PROPER DECISION SUPPORT SYSTEM

TECHNICAL MANUAL

DELIVERABLE 3.5

CEDR PROPER PROJECT

Mike Revitt, Bryan Ellis and Lian Lundy
Middlesex University, UK

Conference of European Directors of *Roads (CEDR)*

Executive summary

This report is the fifth deliverable of WP3 (Sustainable assessment of measures and treatment systems for road runoff) of the CEDR PROPER project. It directly compliments PROPER Deliverable 3.3 (the PROPER decision support system; DSS) and PROPER Deliverable 3.4 (PROPER DSS user guide) by describing the approaches used to grade the performance of 12 different SUDS/BMPs against a range of relevant indicators (i.e. it provides the justification for each of the grades which appear in the PROPER DSS performance matrix). This technical manual describes each of the six criteria (key decision making aspects) and supporting indicators (aspect of the criterion under consideration), including a review of the evidence base used to inform grade allocations) for each of the 12 SUDS/BMPs evaluated.

The scientific and technical literature included in this report are drawn from a range of national and international studies and databases which, between them, cover a variety of climatic and geographic circumstances. However, it is recognised that a single default value may not be the most appropriate grade in all locations. Therefore, as well as providing a greater insight into the technical and scientific considerations underpinning each grade allocation, this technical manual supports the more experienced user to:

- modify allocated grades depending on local circumstances
- develop grades for 'alternative treatment types' should the user wish to evaluate the use of further / proprietary treatment technologies within the DSS

Acknowledgements

We gratefully acknowledge the financial and technical support of the CEDR transnational road programme call 2016: Environmentally Sustainable Roads: Surface- and Groundwater Quality (funded by Austria, Finland, Germany, Ireland, Netherlands, Norway and Sweden) and the CEDR Programme Advisory Board.

Contents

Tables

Figures

Introduction

This manual describes in detail how the grades (which are used in the PROPER DSS) have been allocated to each of the criteria/indicators in relation to the use of the different SUDS/BMPs for the treatment of highway runoff. The manual is structured into different sections corresponding to the criteria chosen to describe the important characteristics of the selected SUDS/BMPs with respect to their treatment of highway runoff. The criteria are further divided into indicators to provide a more descriptive explanation of their role in influencing the suitability of a particular SUDS/BMP. The criteria and associated indicators used in the PROPER DSS are identified below:

Technical criteria
- Flood control indicator
- Pollution control indicator
- Adaptability to highway widening and climate change indicator

Environmental criteria
- Impact on receiving waterbody volume indicator
- Impact on receiving waterbody quality indicator
- Impact on receiving waterbody ecology indicator

Operation and Maintenance criterion
- Maintenance and servicing requirements indicator

Socio-environmental awareness criteria
- Sustainable development (biodiversity) indicator
- Aesthetics & public awareness indicator

Economic criterion
- Unit rate costing indicator

Legal & highway planning criterion
- Ability to comply with the EU Water Framework Directive objectives

For each combination of criteria/indicators, a total of 12 different SUDS/BMPs are considered in terms of their suitability for use in the highway environment. The SUDS/BMPs can be allocated to 4 different categories, shown below, according to their structural characteristics and modes of action:

Basins and wetlands
- Detention basins (DB)
- Extended detention basins (EDB)
- Retention ponds (RP)
- Constructed wetlands (CW)

Filter strips and swales
- Filter strips (FS)
- Swales (SW)

Infiltration systems
- Filter drains (FD)

Soakaways (SO)
Infiltration trenches (IT)
Infiltration basins (IB)

Porous surfacing
Porous surfacing (without sub-structure or without storage) (PS)
Porous surfacing (with sub-structure or with storage) (PS+)

TECHNICAL CRITERIA

incorporating

FLOOD CONTROL INDICATOR

POLLUTION CONTROL INDICATOR

ADAPTABILITY TO HIGHWAY WIDENING AND CLIMATE CHANGE INDICATOR

FLOOD CONTROL INDICATOR

Peak Runoff and Storage Volume

Controlling runoff quantity is an extremely important objective for highway stormwater management and remains the principal criterion for the design and selection of drainage systems by the majority of highway authorities given the potential impacts of impermeable surface runoff on flooding, receiving water morphology, habitat and ecology. A major goal of quantity control in runoff system design is to maintain the pre-construction greenfield hydrograph or flow regime in terms of maximum runoff rate and peak/total flow volumes. Maintaining the pre-construction flow regime requires replacing (or compensating for) the lost depression and soil storage caused by impervious surfacing. This can only be done through extensive infiltration or storage volumes given that, for example, matching the pre-construction greenfield peak rate alone means recovering between 30% to 60% of the lost storage capacity. It is also the case that control provision for a range of runoff volumes as well as for the larger magnitude, lower frequency storm events (plus 20% climate change uplift) will offer a greater "level of protection" and sustainability within the wider highway catchment.

Important physical factors to consider in the assessment of SUDS/BMP suitability for runoff quantity control are the effective contributing area as well as rainfall intensity/duration relationships in terms of the potential SUDS/BMP storage volumes. There is also the consideration that impermeable highway surfaces can be expected to generate a much higher level of effective runoff from smaller contributing areas than experienced in general urban situations where the impermeable surface coverage is much lower (normally less than 30%). This is examined in more detail in the Site Screening Characteristics section under Contributing Area Drainage. It is therefore important that the effective catchment area rather than the total catchment area is considered in the evaluation of the flood control capability. Clearly detention and wetland basins require a larger contributing area than swales or infiltration trenches to ensure an effective operation. The lower range of suitability is set by the orifice size for extended detention basins, or the capacity to maintain water levels in retention basins and wetlands. By contrast, infiltration trench and grass filter facilities are generally only applicable on sites less than 2 hectares due to flow velocity constraints (as well as space and cost) and have low storage volume:storm runoff volume (Vs:Rv) ratios. Highway infiltration basins operate most effectively within an operating range of 2 to 3 hectares with extended detention basins and constructed wetlands requiring a minimum of 4 hectares contributing area.

The degree of impermeability and rainfall intensity/duration within a contributing catchment will also affect runoff volumes; in small catchments, runoff volume is particularly sensitive to impervious area hydraulics. Storage (S) in these terms can be defined as runoff volume from the critical storm duration (D) for a given rainfall intensity (I) over a specific impervious contributing area (Ai):

$$\text{i.e } S = I.Ai.D\ [-Inf_s.\ Inf_a.\ D]$$

For infiltration devices, soil infiltration rate (Inf_s) and effective infiltration surface area (Inf_a) must also be considered as indicated by the bracketed terms in the above equation. Thus effective contributing area can be considered as being the impervious surface driver for the generation of runoff volumes and peak flow rates by critical storm events within the highway catchment. A frequently adopted critical design peak flow volume standard for flood control is that generated by the 1:100 return period (RI), 6 hour duration storm event (the M100-360 rainfall depth; mm). Exceedance flows and flow routes are also frequently determined by a nominal 1.5 - 2.0 l/s/ha peak flow discharge rate.

Effective contributing area can thus provide a very basic surrogate benchmark for the capacity-performance of different SUDS/BMP forms as it represents the transferring interface between impermeable surface and rainfall intensity/duration and this is included in Figure 1. The benchmark scaling methodology used is thus simple in principle and follows the allocation of a ***utility score*** to the "level of protection" offered by the SUDS/BMP expressed in terms of the peak runoff control, the storage volume:storm runoff volume ratio and the effective contributing area. In the utility function approach used, a utility score of 1.0 is reserved for the maximum level of protection offered (Figure 1).

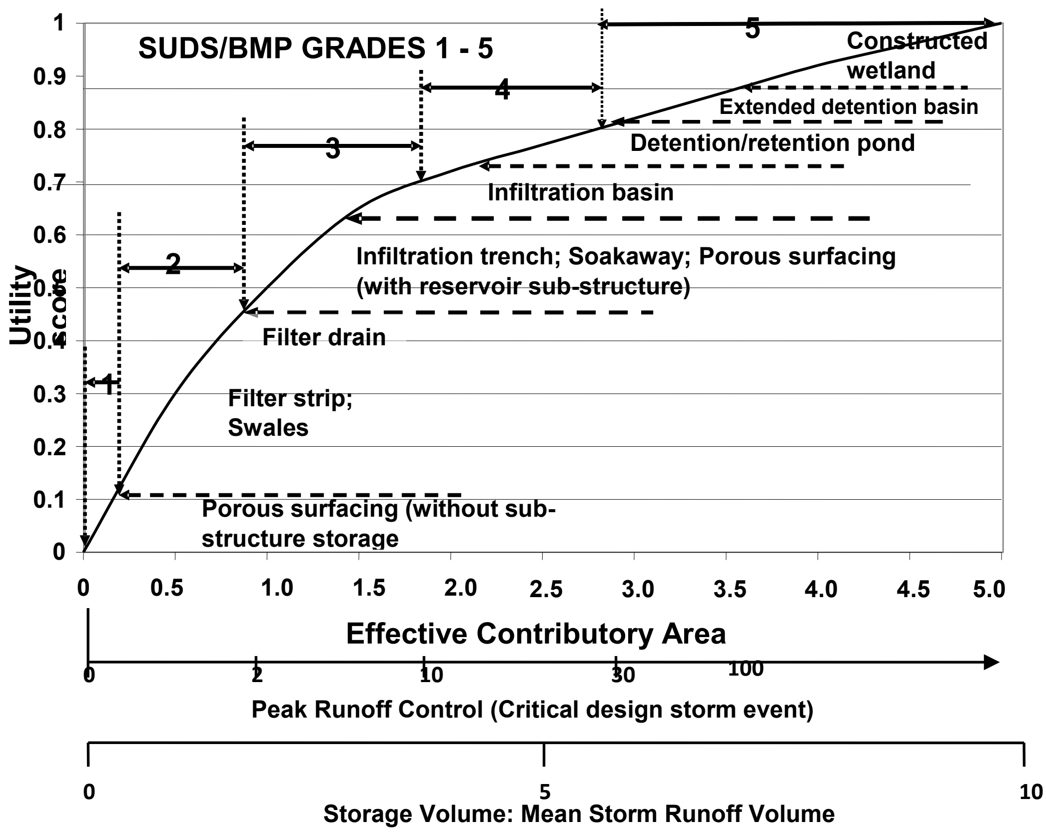


Figure 1. DSS benchmark utility scores and ranking values for the Flood Control Indicator.

An effective contributing area of 1 hectare and corresponding to a 2 year peak runoff control rate, has been allocated a mid-utility score of 0.5 as this is the pivotal "knee-of-the-curve" at which diminishing returns commence. A score of 0.8 and above has been allocated to the SUDS/BMPs offering the potential for the highest ratio of storage volume to runoff volume and having larger effective contributing areas. The SUDS/BMP level of performance as indicated by control of the peak runoff rates for critical storm durations is also included as a further point of reference to aid the benchmarking. The utility curve plotted on Figure 1 is therefore derived from these allocated values but end-users could identify their own benchmark utility scores and substitute their own utility plots based on local required storage or peak runoff discharge standards.

It is possible to directly use the utility score as derived from the graphical plot or to standardise the DSS matrix scoring within a grouped grading scale (e.g. 1 to 5). Using this latter approach a score of 5 would be allocated to the highest performance (in this case a level of protection afforded by the highest storage capacities) and 1 to the lowest (where runoff control and storage capacity `are at a minimum), as illustrated in Figure 1.

