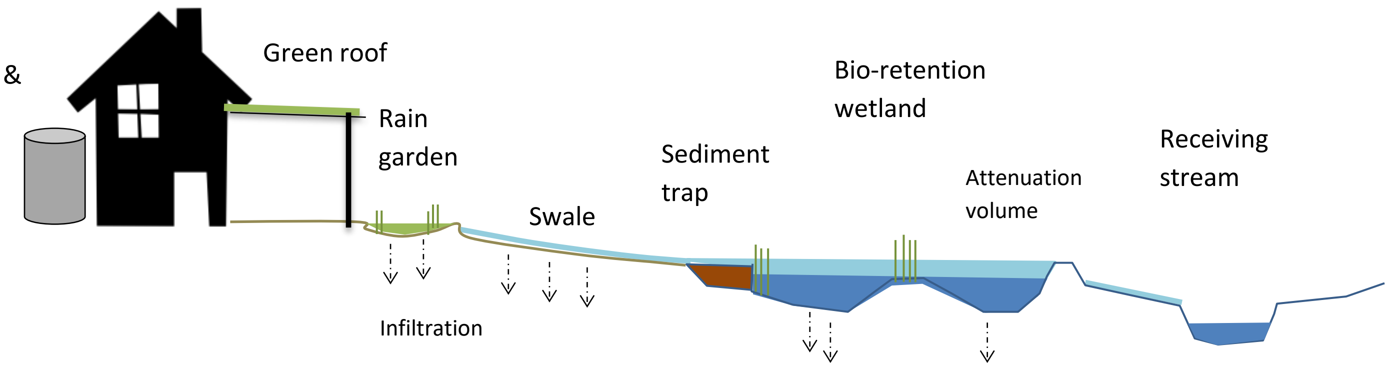
Green Roof Analysis

Analyse the performance of a green roof in reducing the annual runoff (hydraulic load) from the roof of a building.

Q: What makes the biggest difference; soil depth or soil texture?

Green roof are one of the technologies usen in Sustainable (Urban) Drainage Systems (SuDS)?

The Treatment Train:



Design Capacity:
(for example)

Daily storm

Daily storm

< 1yr event

2 - 5yr event

> 10yr to 100yr event

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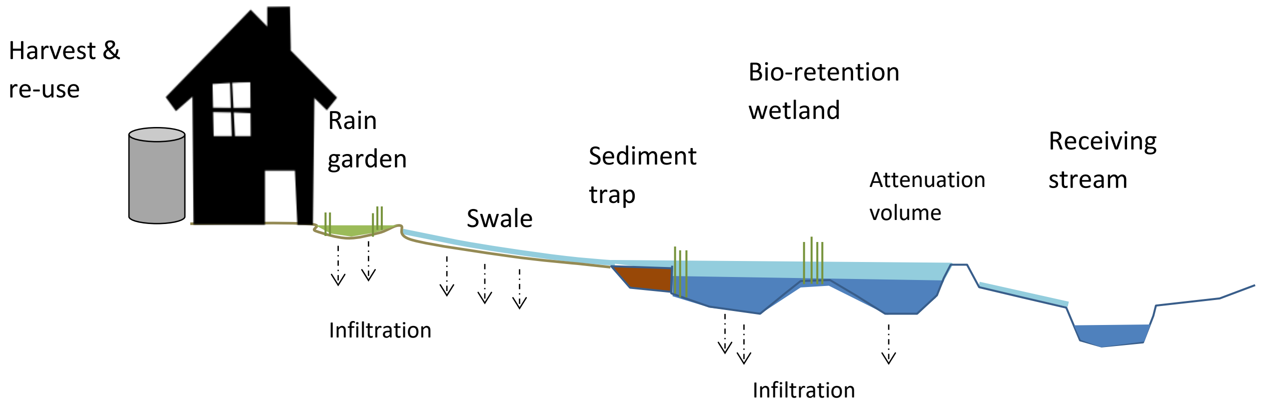
SuDS Principles

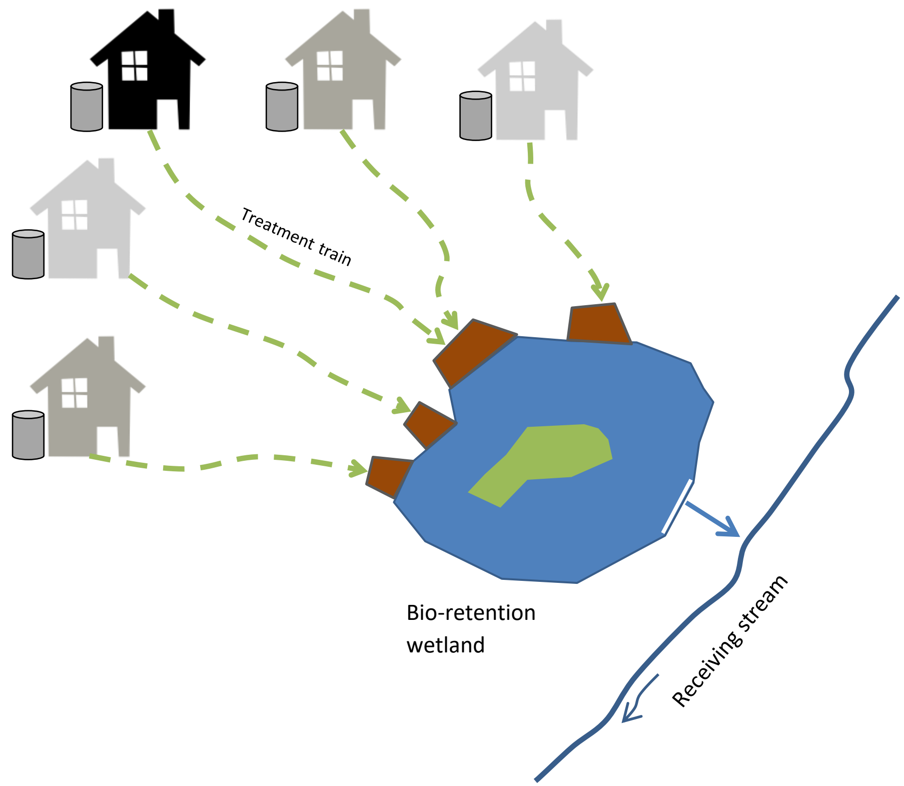
1. Seek to match pre-development runoff. (it's in the By-laws).
2. Start treatment from the point where the rain touches the ground.
3. Develop a Treatment Train.
4. Volume control

