A Methodology to Assess the Potential Impact of Swales on Groundwater Quality

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Paper objectives

- detailed analysis of the surface and sub-surface processes which contribute to the performance criteria associated with swales
- development of an impact assessment methodology to determine how swales may influence both adjacent ground- and surface-waters
- application of developed approach to contaminated highway runoff containing TSS, nitrate, chloride, metals (Cd, Cu, Pb and Zn) and PAHs (fluoranthene)
- specific emphasis on predicting the potential groundwater impacts arising from the use of swales to treat stormwater.

Outline of impact assessment procedure

(Ellis, Revitt and Lundy; Sci Total Environ, 416, 172-179, (2012)

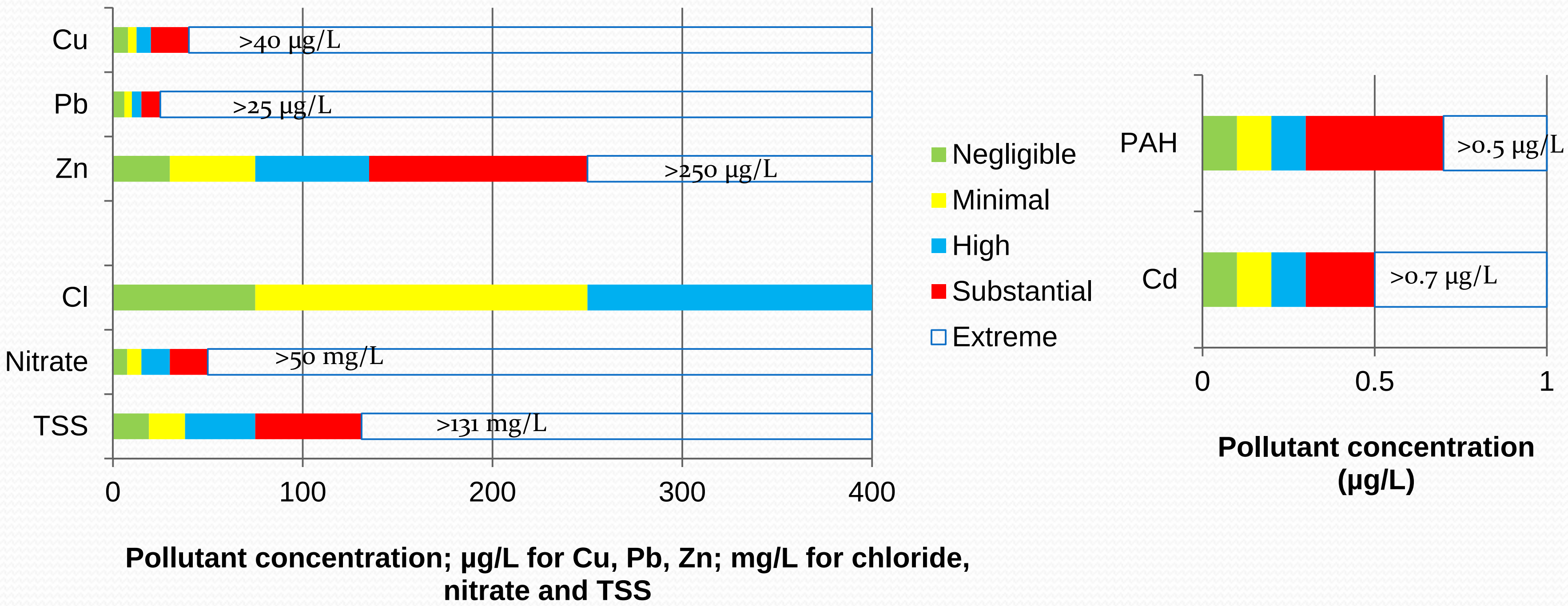
- allocate a pollutant index (PI) value (0 to 1) to a pollution source based on the likelihood that the 50th percentile of reported EMC values will exceed receiving water body environmental quality standards.
- assess the relative treatability of the runoff pollutants within a SUDS using a pollution mitigation index (PMI) value (0 to 1) with lower values indicating a better treatment performance.
- combine the PI and PMI indices to obtain a site pollution index (SPI) which provides screening guidance on the water quality risk following the passage of stormwater through a SUDS facility by comparison with a recognised value for receiving water quality and ecological status

Groundwater impact in relation to SPI values

Derived by relating the PI value allocated to a typical pollutant concentration in the runoff from a motorway/major road to the 'trigger' concentrations reported for a pollutant in terms of its potential impact on groundwaters (shown below for Cu)