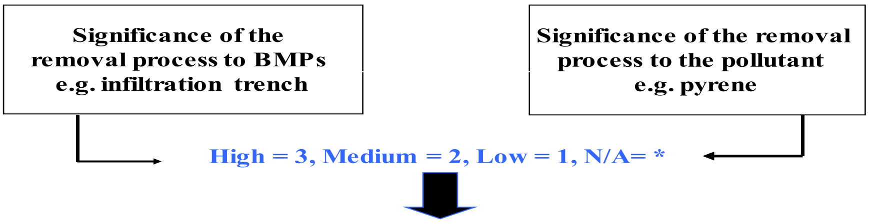
Porous asphalt surfaces without any sub-grade reservoir normally possess low storage volume:mean storm runoff volume (Vs:Rv) ratios and can handle only low peak flow rates, usually well below critical mean annual storm volumes and thus have the lowest utility scores and default scores. Where open porous asphalt (such as the Dutch ZOAB asphaltic mix) is used in the highway construction, or where there is a geocellular reservoir used in the sub-base construction, the infiltrative and volumetric capacity can be significantly increased and would be at least equivalent to that offered by soakaway systems (Grade 3). Grass swales (and to a lesser extent filter/vergeside strips) do offer some attenuation as well as potential on-line storage capacity along the swale channel with peak flow rate diminishing as it travels down the SUDS/BMP device. If check dams or stop logs are placed in the swale channel, the storage potential can be increased. However, it is rare for these SUDS/BMP biofilter devices to provide a level of protection greater than that generated by the critical 2 - 5 year peak storm runoff rate and therefore these SUDS/BMPs have been allocated a default grade of 2 (and up to a near mid-utility score). Infiltration basins operate best within a 1.5 – 3.0 ha range but can be marginally feasible up to nearly 8 ha particularly if they possess a basal reservoir (such as geocellular filters). Wetlands and retention basins can likewise be marginally feasible at effective contributory areas as low as 2 – 3 ha but would be liable to drying out and plant wilting during extended dry periods at this lower contributing area level.

The benchmark grade values for the various SUDS/BMPs as derived from Figure 1 appear as default values in the DSS matrix for the “Flood Control” indicator within the Technical criteria section. It is possible for end-users to modify these gradings to take account of local design conditions or in negotiation with specific stakeholder interests and issues. Re-grading of the utility score plots can be achieved using the guideline storage volume and effective contributing area discussion provided above.

POLLUTION CONTROL INDICATOR

<u>Pollutant Capture</u>

The Pollution Control Indicator within the Technical Criteria has been developed by benchmark referencing to the SUDS/BMP performance for the removal of a suite of 25 stormwater priority pollutants including TSS, BOD, COD, nutrients, faecal coliforms, metals, PAHs, herbicides and other organic pollutants (see DayWater Deliverable 5.4, Scholes *et al*, 2005). In this instance the utility score is benchmarked through the ranking of the SUDS/BMP in terms of its performance as determined from a detailed consideration of the efficiency potential of the primary removal processes for each pollutant. This has involved the quantitative evaluation of adsorption (K_d value), sedimentation (as derived from settling velocity) and filtration (K_d; solubility), microbial degradation (half-life), volatilization (K_h), photolysis (half-life) and plant uptake (K_{ow}) in respect of each SUDS/BMP type. The pollutant removal and BMP performance rates are initially classified as High, Medium or Low (or as Non-Applicable) using a scaling technique based on the determined quantitative values. This classification is then converted into a quantitative scale by summing the individual pollutant and SUDS/BMP removal process potentials to derive an overall single value for each SUDS/BMP device as shown in Figure 2 below.



Removal process	Significance of process to BMP	Significance of process to pollutant	Combined Value
Adsorption to substrate	2.5	3.0	7.50
Sedimentation	1.5	3.0	4.50
Microbial degradation	2.0	1.0	2.00
Filtration	2.5	3.0	7.50
Volatilisation	1.0	2.0	1.00*
Photolysis	N/A	3.0	-*
Plant uptake	1.0	3.0	3.0
		Overall value	25.5

* = weighted 0.5

Figure 2. Derivation of SUDS/BMP scores

The individual overall values can then be used as a basis for ranking the range of SUDS/BMP devices to indicate their order of preference for the treatment of specific pollutants e.g. TSS, cadmium, pyrene etc., or a combination of pollutant species e.g heavy metals, hydrocarbons etc. It is also possible to consider a merged combination of all pollutants in terms of the removal potential ranking of SUDS/BMPs for the user who is interested in the treatment potential of the full range of stormwater pollutants. For the purposes of this PROPER analysis of highway runoff, the primary benchmark used is that related to the performance capabilities of SUDS/BMP devices in terms of their TSS removal potential as described in the short general description overview accompanying this more detailed indicator page. A much more detailed explanation of the methodology used to develop the scoring procedure quantifying the BMP pollutant retention capability is given in the EU 5th Framework project DayWater, Deliverable 5.4 (Scholes et al., 2005).

It is the grades derived from the TSS parameter that have been used as the default value which appears in the PROPER DSS matrix. The graphical plot of the ranked order of preference for TSS is shown in Figure 3 and is graded according to the common 1 – 5 scale to derive the scores to be entered into the DSS matrix. It is also possible for the user of the DSS to enter grades, which they believe to be relevant to their own particular local circumstances, as described in the User Guide.

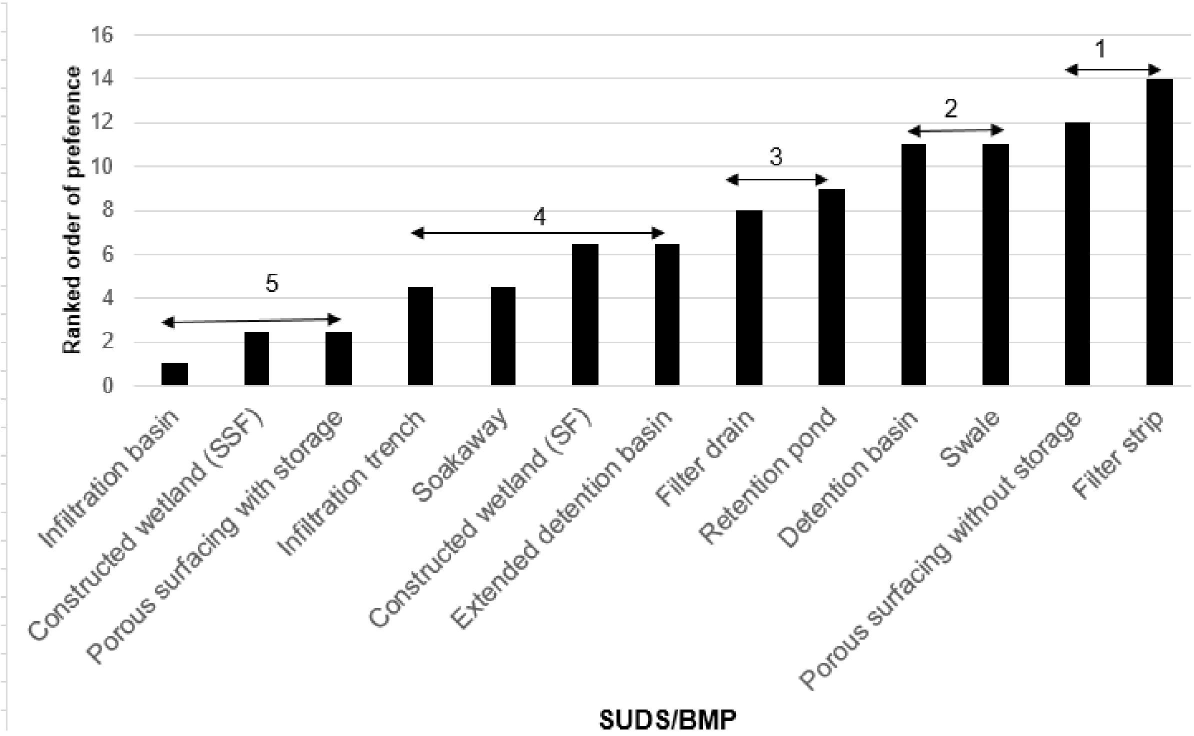


Figure 3. SUDS/BMP ranking and scores for TSS removal performance

The highest rating grades reflecting effective removal potentials have been allocated to constructed wetlands, infiltration basins and trenches as shown in Figure 3. Extended detention basins, soakaways and porous surfacing with sub-structure storage also perform well in terms of pollutant removal. The removal potential of all these SUDS/BMPs can be further enhanced where they are fitted with pre-treatment facilities such as sediment forebays. It is also interesting to note that sub-surface flow wetlands perform more effectively than surface flow wetlands.

Figure 4 shows the ranking of SUDS/BMPs in terms of their order of preference for the reduction of PAHs together with the 1 – 5 grading scores which can be used as default values in the DSS matrix. The data show an essentially linear distribution as measured by the ranked order of preference. Separate performance rankings have also been completed for a range of more specific organics including BOD, Organics and herbicides (see Daywater Deliverable D5.4, Scholes *et al.*, 2005).

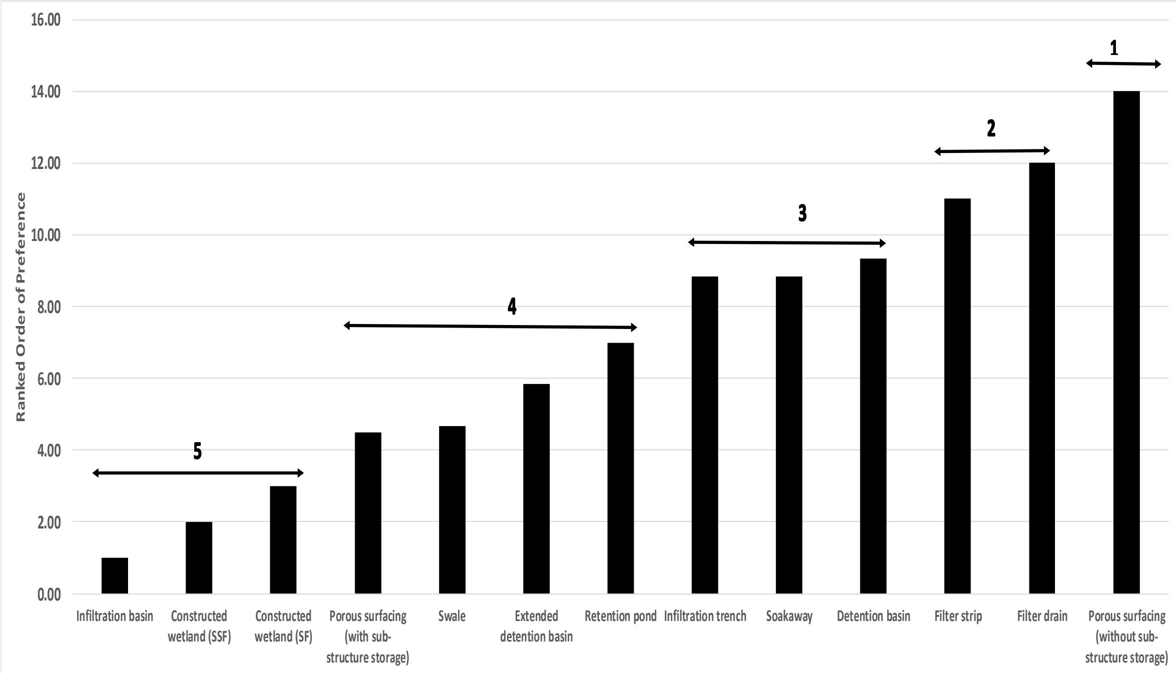


Figure 4. SUDS/BMP Ranking and Scores for PAH Removal Performance

Figure 5 shows the ranking of SUDS/BMPs in terms of their order of preference for the reduction of total metals (Cd, Cu, Zn, Pt, Cr, Ni, Pb) and the 1 – 5 grading scores to be used as default values in the DSS matrix. The heavy metals coverage includes species which are primarily solids-associated (e.g Pb), those which tend to occur in a more soluble state (e.g Zn) and those which occur predominantly in the anionic form (e.g Cr). Given that the graphical plot combines seven heavy metal groups, standard deviation bars are also included to provide an estimation of the variability of the combined distributions. As before, it is also possible for the user to choose scores they feel to be more relevant to their particular local circumstances and field evidence.