→ Retention is key!



Principles

Treatment Train: Cumulative Effect



Developing a Treatment Train (CoJ Manual)

Need at least 4 of the 5 primary functions:

Primary Function	SuDS technologies	Method of analysis
Sediment trapping	Sediment traps, sediment basins.	Detention pond analysis
Retention and water quality treatment	Bio-retention filters, infiltration trenches, filter strips, rain gardens, sand filters, green roofs, permeable pavements, soakaways, retention ponds, constructed wetlands	Hydrological soil model
Reuse	Rainwater harvesting, underground tanks	Water balance and detention pond analysis
Conveyance	Swales, inlet and outlet structures, outfalls.	Hydraulic analysis
Flood management	Detention basins	Detention pond analysis

Principles: Multiple Benefits

Sustainable Drainage Systems (SuDS)

=

Primary objective

Reduce runoff volume (reduce flood risk)

Improve water quality

Benefits

Habitat & biodiversity

Public amenity

Green Infrastructure (Shared space for services)

Co-benefits

Improved property values

Water Security

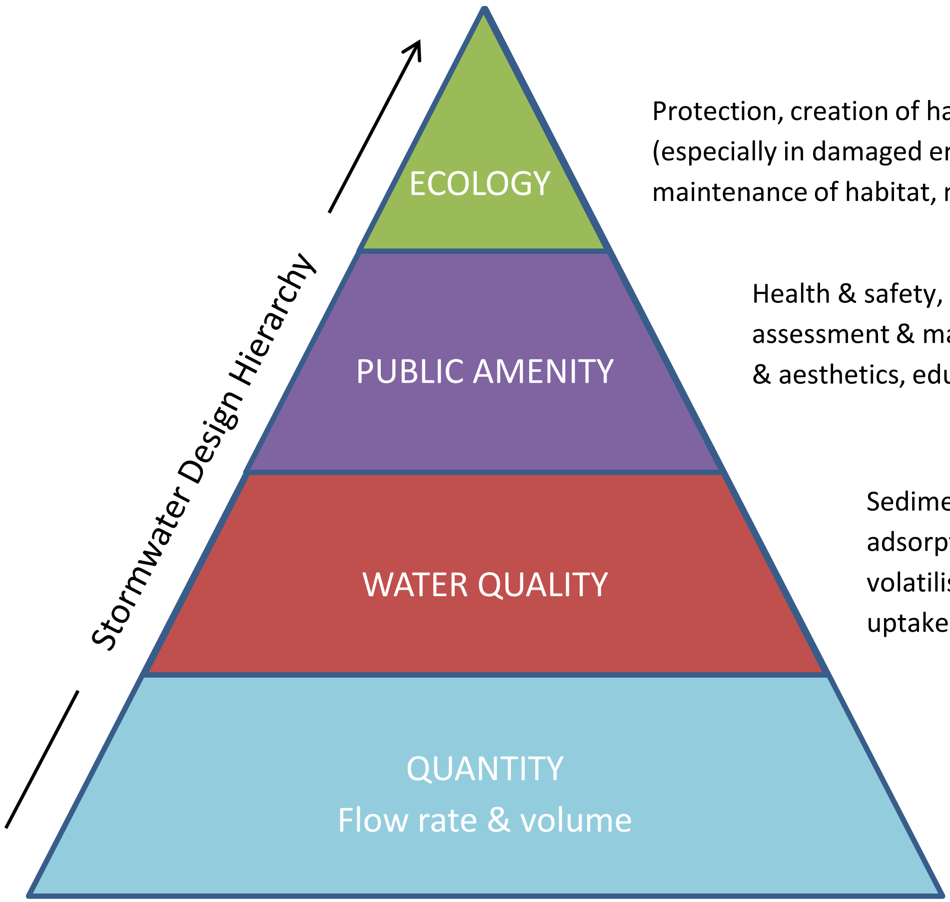
Climate Adaptation

Heat island effects

Lower maintenance & costs (!)