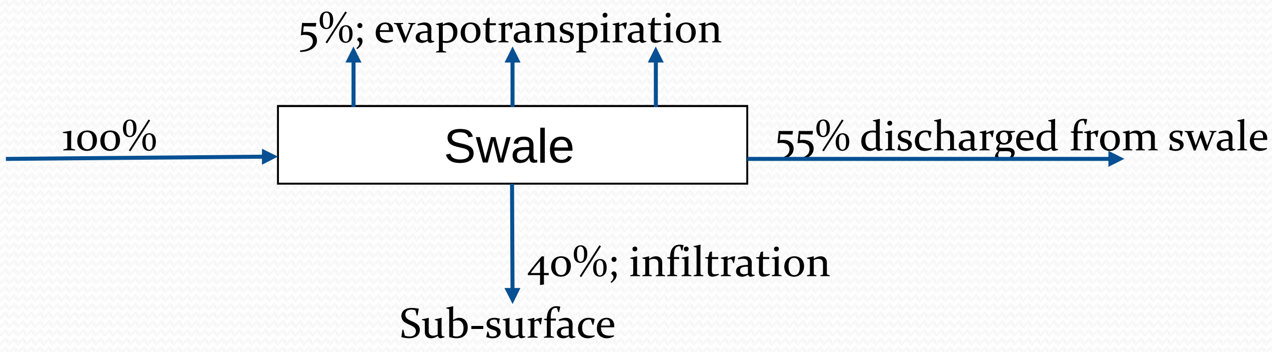
Groundwater impact category (SPI value)	Predicted ranges based on highway runoff data (µg l^{-1})	Predicted 'trigger' concentration ranges based on from Thames Catchment groundwater data (µg l^{-1})	Predicted combined concentration ranges (µg l^{-1})
Negligible (<0.1)	<8.3	Below average minimum natural background level (<4.0)	<8.0
Minimal (0.1-0.2)	8.3-16.7	Average minimum natural background level– Average action level (4.0 – 10.27)	8.0 – 12.5
High (0.2-0.4)	16.7-33.3	Average action level - Average threshold level (10.27 – 13.70)	12.5 – 20.0
Substantial (0.4-0.7)	33.3-58.3	Average action level – Maximum detected concentration (13.70 –25.85)	20.0 – 40.0
Extreme (>0.7)	*	Above maximum detected concentration (> 25.85)	>40.0

Relationships between SPI values, pollutant concentrations and groundwater impacts



Hydrological performances of swales

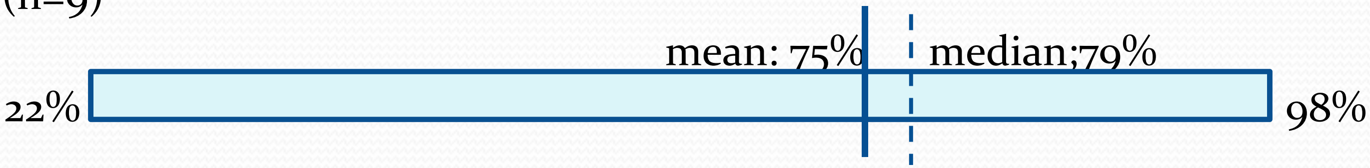
- Literature data indicates that a volume reduction of 45% is reasonably representative of the typical performance of a grassed swale with respect to volume reduction.
- The main water loss pathway within swales is by infiltration with an additional contribution due to evapotranspiration; water losses by evapotranspiration are typically less than 10% of those by infiltration.



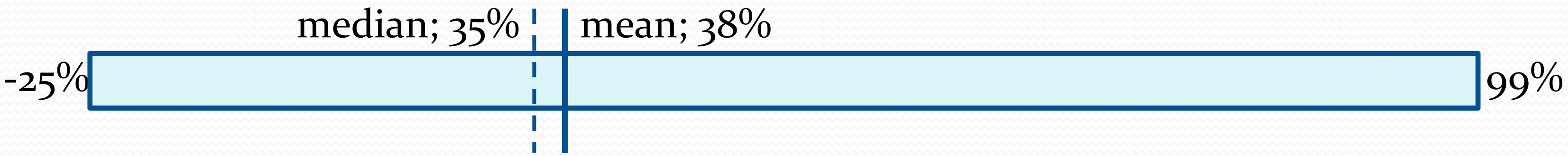
Pollutant removal mechanisms within swales

- Surface processes including vegetative filtration (mainly particles), sedimentation (of solid particles) and plant uptake (particularly nutrients; some metals)
- Infiltration removes pollutants by the filtering of particles through the underlying soil matrix and the adsorption of dissolved contaminants to soil media, particularly in the first 20-50 cm below the surface