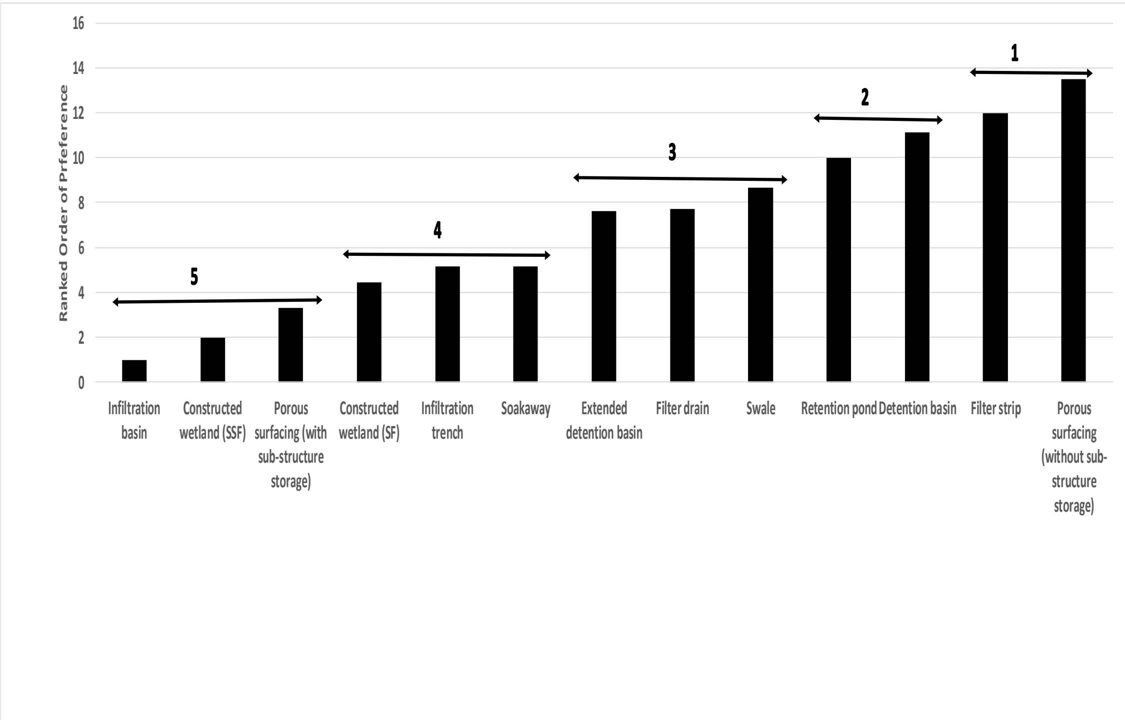


Figure 5. SUDS/BMP Ranking and Scores for Metals Removal Performance.

References

Scholes, L., Revitt, D.M and Ellis, J.B. 2005. The Determination of Numerical Values for the Assessment of BMPs. EU 5th Framework DayWater Project, Deliverable No. 5.4., 5 April 2005.

ADAPTABILITY TO HIGHWAY WIDENING AND CLIMATE CHANGE INDICATOR

1. SUDS/BMP Adaptability and Increased Flow Volumes.

SUDS/BMPs can represent a viable rehabilitation option for retrofitting into existing highway situations which might experience flooding and/or pollution problems as a result of road widening, carriageway works/activities, culverting, increased traffic densities etc. Identifying which SUDS/BMPs are viable to specific locations is extremely difficult as it involves design constraints covering planning and construction regulations, land availability as well as cost and local ground conditions. In addition, the type of surfacing and the mode of SUDS/BMP operation (storage, disposal, infiltration etc.) can also be important considerations. Infiltration systems for example, may be a highly viable option as a SUDS/BMP retrofit solution to resolve a hydraulically overloaded situation and may also represent a low pollution risk option, but can be very expensive to install and maintain within a constrained highway situation. In addition, some infiltration systems such as porous asphalt (without sub-structure reservoirs) may not be capable of handling substantial flow volumes resulting from expansion of the impermeable highway surface. It is therefore a considerable advantage if the highway configuration and associated drainage system possesses sufficient flexibility to be appropriately and effectively adapted to accept additional or enhanced capability to collect, convey and attenuate any increased future runoff volumes.

All increased surface runoff as a result of road widening should be subject to attenuation with overflow outfalls introduced to existing drainage facilities if sufficient freeboard is available or to enhanced retrofitted or new drainage controls. Whilst the critical design peak discharge for highway runoff may frequently be determined by the 1:100 RI 6 hour duration storm event, the standard design normally requires that the edge of pavement drainage systems (central reservation, vergeside drains and slip/access roads) should be at least able to convey flows generated by storms with a 1 year return period (plus 20% climate change uplift) without surcharging or flooding. A 5 year RI event (+20% climate change uplift) is often acceptable for hard shoulder drainage, with a return period of 50 – 75 years being generally acceptable for effective swale channels and interceptor ditches. The capacity of unconstrained surface SUDS/BMP drainage systems (ponds, wetlands, basins, soakaways) may be designed to accept higher flows up to the critical 1:100 RI (plus climate change uplift). Exceedance outflows should be limited to the equivalent 1:2 year greenfield runoff rate (or 2 – 3 l/s/ha). Where the proposed impermeable area increases above 10% relative to the existing impermeable area as a result of the localised widening, flow restrictions should be in place to ensure that outfall discharge rate does not exceed 2 – 3 l/s/ha (or to the existing outflow flow rate) in order to minimise flood risks. Such controls might be active systems such as penstocks, valves, weirs etc., or alternatively and preferably passive SUDS/BMP systems. A 24 hour residence time (Rt) is widely accepted as representing best practice for storm storage/attenuation facilities and determined by:

Rt = (SUDS/BMP Volume [V] / Discharge Rate [Dr])
where Dr is frequently taken as being between 2 – 4 l/s/ha.

The required storm storage volume and attenuation value on a m^3/m^2 basis can be determined by dividing the calculated attenuation value by the additional impermeable area brought about as a result of highway widening.

2. Highway Widening.

In terms of road widening, four basic configuration options can be identified, each having their own specific advantages and limitations which need to be considered in the final decisions on drainage infrastructure provision. Parallel widening is perhaps the least disruptive, especially if it is undertaken “on-line” as it involves construction immediately alongside the existing carriageway(s) but demands that sufficient adjacent land take is available. However, it normally requires considerable refurbishment to existing bridges, culverts and other structures. Such parallel widening can enable the full suite of SUDS/BMP drainage options to be implemented and thus the configuration offers both adaptability and flexibility at relatively low cost. Symmetric/asymmetric widening involves "in-situ" construction works which is nearly always highly disruptive to ongoing traffic flows. Intermittent hard shoulders and occasional by-pass lanes behind existing bridge piers are required and the approach reduces land availability for filter strips and swale channels. Central reservation and roadside edge drainage may only be capable of supporting narrow fin drains rather than wider higher-capacity infiltration (french) drains. Narrowing existing lanes to a reduced width in order to insert an additional lane can be equally disruptive to traffic flows and has significant safety implications. However, such an approach can have zero land take requirement and thus leave open full options in terms of SUDS/BMP drainage systems. Smart motorways incorporating active dynamic traffic management allowing use of the existing hard shoulder as an additional "running" traffic lane have become a popular renovation option in Europe. The approach uses occasional emergency refuge areas and controlled variable speed limits but involves minimal adjacent land take leaving flexible opportunities for SUDS/BMP retrofit to the drainage infrastructure.

3. <u>Catchment Area.</u>

The primary benchmark that has been selected for use within the DSS as a threshold index for System Adaptability is based on the hydraulic robustness of performance following increased volumetric discharge within the highway catchment due to road widening or other carriageway works/activities. The insertion of an additional 3.65m wide lane (plus 3.3m hard shoulder) can readily result in an increase of the effective contributing area by up to 35% which in turn would generate a significant increase in the peak volumetric discharge rate (Highways Agency, 2015). In this context, adaptability can be represented by the percentage increase per unit area (m^2 or km^2) in the ultimate treatable volume (Vt) arising from the increased impermeable surface discharge to the ultimate or final value at which exceedance overflow from the system would occur. It should be noted that the total highway catchment area is rarely fully covered by impermeable surfacing and typically only between 65% to 75% will be trafficked. The lower areal percentage represents the effective impermeable area as far as the majority of the rainfall-runoff is concerned and it is this reduced area which should be used in the determination of average annual volumetric rates otherwise the control facilities are liable to be considerably oversized. However, it is possible that at or near the critical peak 1:100 design discharge, some of the non-trafficked "permeable" areas may generate overland flows from saturated vergesides, particularly if they have experienced prolonged antecedent wet weather conditions. It may therefore be acceptable to consider the total catchment area in the determination of effective peak outfall discharge for the critical design storm event as a basis for a worst case scenario. Two level control facilities such as extended detention basins and cellular wetland designs can be appropriate best management approaches under these conditions.

4. <u>Climate Change.</u>

Most highway authorities have acknowledged that future climate change represents a significant potential disruptive impact which will subject highway drainage to a time-critical vulnerability (Meyer et al., 2014). UK highway authorities for example, have already identified a methodology to assess the increased flood risk associated with increased extreme weather events over the next 30 to 50 years (Sayers et al., 2015) and suggest that at minimum this would be 10% to 18%. The 1:30 RI flood event in the UK might well become the 1:1 annual event (Reeves et al., 2012). Predicted rainfall increases by the 2050/2080s in the UK average 40% which would generate a very significant uplift in the 0.5% annual exceedance flood probability. This might result in anything between a 50% to 90% increase in surface water pluvial flooding. Estimates for maximum 100 year flood magnitude by 2050/2080 indicate global increases between 30% to 170% (Arnell and Gosling, 2016). The frequency of the current 1:100 flood event is also expected to reduce to between 10 to 50 years (Mayer et al., 2014). The grid-cell modelling estimates do not consider the temporal effect of rainfall intensity which potentially underestimates the effect of climate change on flood outcomes. Some estimates suggest there is a strong probability that for the UK, average storm rainfall intensities might increase from 20mm/hour to a range between 30 – 45 mm/hour. Future climate change is therefore a fundamental consideration for "future proofing" designs in order to achieve effective highway drainage management and as such comprises an essential and critical parameter for system adaptability. However, climate change is already included as a basic component in the Flood Control criteria with 20% uplift incorporated in the critical peak flow volume determination. Thus in the benchmarking of this Adaptability criteria it has not been over-weighted and only allocated a unity value to avoid double counting.

5. <u>Benchmarking.</u>

The three adaptability benchmarks (road widening, space availability/flexibility and climate change) have been weighted on a 2:1:1 ratio which takes into account the expected magnitude of their respective roles in determining discharge volumes. Given that the working methodology already includes a basic 20% uplift for climate change in the determination of peak flow volumes (see Flood Control Criteria), this parameter is allocated a unity value in the weighting ratio. Table 1 below identifies the weighted average utility score distribution for the different SUDS/BMPs. A low utility score reflects the individual SUDS/BMP vulnerability to the benchmark parameter and an increased sensitivity to disruption from increased surface water flows. A high utility score represents a greater resilience and adaptability to maintain an effective performance in the event of increased flow volumes. The individual SUDS/BMP weighted average utility scores for the overall Adaptability criteria are given in the final column of Table 1 below. However, it is possible for the user to develop their own utility scores and associated weightings and implement them in the matrix as explained in the User Guide.