Co-Benefits: Habitat & Amenity

Stormwater Design Hierarchy



Protection, creation of habitat (especially in damaged environments), maintenance of habitat, monitoring.

Health & safety, environmental risk assessment & management, recreation & aesthetics, education & awareness

Sedimentation, filtration & biofiltration, adsorption, biodegradation, volatilisation, precipitation, plant-uptake, nitrification, photosynthesis

Rainwater harvesting, infiltration, detention, conveyance, long-term storage, extended attenuation storage

"Simply put, there is no point focussing on biodiversity if life and property have not been protected" (Armitage et al, 2013)

(After Armitage, et al, 2013)

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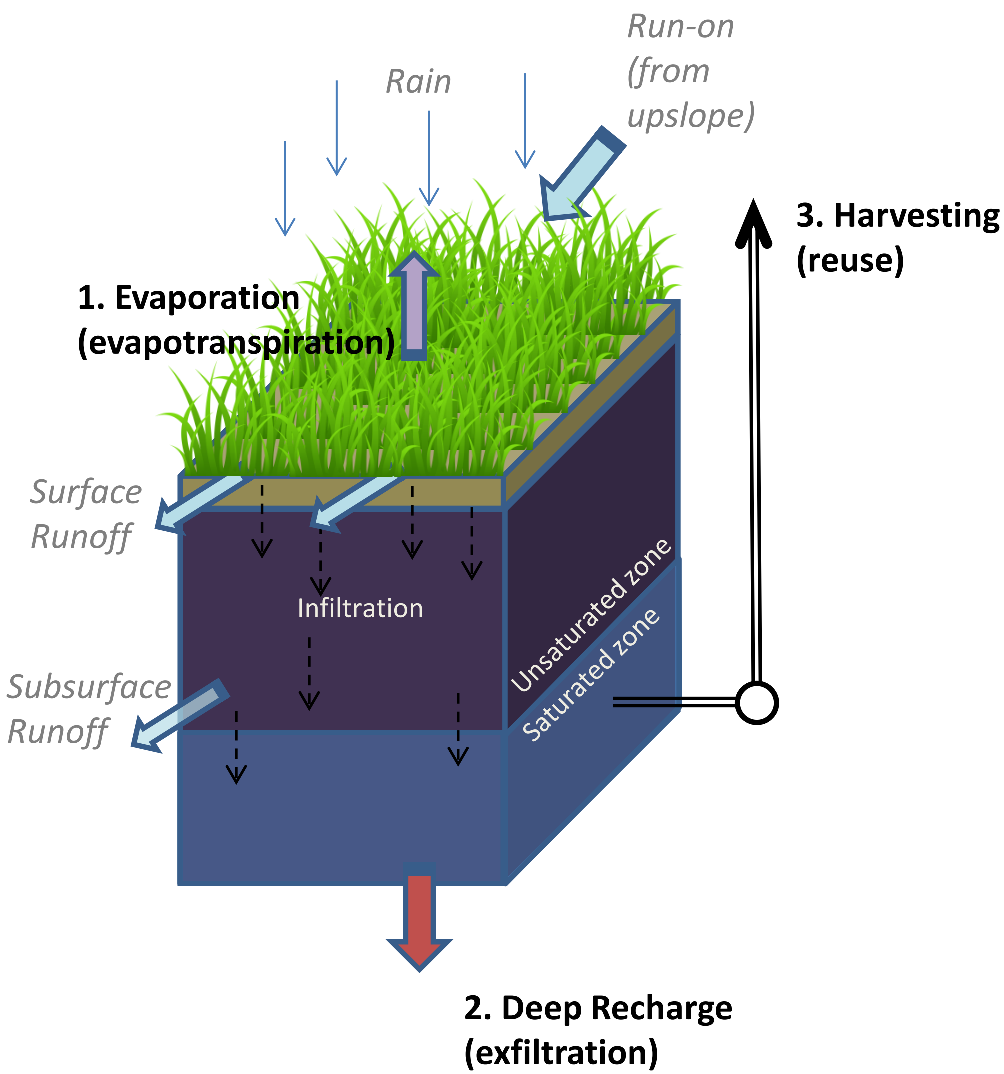
Hydrological soil model
(with primary "use" factors)

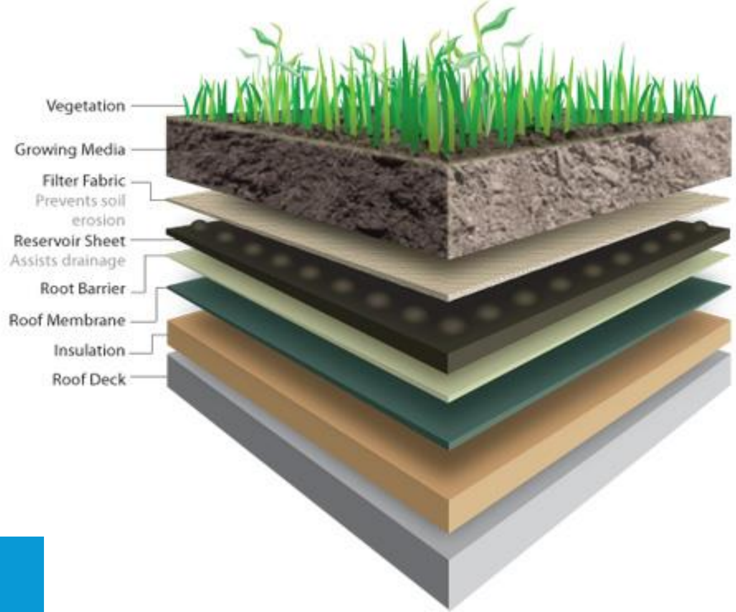


The hydrological soil model is the primary model for designing green stormwater systems.