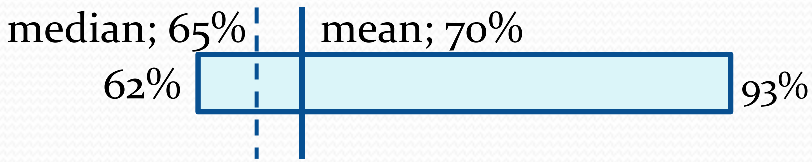
- TSS removal (n=9)



- Nitrate removal (n=7)

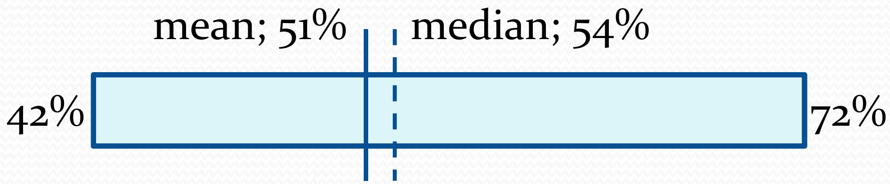


- PAH removal (n=2)

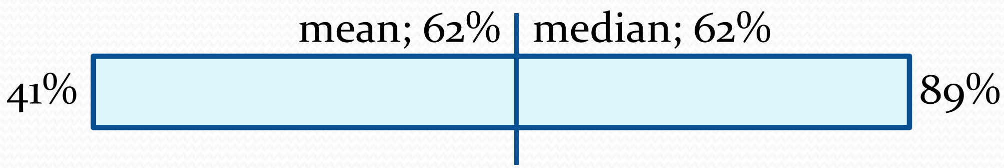


Percentage removal efficiencies for metals in swales

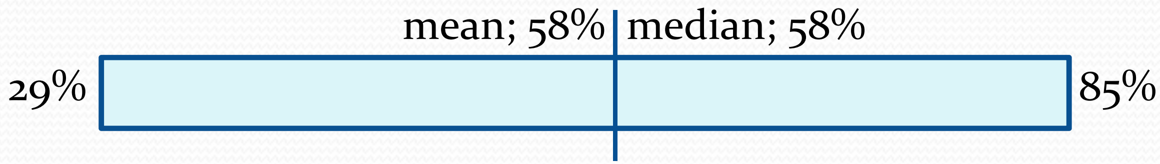
- Cadmium (n=3)



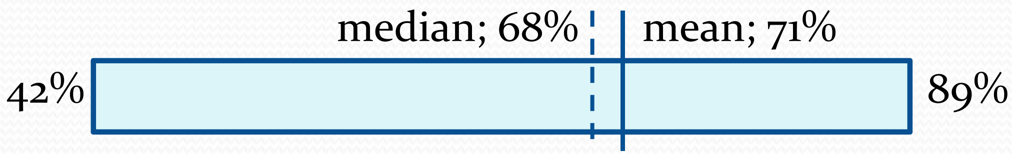
- Copper (n=7)