Table 1. SUDS/BMP Benchmark Scores for the Adaptability Criteria

SUDS/BMP	Benchmark	Impact and Utility Score	Weighted Average Utility Score
Swale	Road widening	H: 0.3	0.33
	Climate Change	H; 0.3	
	Space/Flexibility	M/H; 0.4	
Filter Strip	Road widening	VH; 0.2	0.18
	Climate Change	VH; 0.1	
	Space/Flexibility	VH/H; 0.2	
Filter Drain	Road widening	M/H; 0.4	0.30
	Climate Change	H; 0.3	
	Space/Flexibility	VH; 0.1	
Soakaway	Road widening	M; 0.5	0.53
	Climate Change	M/l; 0.6	
	Space/Flexibility	M; 0.5	
Infiltration Trench	Road widening	H/M; 0.4	0.35
	Climate Change	H/M; 0.4	
	Space/Flexibility	VH/H; 0.2	
Detention Basin	Road widening	M; 0.6	0.61
	Climate Change	M; 0.6	
	Space/Flexibility	L; 0.65	
Extended Detention Basin	Road widening	L; 0.7	0.73
	Climate Change	L; 0.8	
	Space/Flexibility	L; 0.7	
	Road widening	M/L; 0.6	

Retention Pond	Climate Change	M; 0.5	0.55
	Space/Flexibility	M; 0.5	
Constructed Wetland	Road widening	M/L; 0.6	0.71
	Climate Change	L; 0.8	
	Space/Flexibility	VL; 0.85	
Infiltration Basin	Road widening	M; 0.5	0.40
	Climate Change	H/M; 0.4	
	Space/Flexibility	M/H; 0.4	
Porous Surfacing (without sub-surface storage)	Road widening	VH/H; 0.2	0.20
	Climate Change	VH; 0.1	
	Space/Flexibility	H; 0.3	
Porous Surfacing (with sub-surface storage)	Road widening	M/L; 0.6	0.65
	Climate Change	L: 0.7	
	Space/Flexibility	L; 0.7	

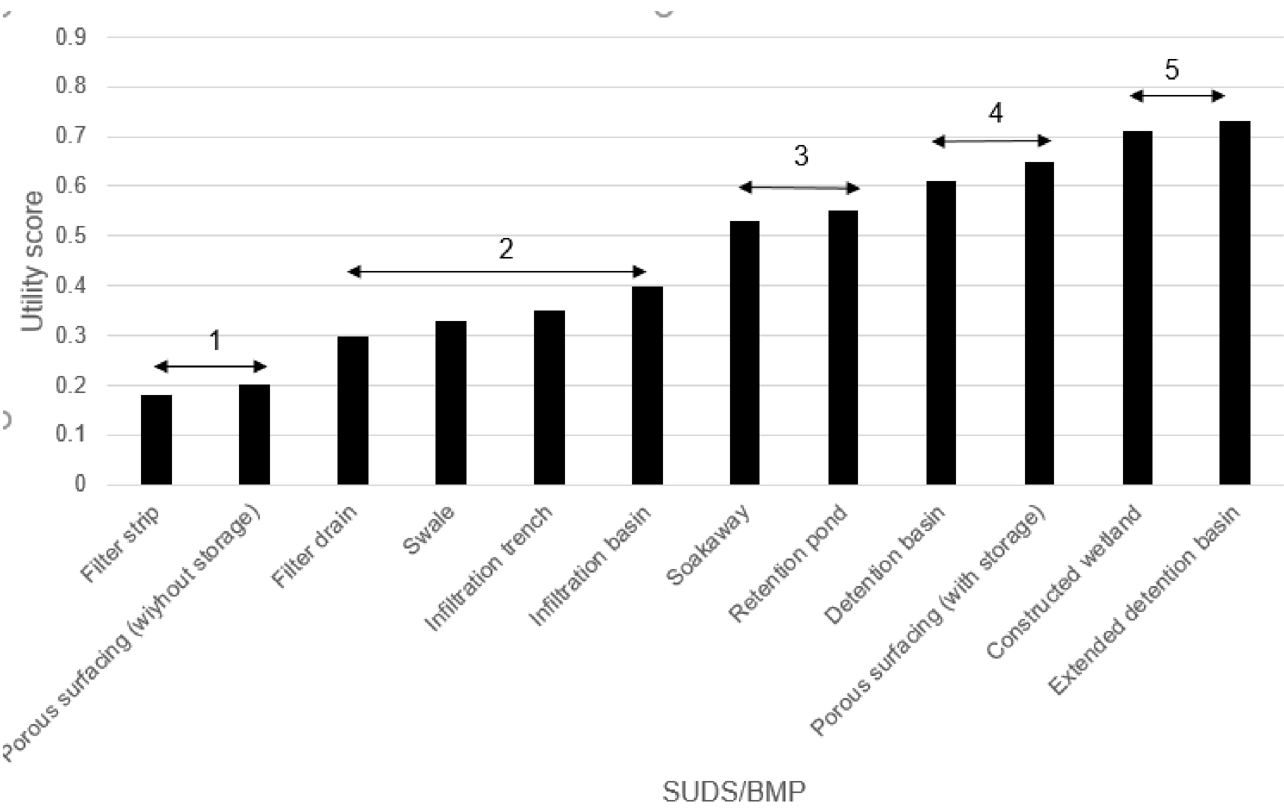


Figure 6. DSS Benchmark Utility Scores for System Adaptability Indicator

The methodology assumes a linearity of response between the increased impermeable area and resulting increase in effective runoff volume as represented by the peak flow rate. This assumption has limited field evidence and pre-construction flow monitoring of the highway outfall is recommended to provide a robust database on which to model predicted 95% percentile and 5% percentile discharge rates (including 20% climate change uplift) following road widening. The graphical plot shown in Figure 6 illustrates the utility scores that have been developed from the “hydraulic robustness” values based on an assumed linear relationship. The allocation of specific SUDS/BMP types to the derived utility scores is then based on a consideration of the hierarchies in terms of highway flexibility, increased peak flow/storage volume and SUDS/BMP operational modes as identified in Table 1. The Grade 1 drainage options shown by the red arrows and font indicates that where symmetric/asymmetric road widening is implemented, these SUDS/BMP facilities may be inappropriate or impossible to install due to lack of available space.

Retrofitted infiltration and disposal devices which can be fitted into the existing land take area are likely to be more cost-effective than storage in already overloaded highway catchments as they may be able to directly remove runoff from the existing drainage system rather than seeking further attenuation capacity. In addition, storage (dry/wet) basins and soakaways are more likely to have sufficient freeboard in the original design to allow increased storage volumes and therefore carry higher utility scores.

No consideration of a costing hierarchy has been included in the methodology as there is a separate Costing Criteria included in the DSS matrix. The allocations shown on Figure 6 are therefore essentially based on the SUDS/BMP rankings according to hydraulic factors i.e. how well they are likely to control and manage peak storm runoff flows generated by increased surface flow from the enlarged impermeable highway, road works or climate change. Given the likelihood of increased solids and solid-associated pollutant loadings which will result from intensification of traffic densities on the widened/improved highway, it would be advisable to install appropriate pre-treatment facilities as indicated in Figure 6 for Grade 4 and 5 designations.

The benchmark grade values for the various SUDS/BMPs as derived from Figure 6 appear as default values in the DSS matrix for the 'Adaptability to Highway Widening and Climate Change' indicator within the Technical criteria section. It is possible for end-users to modify these gradings to take account of local design conditions or in negotiation with specific stakeholder interests and issues. Re-grading of the utility score can be achieved using the guidelines for the adaptability criteria described in the discussion provided above.

References

Arnell, N and Gosling, S.A. 2016. The impact of climate change on river flood risk at the global scale. Climatic Change, 124(3), 387 – 401.

Highways Agency. 2015. M4 Junctions 3 – 12 Smart Motorway: Flood Risk Assessment. Report TR010019. Volume 5.0. Highways Agency. Bedford. UK.

Meyer, M., Flood, M., Keller, J., Lennon, J., McVoy, G., Dorney, C., Leonard, K., Hyman, R and Smith, J. 2014. Climate Change, Extreme Weather Events and the Highway System: A Practitioner's Guide. National Cooperative Highway Research Program. Transportation Research Board. Washington DC. US.

Reeves, S., Benton, M., Buckland, T and Anderson, N. 2012. Development of Methodology for a Highway Drainage Risk Model for Pluvial Flooding. Report PPR637. TRL Ltd. London. UK.

Sayers, P.B., Horritt, M., Penning-Rowsell, E and McKenzie, A. 2015. Climate Change Risk Assessment 2017: Projections of Future Flood Risk in the UK. Sayers & Partners LLP. Committee on Climate Change. London. UK.

ENVIRONMENTAL CRITERIA

incorporating

IMPACT ON RECEIVING WATERBODY VOLUME INDICATOR

IMPACT ON RECEIVING WATERBODY QUALITY INDICATOR

IMPACT ON RECEIVING WATERBODY ECOLOGY INDICATOR

IMPACT ON RECEIVING WATER VOLUME INDICATOR

The major environmental considerations for SUDs/BMP controls in terms of impact upon receiving water volume are considered separately for surface waters and for groundwater. For surface waters it is important to consider the potential for downstream channel and bank erosion (which in turn impacts on stream habitat) and the thermal impacts of discharges. For groundwater, the potential for groundwater recharge and maintenance of minimum flows are considered in order to assess the impact on water volume.

<u>Surface waters</u>

a) Downstream impacts

The hydrological changes resulting from the presence of highway surfaces can lead to significant geomorphic changes in receiving surface waters, including habitat simplification, scouring of sediments and the creation of larger, deeper channels. The enhanced shear stress generated within the receiving stream due to increases in both the frequency and magnitude of elevated flows results in an increase in the mobilisation and transport of sediments. The consequences of all these effects are a deterioration of stream ecosystems due to reductions in habitat and aquatic organisms. The installation of SUDs/BMPs can mitigate these impacts by controlling peak discharges. This is particularly relevant where the first flush phenomenon exists due to their ability to deal effectively with the initial portion of the runoff volume. It is estimated that for the 1:5 to 1:2 year storm event, treatment systems can provide some degree of downstream stream bank erosion control. However, even the 1:2 storm will create a potential erosive condition in natural channels as this is the channel-forming bankfull discharge. Extended detention basins, detention basins and infiltration basins, if properly sized, can effectively reduce the frequency with which such high frequency bankfull flooding occurs and thus have potential for downstream erosion control. Retention ponds and constructed wetlands basins however, have a comparatively lower capability in this regard. The roles that different SUDs/BMPs can play in ameliorating receiving stream erosion impacts are described in Table 2 together with the allocated size of the impact and associated utility score. The relationships between the levels of impact and corresponding utility scores distribution are shown in Table 3.

b) Thermal impacts

Water temperature is known to influence the metabolic and reproductive rates of algae, benthic invertebrates, and fish. Aquatic organisms have characteristic temperature preferences and tolerance limits with game fish for example, requiring a maximum of 13°C for egg incubation and spawning with sustained water temperatures in excess of 21°C being either extremely stressful or lethal. A rise in temperature of only a few degrees over ambient conditions can reduce or eliminate sensitive receiving water species such as stoneflies and mayflies. In prolonged summer periods, urban runoff can warm receiving waters to the detriment of these organisms not only in terms of direct thermal impact but also because warm discharge waters can reduce the available dissolved oxygen. Studies have shown that average stream temperatures increase linearly with impervious area percentage with elevated temperatures occurring at levels as low as 12% imperviousness. SUDs/BMPs can exacerbate this thermal effect when they retain water for an extended time in hot weather with temperature stratification also being possible in waterbodies as shallow as 0.5m. Runoff leaving shallow wetlands and wet retention ponds can be 5°C to 10°C warmer than the runoff entering the SUDs/BMP structure. The release of impounded waters which have been heated during retention between storm events, can therefore be detrimental to the receiving water ecology. The roles that different SUDs/BMPs can play in influencing receiving stream temperatures are described in Table 2 together with the allocated size of the impact and associated utility score. The relationships between the levels of impact and corresponding utility score distributions are shown in Table 3.

c) Combined effect of downstream impacts and thermal impacts on receiving surface waters

A comparative basis for the assessment of SUDs/BMP volume control benefits to receiving surface waters for the above two parameters can be made using a semi-quantitative approach with the descriptive values corresponding to a utility score distribution as illustrated in Table 3. Mid-value utility scores e.g. 0.5 are taken as being equivalent to a descriptive value corresponding to a medium impact (M), with a very low impact (VL) receiving a utility score of 0.9 and a high impact (H) being awarded a utility score of 0.3 as shown in Table 2. The two potential impacts affecting surface waters (erosion and thermal) are weighted on a 3:1 ratio taking into account the expected magnitude of their roles. The weighted average utility score for the water volume impact on receiving surface waters is shown in the final column of Table 2. The SUDs/BMP showing the least impact with respect to receiving surface waters is the extended detention basin with a weighted utility score of 0.75 (low impact) despite the potential thermal impact being classed as high. Porous surfacing (without sub-structure storage) is identified as posing the greatest impact (high; utility score 0.28). The allocation of grades, based on a 1 to 5 scale, for each of the SUDs/BMPs with regard to the water volume impact on receiving surface waters is shown in Figure 7. Extended detention basins receive the highest grading of 5 with porous surfacing (without sub-structure storage) getting to lowest grade of 1.