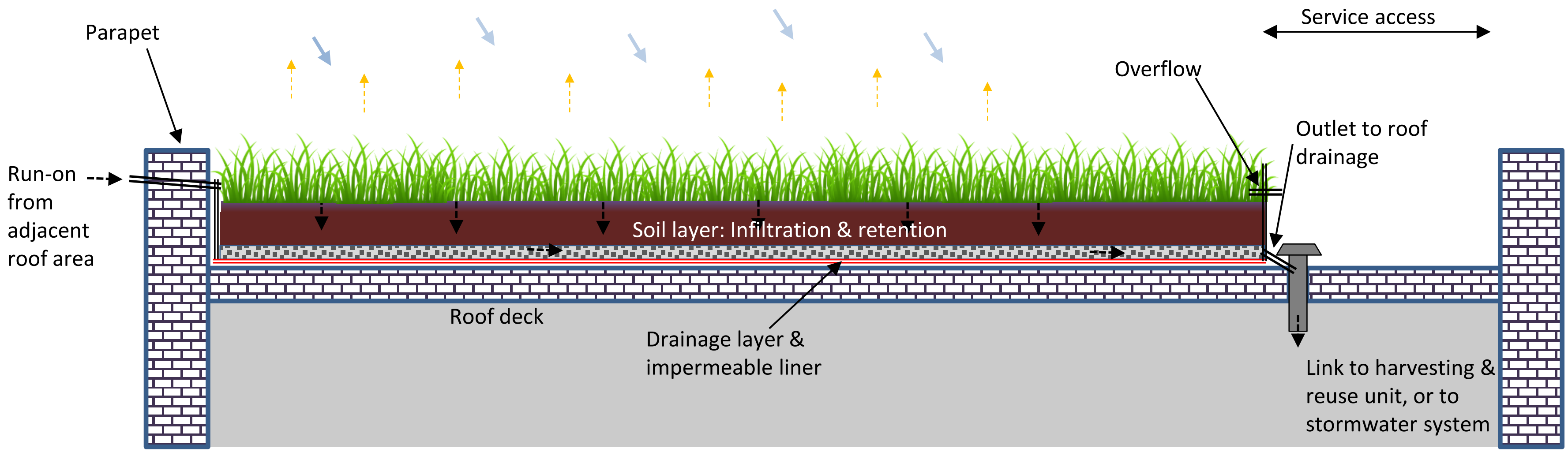
- Soil water retention characteristics influence (reduces) the rate of surface runoff.
- A wet soil performs differently to a dry soil. Therefore the performance of a SuDS systems is measured over a season, or a year.
- Engineered soils improve soil water retention and can perform well in receiving runoff from paved or roof surfaces.
- "Primary use" factors can also be enhanced to improve performance.

GREEN ROOF EXAMPLE

Green roofs
("Blue Roofs")



Green roof: Design basics



Key performance features:

- Hydraulic loading ratio
- Soil permeability & depth (usually an engineered soil mix with high sand content)
- Combination of soil depth, soil texture and vegetation selection.

Pro's & Con's:

- Limited to roofs with load bearing capacity.
- Easy to landscape and integrate into rooftop amenity areas.
- Soil depth and irrigation requirements need to be carefully planned for Highveld.
- Can accommodate runoff from adjacent (e.g. pitched roof) areas.

Johannesburg CBD

- Flood hazard (Booysens)
- High sewage loads
- High GW (basement dewatering)
- No infiltration!

Johannesburg CBD

Land cover attribute	% of area
Roof surface area	40 – 45% of entire area
Street surface area (excluding pavements)	30 - 35%
Paved areas at ground level (parking, front of buildings, pavements, etc.)	20 - 25%
Landscaped open spaces	<10% (typically 3-5%)
Open areas at ground level that offer potential for retro-fit SuDS. These include • Off street parking areas (informal & formal) • parks & landscaped areas • Forecourt and apron areas (in front of buildings) • Vacant areas • Sites under construction	10 - 15%
Typical area of a block	3600 – 5600m^2 Median 4530m^2
Length of block (in direction of drainage)	60 – 75m
Width of streets (generally 5 lanes, including parking lane)	15m