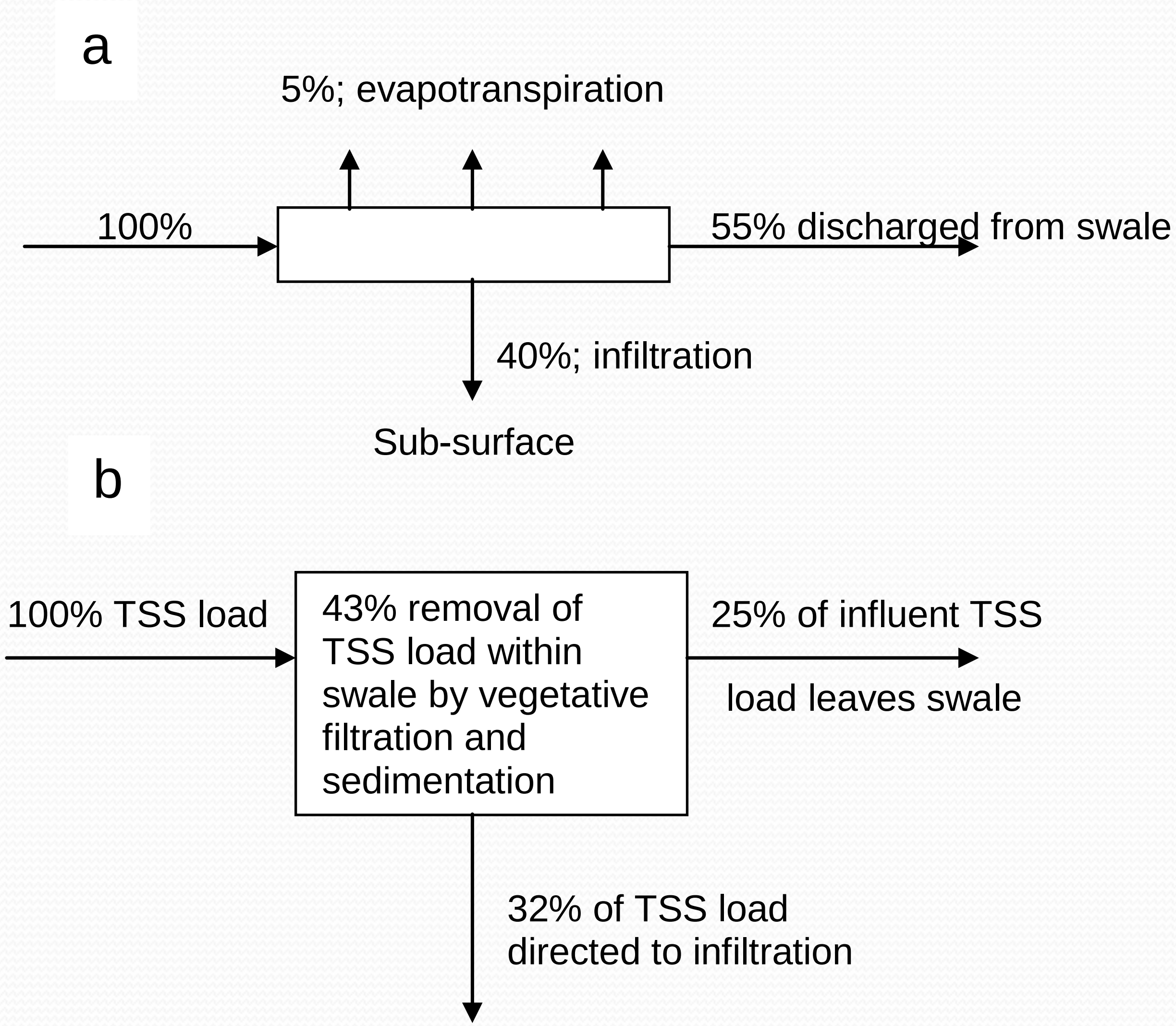
- Lead n=7)



- Zinc (n=6)