Table 2. Description of the roles of different SUDs/BMPs in reducing the impacts caused to receiving surface waters due to downstream erosion and thermal impacts and allocation of utility scores

	Type of impact	Description of impact	Level of impact	Utility score	Weighted utility score
Swale	Erosion control	Swales are essentially conduits delivering runoff from the highway surface and with only limited storage can provide only low flow attenuation	H	0.3	0.40
	Thermal control	Minimal impact on temperature of receiving waters as no significant surface or underground storage	L	0.7	
Filter strip	Erosion control	Filter strips are essentially conduits delivering runoff from the highway surface and with only limited storage can provide only low flow attenuation	H	0.3	0.40
	Thermal control	Minimal impact on temperature of receiving waters as no significant surface or underground storage	L	0.7	
Filter drain	Erosion control	Filter drains provide temporary sub-surface storage and therefore some flow attenuation	M	0.5	0.50

	Thermal control	Some degree of warming possible due to temporary sub-surface storage	M	0.5	
Soakaway	Erosion control	No discharge to surface waters	N/A	-	-
	Thermal control	No discharge to surface waters	N/A	-	
Infiltration trench	Erosion control	No discharge to surface waters	N/A	-	-
	Thermal control	No discharge to surface waters	N/A	-	
Detention basin	Erosion control	Detention basins provide surface storage for 6-12 hours and therefore capable of substantial flow attenuation	L	0.7	0.63
	Thermal control	Because of surface storage capability there is the potential for thermal warming	M/H	0.4	
Extended detention basin	Erosion control	Extended detention basins provide surface storage for 24-48 hours and therefore capable of very substantial flow attenuation	VL	0.9	0.75
	Thermal control	Because of prolonged surface storage capability there is the potential for substantial thermal warming	H	0.3	
Retention pond	Erosion control	Surface storage provided but above existing permanent pond therefore less flow attenuation than for detention basin	L/M	0.6	0.55
	Thermal control	Mixing potential with already retained water will reduce warming effect	M/H	0.4	
Constructed wetland	Erosion control	Will depend on design type; sub-surface flow systems provide storage in substrate (i.e. volume attenuation) whereas surface flow systems allow flow through plants and above substrate (i.e. lower attenuation); overall less storage that retention pond	M	0.5	0.45
	Thermal control	For surface flow systems there will be warming within the substrate where microbial action also occurs whereas less warming in surface floe systems	H	0.3	

		although some impact due to plants; overall more potential for warming than retention ponds			
Infiltration basin	Erosion control	Capable of a similar level of storage to that demonstrated by detention basins and therefore equivalent flow attenuation	L	0.7	0.63
	Thermal control	Capable of a similar level of storage to that demonstrated by detention basins and therefore equivalent thermal warming potential	M/H	0.4	
Porous surfacing (with sub-structure storage)	Erosion control	Presence of underground storage provides potential for surface flow attenuation	L/M	0.6	0.58
	Thermal control	Discharge to surface waters is through overland flow which may be subjected to a small warming effect depending surface exposure time	M	0.5	
Porous surfacing (without sub-structure storage)	Erosion control	Direct discharge to surface waters by overland flow provides little opportunity for flow attenuation	H/VH	0.2	0.28
	Thermal control	Discharge to surface waters is through overland flow which may be subjected to a small warming effect depending surface exposure time	M	0.5	

N/A = not applicable to surface waters as discharges are to groundwaters only

Table 3. Allocation of Utility Scores to Descriptive Values

Descriptive Value	Utility Score Range
Very High (VH)	0 – 0.2
High (H)	0.2 – 0.4
Medium (M)	0.4 – 0.6
Low (L)	0.6 – 0.8
Very Low (VL)	0.8 – 1.0

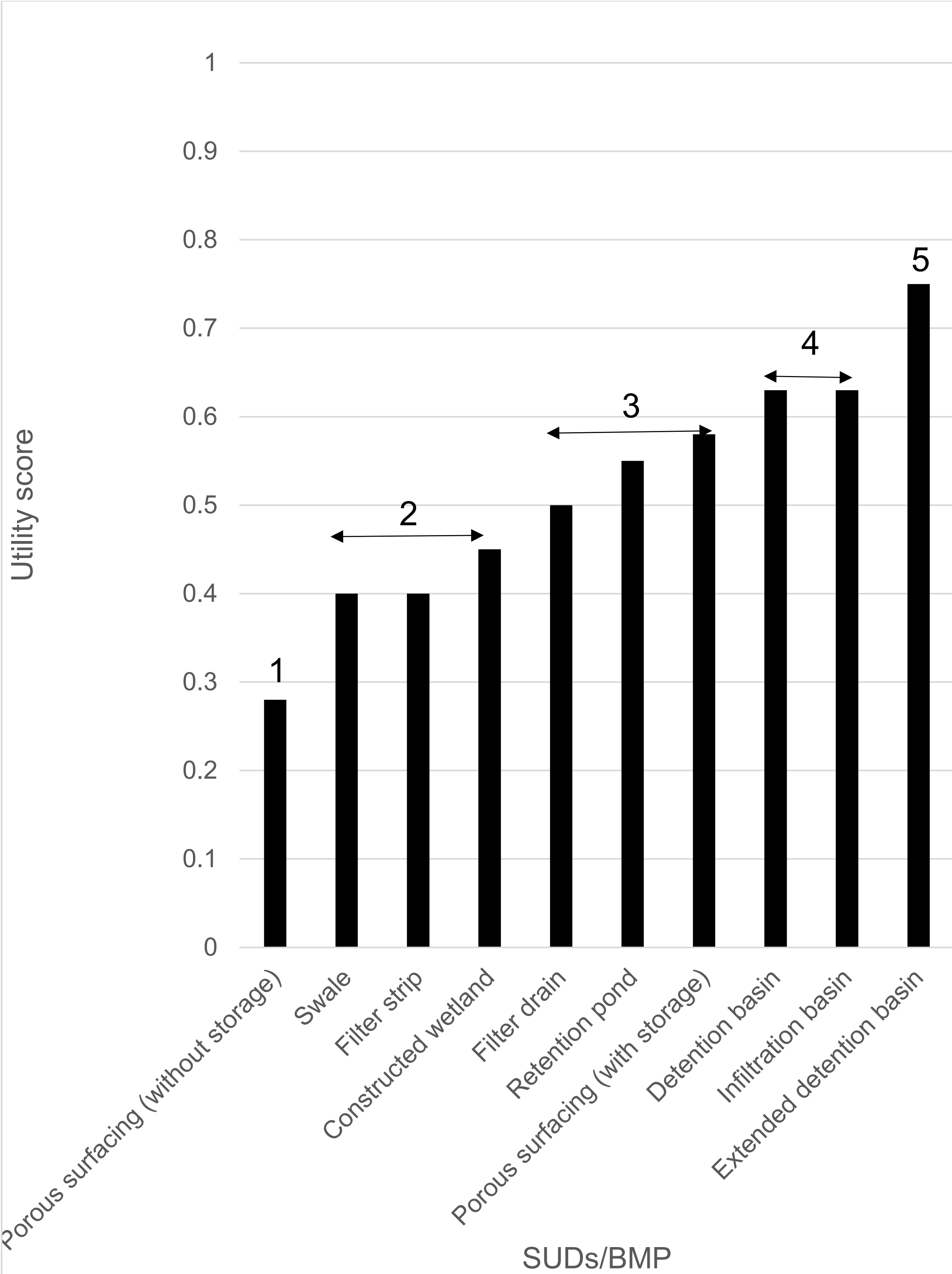


Figure 7. SUDs/BMP ranking and allocated scores for prevention of downstream erosion and thermal impacts in receiving surface waters.

<u>Groundwaters</u>

Infiltration SUDs/BMPs contribute directly to the recharge of receiving groundwaters and thus also contribute to the long term maintenance of minimum receiving water flows. In contrast surface storage treatment systems such as whilst detention basins, retention ponds and wetland facilities are frequently lined or have compacted beds which prevent seepage to groundwater. Although the volume effect of infiltration percolation is beneficial to the groundwater resource, the quality impacts may be detrimental. The comparative assessment of SUDs/BMP in terms of their ability to minimise groundwater recharge/low flow maintenance are described in Table 4. The levels of impact relate to the descriptive comments for each SUDs/BMP with utility scores allocated according to values given in Table 3. Figure 8 shows that only grades 2 to 5 are merited to be awarded based on the plotted utility scores. The SUDs/BMP showing the highest potential to contribute to groundwater recharge/low flow maintenance is the infiltration basin (allocated grade 5) with swales and filter strips (both grade 2) being identified as having the least ability to provide groundwater recharge.

The benchmark grade values for the various SUDS/BMPs as derived from Figures 7 and 8 appear as default values in the DSS matrix for the "Impact on Receiving Water Volume" indicator within the Environmental criteria. It is possible for end-users to modify these gradings to take account of local design conditions or in negotiation with specific stakeholder interests and issues. Re-grading of the utility score plots can be achieved using the guideline impacts for surface waters and groundwater in the discussion provided above.

Table 4. Description of the roles of different SUDs/BMPs in minimising groundwater recharge/low flow maintenance and allocation of utility scores

SUDs/BMP	Description of impact relating to minimisation of groundwater recharge/low flow maintenance	Level of impact	Utility score
Swale	Provides a gradual discharge to groundwater	M	0.5
Filter strip	Provides a gradual discharge to groundwater	M	0.5
Filter drain	Provides sub-surface storage which will be released during wet weather	L/M	0.6
Soakaways	Volume release to groundwater is the main discharge mechanism but impact in highway environment not substantial	L	0.7
Infiltration trench	Volume release to groundwater is the main discharge mechanism but impact in highway environment not substantial	L	0.7
Detention basin	N/A	-	-
Extended detention basin	N/A	-	-
Retention pond	N/A	-	-
Constructed wetland	N/A	-	-
Infiltration basin	Infiltration occurs over a substantial area providing good potential for groundwater recharge	VL/L	0.8
Porous surfacing (with sub-structure storage)	Where provision for infiltration is provided, storage facility will facilitate controlled recharge of groundwater	L	0.7
Porous surfacing (without sub-structure storage)	Where provision for infiltration is provided, the absence of effective storage result in more rapid recharge of groundwater than where storage is present	L/M	0.6

N/A = not applicable to groundwaters as discharges are to surface waters only

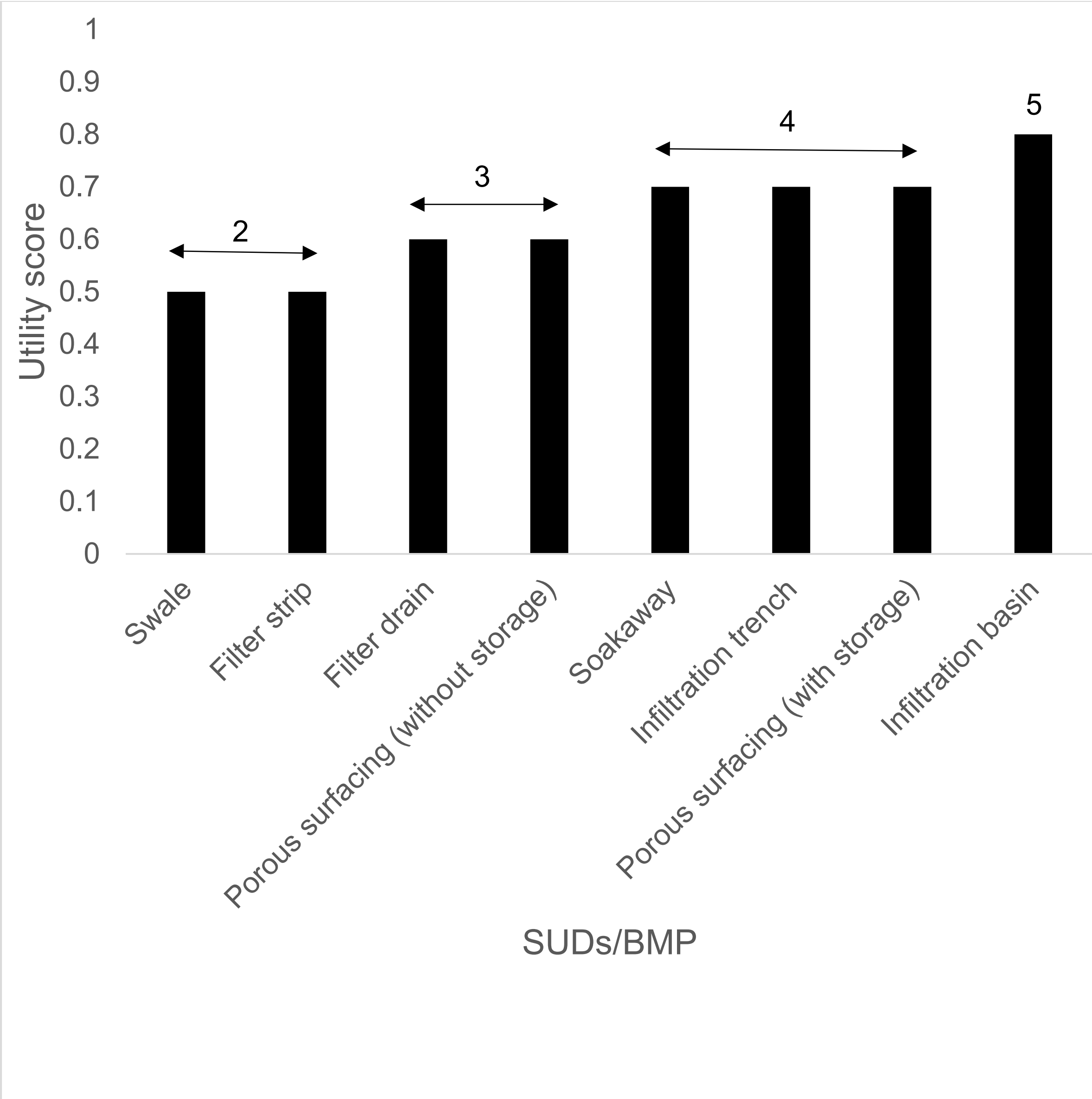


Figure 8. SUDs/BMP ranking and allocated scores for their ability to contribute to groundwater recharge/low flow maintenance.