In this study, focus has been on roofs & streets

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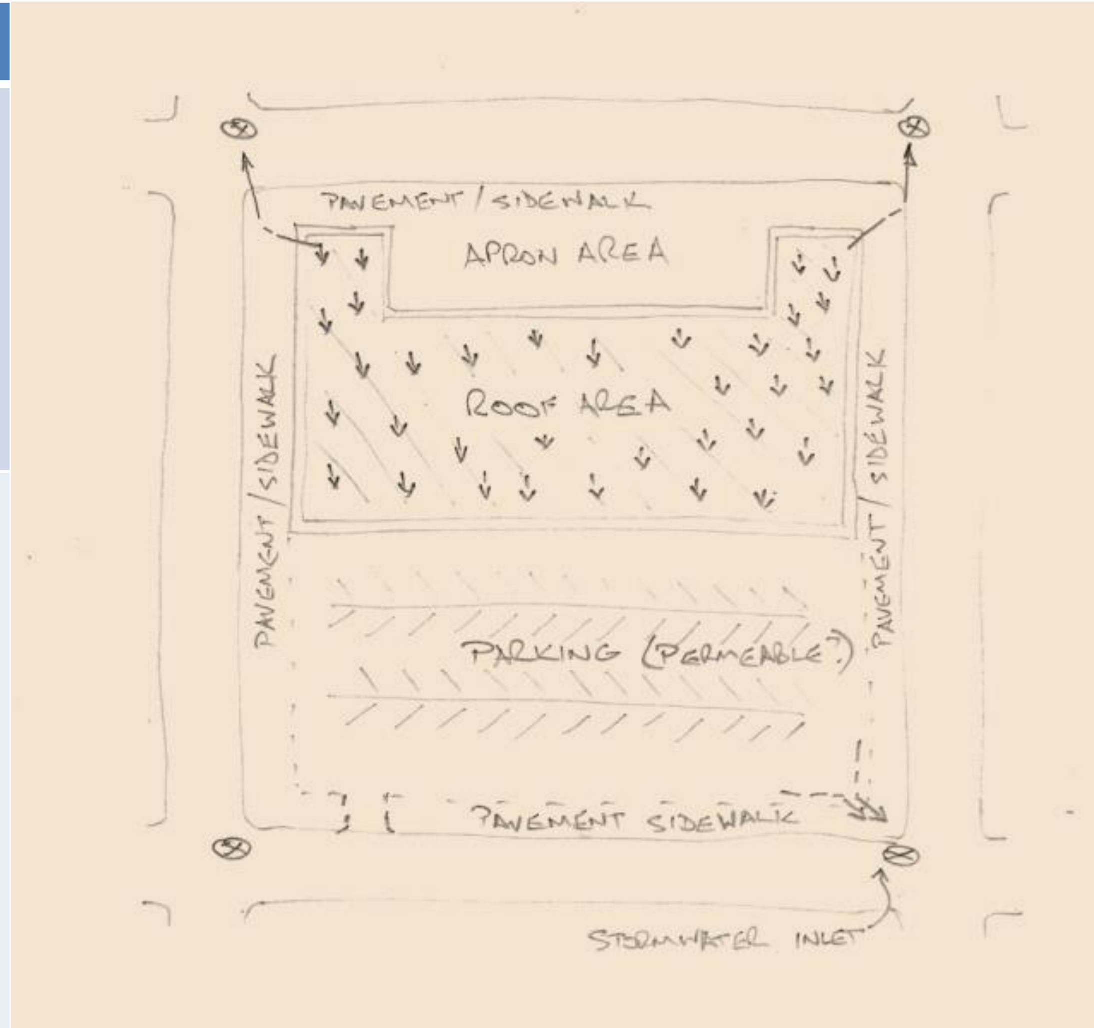
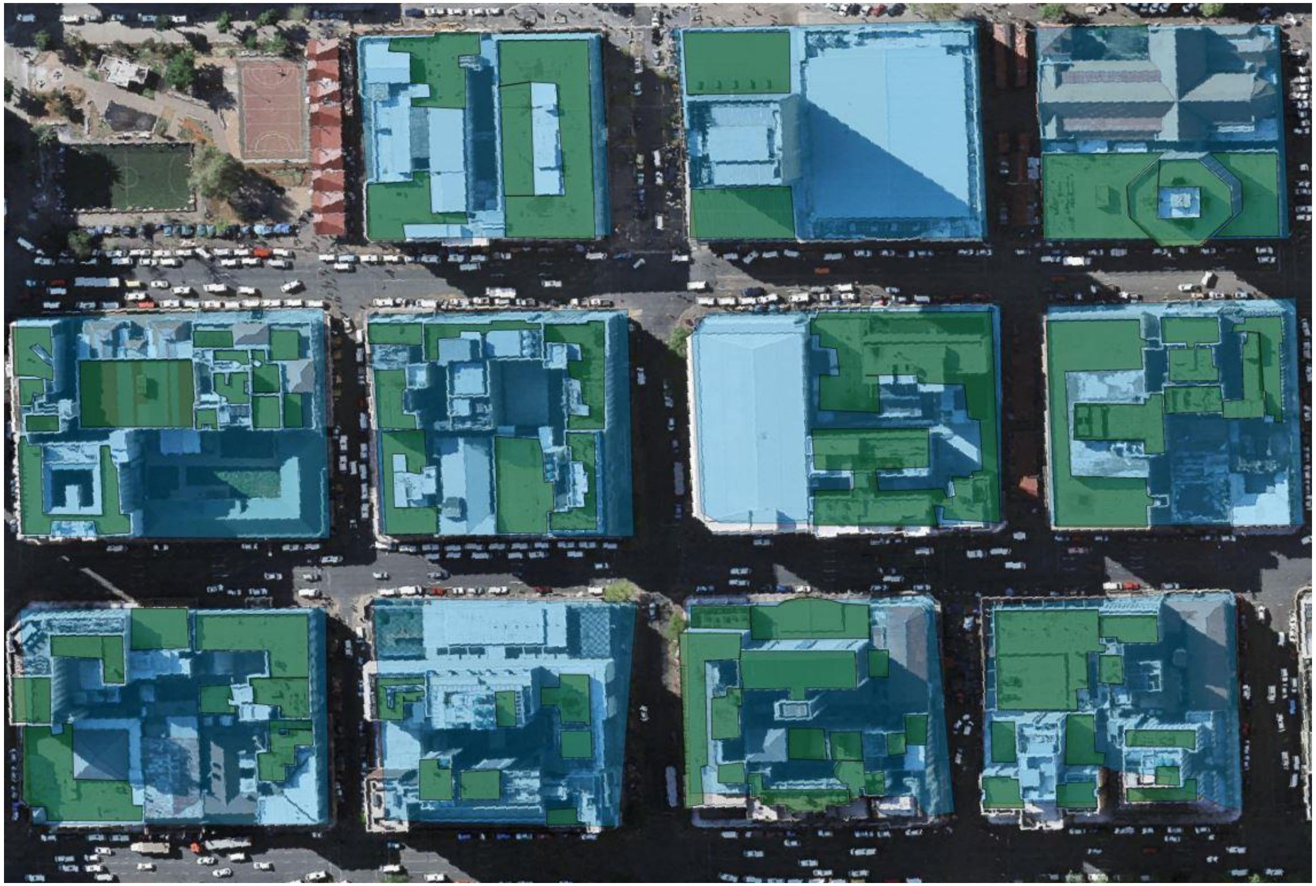
Central Business District Area: City of Johannesburg