Proposed methodology applied to TSS in swales



Impacts of TSS on swale discharges

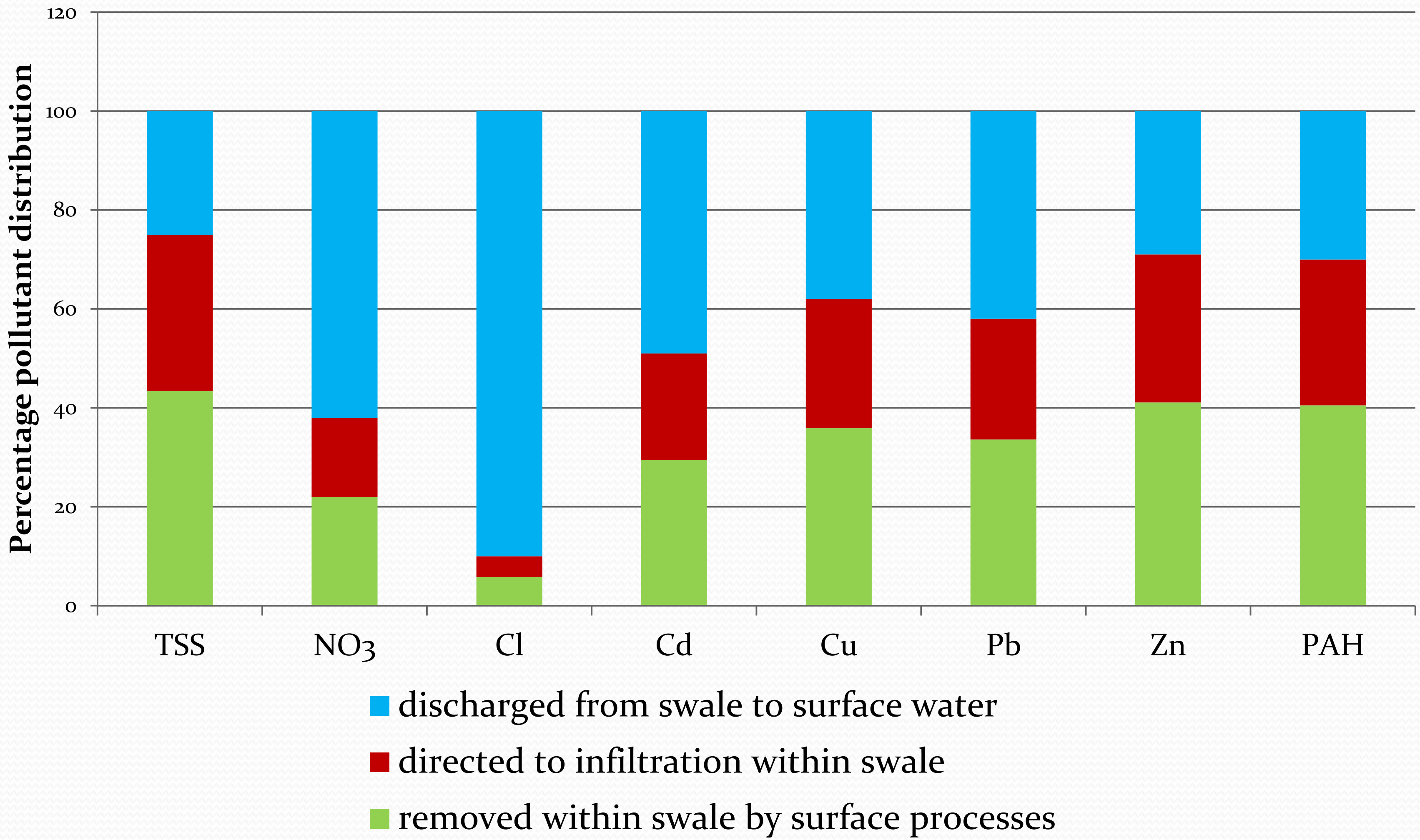
a) Predicted impact on surface waters

	Swale removal efficiency (%)	% removed by surface processes	% removed by infiltration	PI for major highway	SPI for water discharged from swale	Potential impact for receiving surface waters
TSS	75	43.4	31.6	0.8	0.20	High/ Minimal

b) Predicted impact on groundwaters

	SPI for water retained in swale	SPI for water directed to infiltration (42.1% of that retained within swale)	PMI for infiltration	SPI for ground-water impact	Potential impact for ground-water
TSS	0.6	0.25	0.1	0.03	No detrimental effect

Predicted pollutant distributions in swales



Predicted impacts of swale pollutant discharges on receiving surface waters following treatment of highway runoff.

	PI for major highway	SPI for water discharged from swale	Potential impact for receiving surface waters
TSS	0.8	0.2	High/minimal
NO_3	0.1	0.06	Negligible
Cl	0.8	0.72	Severe
Cd	0.5	0.26	High
Cu	0.6	0.23	High
Pb	0.5	0.21	High/ Minimal
Zn	0.8	0.23	High
PAH	0.8	0.24	High

Predicted impacts of metals in swale infiltration on groundwater following treatment of major highway runoff

	SPI for water retained in swale	SPI for water directed to infiltration (42.1% of that retained within swale)	PMI for infiltration	SPI for ground-water impact	Potential impact for ground-water
TSS	0.6	0.25	0.1	0.03	No detrimental effect
NO_3	0.04	0.02	0.9	0.02	Negligible
Cl	0.08	0.03	0.9	0.03	Negligible
Cd	0.24	0.10	0.3	0.03	Negligible
Cu	0.37	0.16	0.2	0.03	Negligible
Pb	0.29	0.12	0.2	0.02	Negligible
Zn	0.57	0.24	0.2	0.05	Negligible
PAH	0.56	0.24	0.1	0.02	Negligible

Conclusions

- Groundwater impact assessment categories have been related to pollutant source concentrations and 'trigger' concentrations for groundwater data
- Consideration of the relative contributions made by different surface and sub-surface processes to the hydrological and pollutant removal performances of swales enables both potential receiving water and groundwater impacts to be predicted
- Discharges from swales used to treat highway runoff pose significant risks to surface waters with regard to TSS, metals and PAH and particularly chloride following winter salting episodes
- The preservation of the permeability and pollutant removal capacities of sub-surface soils is of prime importance in maintaining the level of negligible risk to ground waters; specifically for TSS, Zn and PAH
- A scientific consideration of the unit processes which contribute to pollutant removal in swales offers insights into the potential impacts to surface and ground waters and could be usefully extended to other SUDS.