IMPACT ON RECEIVING WATER QUALITY

The process of surface sealing associated with the creation of impermeable road surfaces represents a substantial and major anthropogenic intervention to the hydrological cycle. The resulting amendment and disruption of natural surface water flow systems leads to increased flow volumes and associated elevated pollutant concentrations and mass loads to receiving waterbodies (Barrett et al., 1995). Untreated highway runoff may be discharged directly to receiving rivers/streams or may be initially directed to a treatment system to reduce/remove highway pollutants. The runoff (treated or untreated) may also find its way to groundwaters following infiltration processes.

The EU Water Framework Directive (EU WFD, 2000) establishes a legal obligation on Member States to protect and restore the quality of European water bodies, both surface waters and groundwaters. The main objective of the EU WFD is to achieve 'good status' for all of Europe's surface waters and groundwater by 2015 or 2027 at the latest and above all, to prevent deterioration of the existing status of a water body. 'Good status' for surface waters is defined through both ecological and chemical conditions in terms of a healthy ecosystem and low levels of chemical pollution. Groundwater status within the EU WFD is defined by whether there is sufficient water to maintain the health of the ecosystem it feeds to and assesses total abstraction against groundwater recharge. Groundwater chemical status is assessed separately through the evaluation of Annex II substances for the specific waterbody (EU Groundwater Directive, 2006).

The chemical status of surface waters is determined through the use of environmental quality standards (EQSs) which have been established for a range of chemical pollutants of concern (termed 'priority substances' and priority hazardous substances (EU Priority Substances Directive, 2013). This list consists of 45 regulated pollutants, which are considered to be bioavailable, toxic and persistent in the environment, with those which been reported to be present in highway runoff identified in Table 5. Also given in Table 5 are the current limit values according to acute/chronic toxic effects and the nature of the surface water. In addition to the pollutants identified in the EU Priority Substances Directive (2013), there are specific standards which have been adopted by individual countries to protect the ecological status of receiving rivers/streams e.g. copper and zinc within the UK. The pollutants raising concern with regard to contaminated inputs arising from highway runoff include total suspended solids (TSS), metals, persistent organic pollutants and salts, particularly sodium chloride following use as a de-icing agent.

Surface waters

For the treatment of runoff prior to discharge to surface waters, the SUDs/BMP should ideally be designed to intercept the volumes and pollutant loads associated with most rainfall events, up to approximately 5 mm in depth, as these constitute the bulk of the annual pollutant load. Treatment is typically directed at frequent rainfall events (up to about the 1:1 year return event) where surface based contaminants are being mobilised and washed off, and the potential pollutant load contribution to the receiving surface water is high. Both monitoring and modelling procedures have consistently highlighted the concerns posed to surface waters by runoff containing TSS, Cu and Zn. TSS represent a principal highway runoff constituent requiring treatment because of the potential harmful physical effect to aquatic habitats. In addition many metals and organic pollutants are attached to suspended solids and therefore TSS act as a surrogate for a wider range of particulate associated substances. Typically greater that 50% of the metal and organic pollutant loads are associated with suspended particles which can accumulate in receiving watercourses leading to chronic pollution. Because of its significance as a highway derived pollutant, TSS has been selected as the representative pollutant to be used to assess the role of SUDs/BMPs on reducing the

Table 5. Environmental Quality Standards for priority substances and priority hazardous substances likely to be identified in highway runoff.

CAS number	Name of substance	AA-EQS Inland surface waters (µg/L)	AA-EQS Other surface waters (µg/L)	MAC-EQS Inland surface waters (µg/L)	MAC-EQS Other surface waters (µg/L)
120-12-7	Anthracene*	0.1	0.1	0.4	0.4
71-43-2	Benzene	10	8	50	50
7440-43-9	Cadmium and its compounds* (depending on water hardness classes)	≤ 0.08 (Class 1)	0.2	≤ 0.45 (Class 1)	≤ 0.45 (Class 1)
		0.08 (Class 2)		0.45 (Class 2)	0.45 (Class 2)
		0.09 (Class 3)		0.6 (Class 3)	0.6 (Class 3)
		0.15 (Class 4)		0.9 (Class 4)	0.9 (Class 4)
		0.25 (Class 5)		1.5 (Class 5)	1.5 (Class 5)
330-54-1	Diuron	0.2	0.2	1.8	1.8
206-44-0	Fluoranthene*	0.1	0.1	1	1
7439-92-1	Lead and its compounds*	7.2	7.2	NA	NA
7439-97-6	Mercury and its compounds*	0.05	0.05	0.07	0.07
91-20-3	Naphthalene*	2.4	1.2	NA	NA
7440-02-0	Nickel and its compounds	20	20	NA	NA
NA	Polyaromatic hydrocarbons (PAH) *	NA	NA	NA	NA
50-32-8	Benzo(a)pyrene*	0.05	0.05	0.1	0.1
205-99-2	Benzo(b)fluor-anthene*	Σ = 0.03	Σ = 0.03	NA	NA
207-08-9	Benzo(k)fluor-anthene*				
191-24-2	Benzo(g,h,i)-perylene*	Σ = 0.002	Σ = 0.002	NA	NA
193-39-5	Indeno(1,2,3-cd)-pyrene*				
122-34-9	Simazine	1	1	4	4

NA = not applicable; * Priority hazardous substance
CAS = Chemical Abstracts Service
AA-EQS Environmental Quality Standard expressed as an annual average value; inland surface waters encompass rivers and lakes and related artificial or heavily modified water bodies.
MAC-EQS Environmental Quality Standard expressed as a maximum allowable concentration; when marked as ‘not applicable’, the values are considered protective against short-term pollution peaks in continuous discharges since they are significantly lower than the values derived on the basis of acute toxicity.

impact of road runoff on receiving surface water quality. Another advantage of using TSS is that the availability of monitoring data is more widespread than for other, more specific, pollutants.

A comprehensive pollutant database has been produced by Mitchell (2005) incorporating UK studies of urban runoff quality together with northern European data. In N America, the international BMP stormwater database (Clary et al.,, 2017) collates data from over 530 studies primarily across the US with additional information also available for Canada (OMOE, 2003). From these databases the statistical values shown in Table 6 have been derived for TSS concentrations in two different categories of highway runoff. The two sets of highway are combined to produce mean values to be used in this interpretation and the most extreme value (369.9 mg/L; 75 percentile) is chosen to ensure that the worst case scenario is covered.

Table 6. Literature values for total suspended solids concentrations in runoff derived from highways

Land use	TSS concentration (mg/L)		
	25 percentile	median	75 percentile
Main highway	62.2	156.9	396.3
Multi-lane highway	110.1	194.5	343.5
Mean values	86.2	175.7	369.9

The performances of SUDs/BMPs can be highly variable with pollutant removal efficiencies being dependent on the following factors:

- Inflow concentration: higher efficiencies typically correspond to higher inflow concentrations
- Climatic/seasonal effects: enhanced growth in vegetative systems can benefit treatment
- Maintenance schedule compliance: well-maintained systems perform better
- Individual design aspects: for example slopes, flow paths, retention times for individual systems can affect pollutant removal rates
- Rainfall intensity and duration: will vary for particular events and influence performance

Therefore it is normal to find pollutant removal potentials for different SUDs/BMPs reported as ranges. The CIRIA SUDs manual (CIRIA, 2015) reports the typical inlet and outlet TSS concentrations for general urban runoff with regard to different SUDs/BMPs and from these the ranges of TSS removal efficiencies, together with the mid-range averages, have been calculated (Table 7). These are then applied to the 75 percentile value for TSS in highway runoff to obtain the top quartile of predicted discharged concentrations to receiving surface waters from the different SUDs/BMPs (Table 7).

The impact posed to a receiving water site can be described by the risk characterisation ratio (RCR) which is defined as the predicted environmental concentration (PEC) divided by the predicted no effect concentration (PNEC). A value of 1 or greater identifies that a potential risk is posed to the receiving water. In the approach adopted here, the PEC is based on the 75 percentile value for TSS in the discharged water (to represent the highest potential risk) following treatment in a SUDs/BMP. This will be subjected to a dilution factor on entering the receiving stream for which a value of 8:1 has been applied as shown in Table 7. The PNEC is the minimum TSS concentration causing observable biological effects in the receiving water, which is 25 mg/L (Woods Ballard et al, 2005).

The derived RCR values, which vary from 0.30 to 0.96, have been plotted for each BMP/SUDs in Figure 9. None of the predicted RCR values exceed 1 and therefore none of the BMP/SUDs are awarded the lowest grade score of 1. However, porous surfacing (RCR; 0.96) is graded 2 as it only marginally avoids the potential risk category associated with an RCR value in excess of 1. The other SUDs/BMP from detention basins to infiltration basins show progressively decreasing RCRs and are accordingly awarded increasing grades of 3 to 5.

Table 7. Predicted top quartile TSS removal efficiencies, discharged and in-stream TSS concentrations and derived risk characterisation ratios for different BMP/SUDs

SUDs/BMP	Percentage removal efficiency range	Average percentage removal efficiency	Predicted discharged TSS concentration (mg/L) based on 75 percentile highway runoff input	Predicted receiving water TSS concentration (mg/L) following 8:1 dilution	RCR
Swale	50-62	56	162.8	20.4	0.81
Filter strip	50-69	60	148.0	18.5	0.74
Filter drain	68-82	75	92.5	11.6	0.46
Soakaway	N/A				
Infiltration trench	N/A				
Detention basin	50-59	55	166.5	20.8	0.83
Extended detention basin	63-75	69	114.7	14.3	0.57
Retention pond	72-78	75	92.5	11.6	0.46
Constructed wetland	80-82	81	70.3	8.8	0.35
Infiltration basin	77-91	84	59.2	7.4	0.30
Porous surfacing (without storage)	35-61	48	192.3	24.0	0.96
Porous surfacing (with storage)	65-79	72	103.6	13.0	0.52