Rooftop SuDS (Green Roof)	
Services	Amenity: ✓✓ Land values: ✓? Ecological: ✓? Attenuation: ✓? Infiltration: X? Treatment: ✓?
Notes	• Roofs are the largest portion of coverage of the CBD • Structural & architectural limitations to retro-fitting • Competition for space with solar energy systems

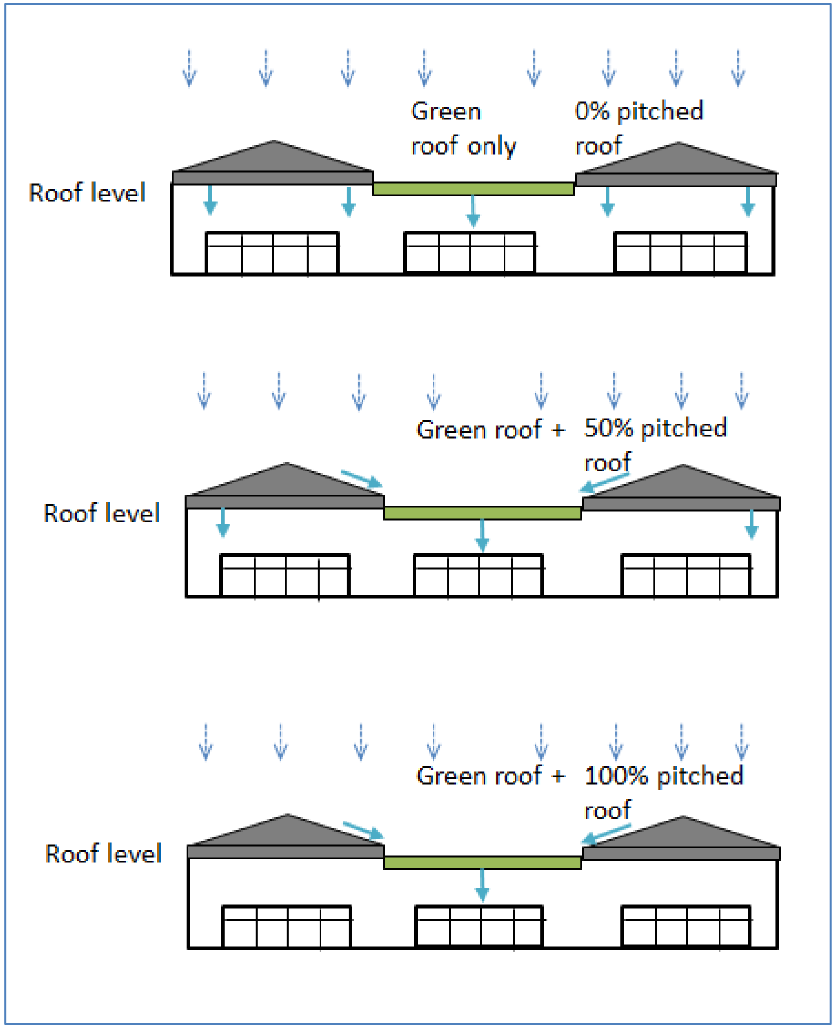


CBD: Green roof analysis



Assessment of flat roof space.
Median for the potential green roof space is 1520m^2 (per block).

