 2007
Swales	£10-£15 per m ² swale area £18-£20 per m length using an excavator £12.5 per m ²	CIRIA, 2007 Stovin & Swan 2007 Environment Agency, 2007
Infiltration basin	£10-£15 per m ³ stored volume	CIRIA, 2007
Soakaways	>£100 per m ³ stored volume £454 -£552 per soakaway	CIRIA, 2007 Stovin & Swan 2007
Infiltration trench	£55-£65 per m ³ stored volume £74-£99 per m length £60 per m ²	CIRIA, 2007 Stovin & Swan 2007 Environment Agency, 2007
Filter strip	£2-£4 per m ² filter strip area	CIRIA, 2007
Constructed wetland	£25-£30 per m ³ treated volume	CIRIA, 2007
Retention (wet) pond	£15-£25 per m ³ treated volume £80,000 per 5000m ³ pond (£16 per m ³)	CIRIA, 2007 SNIFFER, 2007
Detention basin	£15-£20 per m ³ detention volume £35-£55 per m ³ stored volume £18 per m ³	CIRIA, 2007 Stovin & Swan 2007 SNIFFER, 2007
Onsite attenuation and storage	£449-£518 per m ³ for reinforced concrete storage tank. No data available for oversized pipes	Stovin & Swan 2007