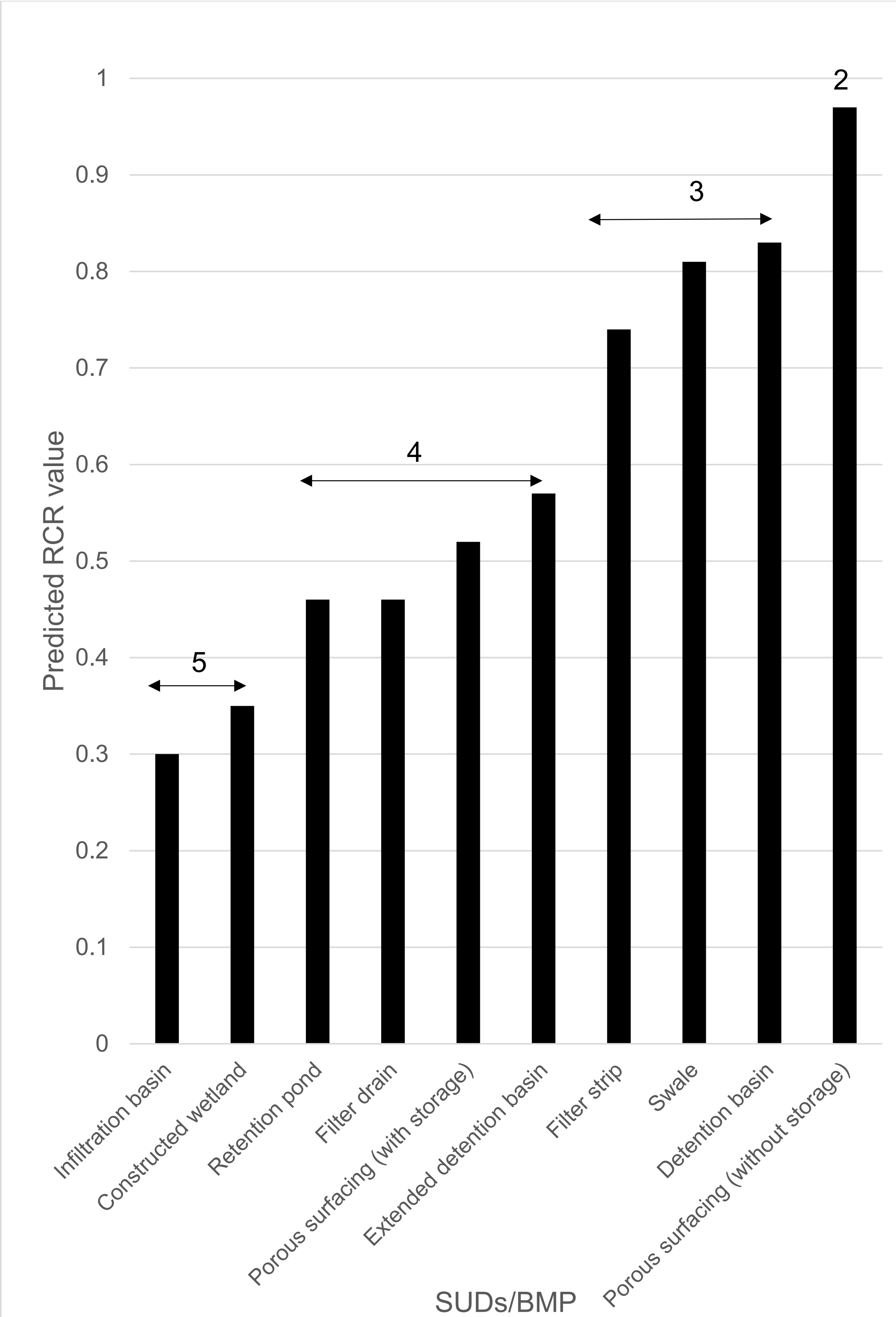


Figure 9. Allocated grading scores for SUDs/BMPs for impact on surface water quality based on predicted RCR values

Groundwater

The quality status of groundwater is an important issue for all EU Member States as it is a major source of public water in many areas. Highway runoff can reach and eventually contaminate groundwater through deposition to adjacent vegetation and ground surface followed by infiltration and percolation into the soil, through streambed losses and/or direct sub-surface “injection” into the unsaturated zone and underlying groundwater zone. The unsaturated zone plays a significant role in transporting, attenuating and mediating pollutants which migrate down from surface and sub-surface highway drainage systems. When substrate levels of trapped pollutants reach saturation concentrations, there is the potential for a time-release breakthrough and downward migration of soluble pollutants (such as salts, dissolved metals and soluble hydrocarbons) into the unsaturated and groundwater zones. There is also the possibility of drying out and ‘cracking’ of basal sediments during dry weather leading to preferential flow paths to greater depths during storm events.

Unfortunately, only rather limited literature exists which examines the transport and fate of highway pollutants within the unsaturated and saturated groundwater zones with the possible exception of de-icing salts which have been identified as posing a particular threat to the good chemical status of groundwaters. In the UK, between 1Mt and 3 Mt of salt are applied annually depending on the severity of the winter but this is lower than the 10-20 Mt in the US and 5 Mt in Canada (Rivett et al., 2016). In Toronto, Canada it has been estimated that around 60% of the applied salt drains to surface water and leaves the catchment with 40% infiltrating to the aquifer. Research undertaken by TRL (2002) in the UK reported that high winter loadings can be rapidly reduced by dilution in the unsaturated zone to below threshold levels during summer and autumn periods. In Sweden, Blomqvist and Johansson (1999) have estimated that 20-63% of applied deicing salt was transported by air and mainly deposited on adjacent ground up to 20 m from the highway. Salt deposited lateral to the highway is likely to infiltrate to groundwater.

The EU Groundwater Directive (2006) identifies groundwater quality standards for nitrates and pesticides (individual and total) and requires that member states set threshold values for groundwater pollutants including arsenic, cadmium, lead, mercury, ammonium, chloride and sulphate which are categorised as substances or ions occurring both naturally and/or as a result of human activities. The threshold groundwater levels for chloride vary widely across 22 EU member states with reported values of between 24 and 12,300 mg L^{-1}. The drinking water standard for chloride is 250 mg L^{-1} which coincides with the environmental quality standard for the protection of aquatic life in surface waters.

The introduction of SUDs/BMPS, involving infiltration (e.g. infiltration trenches/basins, soakaways, swales, filter strips, filter drains and porous surfacing), as treatment systems for highway drainage potentially provides an increased opportunity for release of highway drainage contaminated with chlorides. This is particularly relevant if treatment systems are not designed and/or maintained properly. There is a limited availability of monitoring data relating to the removal of chloride by SUDs/BMPs but because of its high solubility and conservative nature together with its important presence in highway runoff, particularly in cold climate countries, chloride has been selected as the representative pollutant to be used in assessing the impact on groundwaters of the introduction of SUDs/BMPs to treat highway runoff. In addition to contaminating groundwaters, chlorides have the ability to facilitate the movement of previously adsorbed metal species (through competitive adsorption/exchange and/or dissolution effects) although little mobilisation or downward transfer of pollutants from the contaminated basal sediments of SUDs/BMPs has been reported (e.g. Datry et al., 2004).

The highest levels of chloride in highway runoff are experienced in winter and early spring with concentrations as high as 19,000 mg L^{-1} having been reported (Mayer et al., 2011) in Toronto. However, it is difficult to predict how these elevated runoff levels will impact on groundwaters although groundwater vulnerability models such as DRASTIC and MODFLOW utilise flow velocities, travel times and dilution capacities to predict groundwater concentrations of individual pollutants. The dispersive mixing which occurs over extended time periods in the low-velocity, high-storage, aquifer combined with the differing transport distances which can exist between the highway inputs and the receiving aquifer complicate predictions. For example, chloride levels in high-storage, thick-sandstone, aquifers remain well below drinking water standards in spite of the high deicing salt loading (Rivett, et al., 2016) confirming the importance of dilution by low-chloride recharge contributions within the wider capture zone. Other aquifers, for example low-storage, low recharge systems, however may be more susceptible and more dependent on the ultimate fate of deicing salts.

Because of the difficulty of predicting the groundwater chloride concentration arising from discharged highway runoff loadings, the development of utility scores is based on the ways in which infiltration SUDs/BMPs are able to contribute additionally to sub-surface flows/pollutant loads and hence potentially pose an additional impact to groundwater chloride levels. The ease of passage from infiltration SUDs/BMPs to the sub-surface system will be dependent on:

- their ability to release treated highway runoff
- their ability to release chloride

The high solubility and chemically conservative nature of chloride does not support its attenuation by the removal processes operating within most SUDs/BMPs. In swales there is evidence of some retention particularly in fine grained roadside soils (Lundmark and Olofsson 2007) and low chloride removal efficiencies of less than 10%, have been predicted by the US EPA (1999). A review by Revitt et al (2017) supports this low removal efficiency given the potential for subsequent remobilisation and a similar value can be expected for filter strips. Filter drains, soakaways and infiltration trenches all contain filler material such as stones, gravel or rubble through which the incoming highway runoff passes allowing some chloride removal by sorption processes. This can be enhanced by incorporating an additional filter layer such as sand, granular activated carbon or a material which will specifically target anions such as an appropriate exchange resin. Infiltration basins are designed to allow highway runoff to percolate through a filter layer which may typically comprise porous material, such as gravel and/or a suitable adsorbent for removal of chloride. Porous surfacing provides sorption sites within the surface material itself as well as within the sub-base and sub-grade with the inclusion of storage enabling a slowing down of the flow and increased ability for sorption to occur.

The allocation of utility scores to the different infiltration SUDs/BMPs according to their ability to release highway runoff and to release chloride is shown in Table 8, together with brief explanations of the reasons. The overall utility score is calculated based on a 2:1 weighting in favour of the chloride release as this is considered the more important in influencing the ability of chloride to reach the groundwater. The lower overall utility scores shown in Table 8, equate to the lower the ability of the SUDs/BMPs to release treated runoff containing chloride into the sub-surface system.

Table 8. Description of the roles of different SUDs/BMPs in contributing to groundwater quality impact due to ability to release treated runoff and ability to release chloride and thermal impacts and allocation of utility scores

SUDs/BMP	Ability to release treated runoff		Ability to release chloride		Overall utility score
	Comment	Utility score	Comment	Utility score	
Swale	Negligible retention of treated runoff	0.7 (H)	Negligible reported removal	0.9 (V/H)	0.83
Filter strip	Negligible retention of treated runoff	0.7 (H)	Similar removal to swales	0.9 (V/H)	0.83
Filter drain	Negligible retention of treated runoff	0.7 (H)	Removal can be marginally improved by relevant choice of fill material	0.8 (H)	0.77
Soakaway	Only limited retention	0.6 (M/H)	Removal can be marginally improved by relevant choice of fill material	0.8 (H)	0.73
Infiltration trench	Only limited retention	0.6 (M/H)	Removal can be marginally improved by relevant choice of fill material	0.8 (H)	0.73
Infiltration basin	Efficient above ground retention	0.3 (L)	Removal can be marginally improved by relevant choice of filter layer material	0.8 (H)	0.63
Porous surfacing (without storage)	Only limited retention	0.6 (M/H)	Removal can be marginally improved by relevant choice of sub-surface material	0.8 (H)	0.73
Porous surfacing (with storage	Underground storage provides significant retention	0.4 (L/M)	Additional storage allows extra time for sorption processes	0.7 (M/H)	0.60

The overall utility scores, reported in Table 8, are plotted for each of the infiltration SUDs/BMPs in Figure 10 in order to facilitate the award of appropriate grades on a 1 to 5 scale. The absence of combined utility scores less than 0.6 is indicative of the inability of infiltration SUDs/BMPs to efficiently retain chloride containing discharges and which would merit the highest grade of 5. At the other end of the scale, none of the SUDs/BMPs poses a severe threat with regard to chloride discharges (represented by grade 1) to the receiving groundwater. It is considered appropriate to use the mid-range grades (2 to 4) as where chloride is discharged from SUDs/BMPs, the groundwater will be protected by further attenuation during passage through the unsaturated zone. Thus the extremes are porous surfacing (with storage) and infiltration basins with allocated grades of 4 compared to swales and filter strips which receive grades of 2. Soakaways, infiltration trenches, filter drains and porous surfacing (without storage) are given intermediate grades of 3 regarding their ability to prevent the deterioration of groundwater quality with respect to chloride contamination.