Johannesburg CBD – Green Roofs



Median block area = 4536m^2

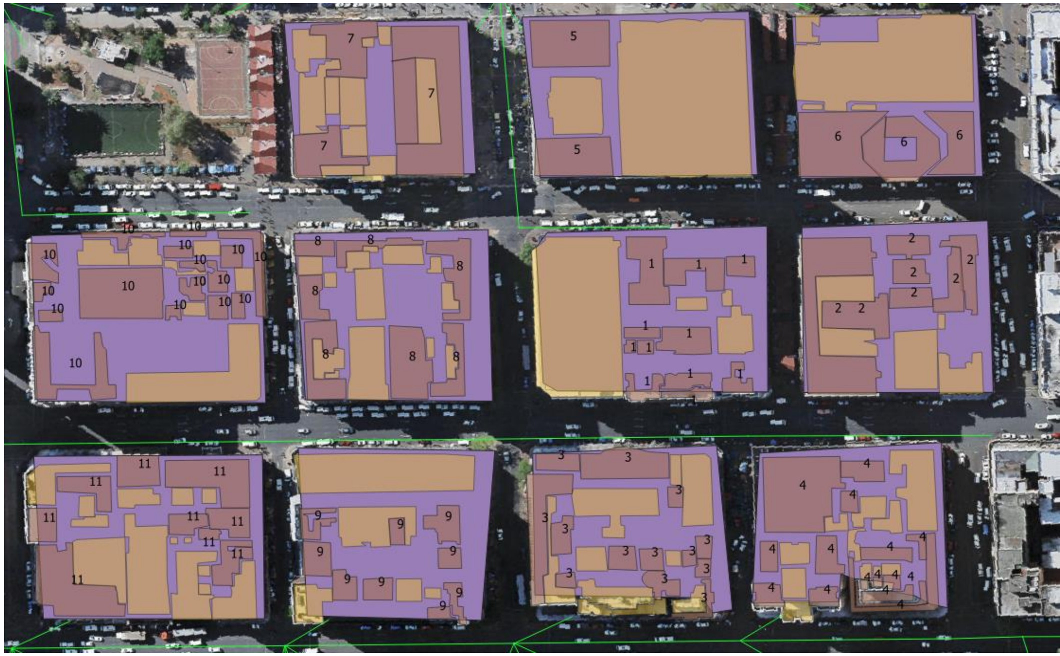
Median roof area = 3455m^2

Usable green roof area = 1900m^2

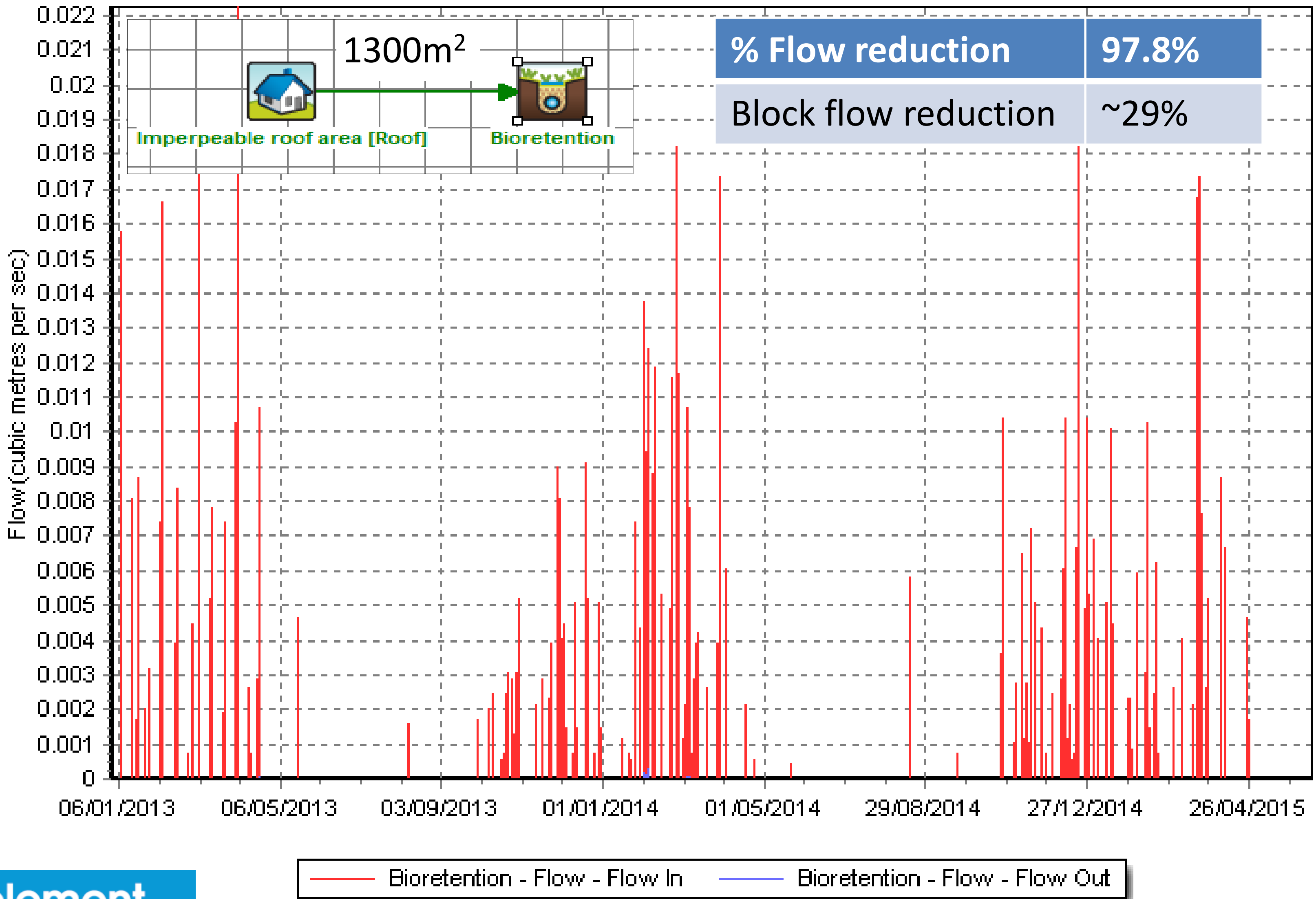
Assume 20% for services & access

Green roof area = 1520m^2

Soil depth = 150mm



CBD: Green roof analysis (MUSIC)



% Flow reduction	97.8%
Block flow reduction	~29%

Johannesburg CBD – Results Overview

- High performance of green roof at a block scale = 60% - 70% load reduction (i.e. annual runoff reduction),
- Evaporation is the dominant “primary use” factor. The others may be enhanced under specific conditions.

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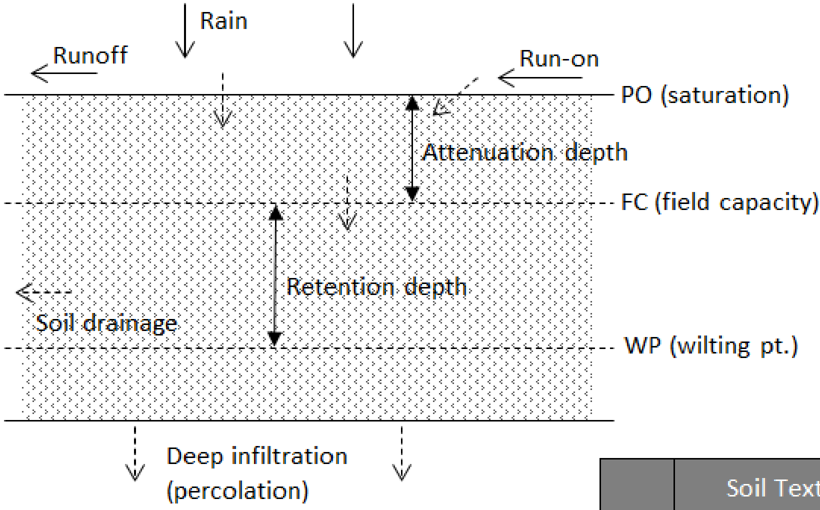
Input data

- 5 minute rainfall records, 5 years.
- Daily evaporation rates.
- Green roof area = use median area 1520m^2
- Soil media depth: 150mm (min) to 300mm (max)
- Soil texture characteristics: sandy loam
- Assume zero irrigation.
- Assume different options for hydraulic loading: e.g.
  - Rainfall on green roof area only
  - Rainfall on green roof + runoff from % of adjacent pitched roof area (e.g. 50% & 100%).

Soil data: Use Sandy Loam



	Soil Texture	Sat. Hyd. Conductivity (K)[2] (mm/h)	Suction Head (Ψ)[2] (mm)	PO[1,2,4] (fract.)	FC[1,2,4] (fract.)	WP[1,2,4] (fract.)	Clay % (SA soils)[1,3] (%)
1	Sand	120.40	-49	0.430	0.062	0.050	0-6%
2	Loamy sand	29.97	-61	0.432	0.105	0.068	0-10%
3	Sandy loam	10.92	-110	0.448	0.189	0.093	6-20%
4	Loam	3.30	-89	0.463	0.232	0.128	0-27%
5	Silt loam	6.60	-170	0.495	0.272	0.135	7-27%
6	Sandy clay loam	1.52	-220	0.398	0.244	0.159	15-35%
7	Clay loam	1.02	-210	0.464	0.310	0.195	27-40%
8	Silty clay loam	1.02	-270	0.471	0.335	0.210	27-40%
9	Sandy clay	0.51	-240	0.423	0.321	0.228	35-55%
10	Silty clay	0.51	-290	0.479	0.371	0.253	40-60%
11	Clay	0.25	-320	0.475	0.378	0.298	>55%

1 *Schulze, et al, 1989. ACRU-2.0: User Manual.*

2 *James, et al, 2010. User's guide to SWMM5 (13th Ed.)*

3 *USDA, 1999. Soil Taxonomy*

4 *PO, FC & WP selected to provide the combined minimum soil water storage.*

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Highveld rainfall

Statistics from the 5½ year (5-minute interval) rainfall record used in the study:

Characteristic	Number
No. days with rain	564 (28% of time)
No. days with rain > 6mm	189 (9% of time)
No. days with rain > 10mm	121 (6% of time)
Max 24h rainfall	75.8 mm (~5 year return period)
No. days with rain ~2 year return period or greater	2
Max 5 minute rainfall	14 mm (~10 year return period)
Max 15 minute rainfall	23 mm (~7 year return period)
Notes: *1. All days of rain are used in determining the hydraulic load on a SuDS system.* *2. Larger events described by return periods are used in flood analysis.* *3. Short duration storms (e.g. 5 minute and 15 minute) are particularly important in urban stormwater management.*	

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