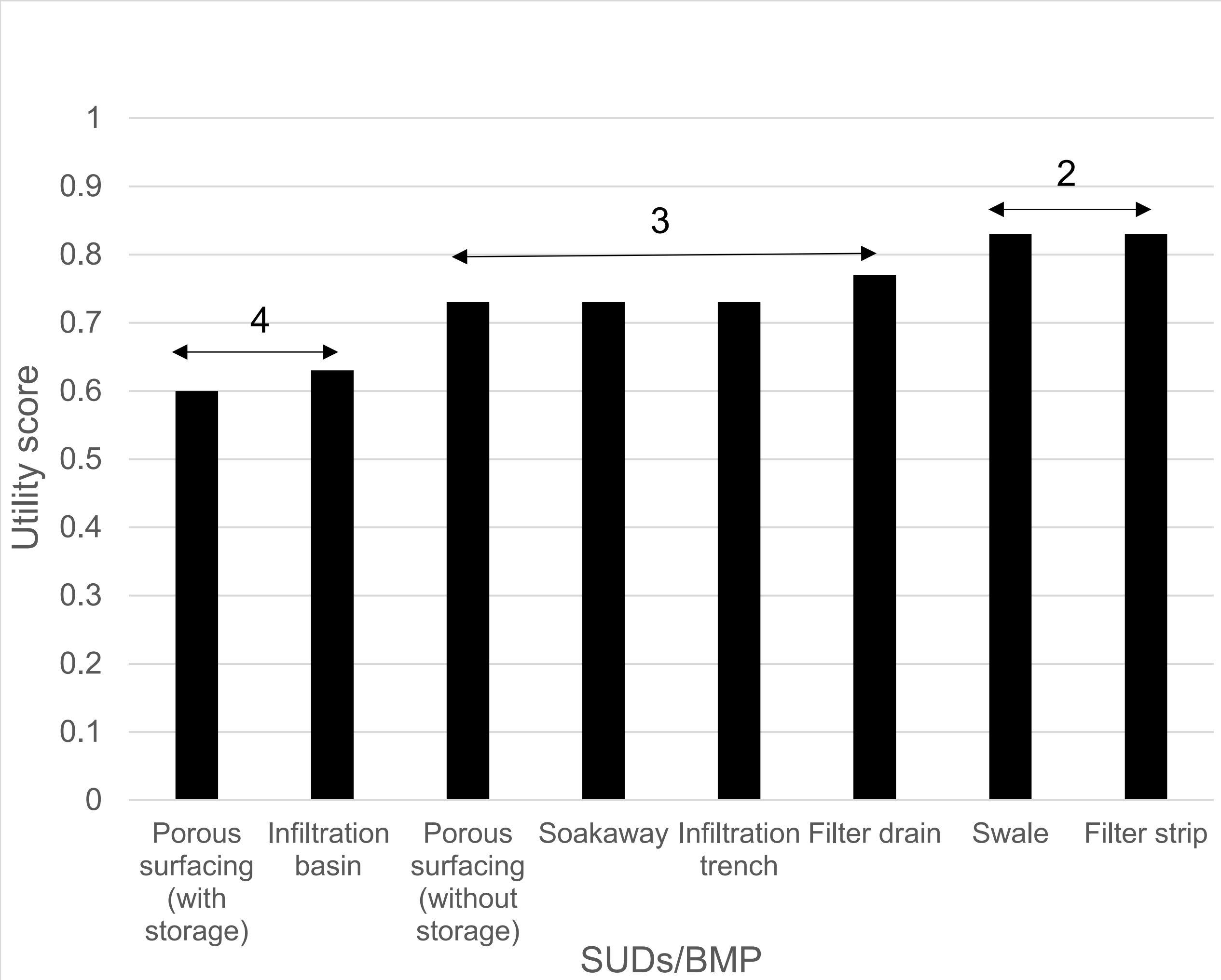


Figure 10. Allocated grading scores for SUDs/BMPs based on predicted combined utility scores for impact on groundwater quality.

The benchmark grade values for the various SUDS/BMPs as derived from Figures 9 and 10 appear as default values in the DSS matrix for the “Impact on Receiving Water Quality” indicator within the Environmental criteria section. It is possible for end-users to modify these gradings to take account of local design conditions or in negotiation with specific stakeholder interests and issues. Re-grading of the utility score plots can be achieved using the guidelines for surface waters and groundwaters in the discussion provided above.

References

Barrett, M.E., Zuber, R.D., Collins, E.R. III, Malina, J.F Jr., Charbeneau, R.J. and Ward, G.H. 1995. A Review and Evaluation of Literature Pertaining to the Quantity and Control of Pollution from Highway Runoff and Construction, Second Edition, CRWR 239, Centre for Research in Water Resources, Bureau of Engineering Research, Austin, Texas, USA.

Blomqvist, G. and Johansson, E-L. 1999. Airborne spreading and deposition of de-icing salt — a case study. Science of the Total Environment, 235 (1-3), 161-168.

CIRIA. 2015. The SuDS Manual. Report No. C753. Construction Industry Research and Information Association,London, UK

Clary, J., Jones, J., Leisenring, M., Hobson, P. and Strecker, E. 2017. Final Report: International Stormwater BMP Database: 2016 SUMMARY STATISTICS. Water Environment and Reuse Foundation (WERF). Available online: www.bmpdatabase.org

Datry, T., Malard, F. and Gibert, J. 2004. Dynamics of solutes and dissolved oxygen in shallow urban groundwater below a stormwater infiltration basin. Science of the Total Environment, 329 (1-5), 215-229.

EU Groundwater Directive (2006) Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration https://www.eea.europa.eu/policy-documents/groundwater-directive-gwd-2006-118-ec

EU Priority Substances Directive, 2013 Directive 2013/39/EC of the European Parliament and of the Council of 12 August 2013 Amending Directives 2000/60/EC and 2008/105/EC as Regards Priority Substances in the Field of Water Policy. 2013. Available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ: L:2013:226:0001:0017:EN:PDF

EU WFD (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy. Available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:HTML

Lundmark, A. and Olofsson, B. 2007. Chloride Deposition and Distribution in Soils Along a Deiced Highway – Assessment Using Different Methods of Measurement. Water, Air, and Soil Pollution, 182 (1–4), 173–185.

Mayer, T., Rochfort , Q., Marsalek , J., Parrott, J., Servos, M., Baker, M., McInnis, R., Jurkovic, A. and Scott, I. 2011. Environmental characterization of surface runoff from three highway sites in Southern Ontario, Canada: 1. Chemistry. Water Quality Research Journal, 46 (2), 110-120.

Mitchell, G. 2005. Mapping hazard from urban non-point pollution: a screening model to support sustainable urban drainage planning. Journal of Environmental Management, 74(1), 1-9.

OMOE. 2003. Stormwater Management Planning and Design Manual. Ontario Ministry of the Environment, Canada. ISBN 0-7794-2969-9

Rivett, M.O., Cuthbert, M.O., Ganble, R., Connon, L.E., Pearson, A., Shepley, M. G. and Davis, J. 2016. Highway deicing salt dynamic runoff to surface water and subsequent infiltration to groundwater during severe UK winters. Science of the Total Environment, 565, 324-338.

TRL. 2002. Pollution of groundwater and soil by road and traffic sources: Dispersal Mechanisms, Pathways and Mitigation Measures. Technical Report. Transport Research Laboratory (TRL). Crowthorne, Berks. UK.

US EPA, 1999. Storm water technology fact sheet: Vegetated swales. Report No.832-F-99-006. USA: Office of Water Washington D.C. Available from: http://ater.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_vegswale.pdf .

Woods Ballard, B., Abbot, C., Dimova, G., Maneiro Franco, E., Weisgerber, A. Smith, H., Kellahger, R. and Stovin, V. 2005. Benefits and performance of ssustainable drainage systems. Report SR 667. Release 2.0. HR Wallingford, Oxon, UK.

IMPACT ON RECEIVING WATER ECOLOGY

Surface water

The EU Water Framework Directive (EU WFD, 2000) intends to achieve 'good surface water status' through the assessment of both chemical and ecological quality. The chemical aspects have been fully considered in the 'Impact on receiving water quality' document which is also part of the PROPER DSS. Although the physical structure of a watercourse may have been altered through prolonged input of highway runoff, further deterioration must be prevented and objectives set for the achievement of 'good ecological status' (or 'good ecological potential' for water bodies which cannot be restored to a natural state). Natural ecological variability does not allow absolute biological standards to be established for implementation across the EU. The WFD proposes that biological quality (or ecological status) be judged on the basis of the degree of deviation of the observed condition from that which would be expected in the absence of significant anthropogenic influence. The important biological elements for most waterbodies include aquatic flora, macroinvertebrates and fish.

In the UK, a forerunner of the WFD criteria was the General Quality Assessment introduced by the Environment Agency (EA, 1996) to provide an accurate and consistent assessment of the 'biological health' of surface waters through the monitoring of 83 groups of macroinvertebrates. Macroinvertebrate population assessments (numbers and types of taxa) provide a good indication of biological status because they possess life spans of months to years, they live in close proximity to streambed sediments and they are relatively sedentary. Based on the number of taxa present, six water classifications decreasing in quality from very good to bad were identified. Very good was considered indicative of a surface water where the biology is similar to that expected for an average unpolluted river of the same size, type and location with a high diversity of groups each containing several species. In contrast, the lowest category identified as 'bad' was considered to be limited to a small number of very tolerant groups (such as worms, midge larvae and leeches).

Benthic macroinvertebrate communities can be substantially altered in many ways as a result of a combination of acute polluted discharges and physical disturbance from highway runoff as well as from the in-situ chronic accumulation of sediment toxicity. Even if some contaminants may not be immediately bioavailable to all aquatic organisms in the receiving stream, benthic communities may become severely impacted over time. The sedentary nature, ubiquity, responsiveness to disturbance, ease of sampling and importance to other ecosystem components make benthic macroinvertebrate communities highly relevant to aquatic systems. They are affected by the intermittent pollutant discharges which are characteristic of highway runoff and the assessment of sedimentary and benthic invertebrate communities has become established as a practical approach for the continued biological monitoring of water quality (e.g. Boxall and Maltby, 1997). As such, benthic monitoring methods are applicable to both short term, physical and acute toxicity assessment as well as the monitoring of longer term, chronic episodic wet-weather discharges.

The biotic communities of surface watercourses can become altered in terms of:
- taxa richness (i.e. the number of taxa present)
- total abundance of taxa
- taxonomic composition
- relative abundance of taxa and evenness of distribution

Decreases in the taxa richness and total taxa abundance represent the clearest signs of detrimental effects and have been selected as the basis for benchmarking the 'Receiving Water Ecology Indicator' for surface waters. Biotic indices provide a relatively simple and understandable presentation of biological data for management purposes and are the foundation of European ecological indices. Table 9 identifies an approach for representing community structure in terms of the numbers of species of different families in relation to biotic scores. In a polluted stream, the more sensitive *Plecoptera, Ephemeroptera, Trichoptera* and *Gammarid* species are replaced by *Asellus*, Chironomids and Tubificid worms (Table 9). The biology associated with the highest biotic scores (≥8) will yield a high diversity of families, usually with several species in each whilst the lowest biotic scores (≤3) are defined by a small number of very pollution tolerant families (e.g. worms, midge larvae, leeches) which may also be present in high numbers.

The biotic index approach is particularly sensitive to organic pollution and there is the possibility that toxicity arising from metals, hydrocarbons etc. may complicate the biotic relationship. Nevertheless, various studies have shown that an ecological approach based on biotic diversity can be successfully applied to receiving waters which are subject to a combination of toxic, chemical and physical impacts as well as loss of habitat. SUDs/BMPs can contribute to improving the ecological status of a receiving water through improving the quality of the discharged water as well as through the benefits provided by their own ecological quality and diversity. It is this latter characteristic which is utilised to predict the impact of SUDs/BMPs on surface water receiving ecology. Table 10 summarises the roles of the different SUDs/BMPs in terms of their abilities to contribute to ecological improvements and allocates utility scores based on these abilities.

The overall utility scores, reported in Table 10, are plotted for each of the SUDs/BMPs, which are able to discharge to surface waters, in Figure 11 in order to facilitate the award of appropriate grades on a 1 to 5 scale. The allocated grades cover the full range of 1 to 5. Constructed wetlands clearly merit the highest grade of 5 as they provide supplementary habitats to those normally found in surface watercourses receiving highway runoff. The wetland habitats provide additional opportunity for emergence of the adult terrestrial stages of organisms such as the caddis fly and dragon fly thus enabling a variety of aquatic species to complete their life cycle and enhance the adjacent receiving water habitat. Such species also have high aesthetic visibility and community value. Retention ponds and extended detention basins are allocated a lower grade of 4 because, although able to provide above ground aquatic storage and potentially possessing vegetated margins, the extent and range of aquatic plants is not comparable to that provided by constructed wetlands. Detention basins and infiltration basins are both allocated the lower grade of 3 because of their inability to maintain a permanent aquatic environment in which a thriving ecological system can develop. Swales and filter strips (grades of 2) are both vegetated systems but do not provide the preferred stationary water environments due to the continuous flows through or over them. The lowest graded SUDs/BMPs (both porous surfacing types (with and without sub-surface storage and filter drains) do not provide either above ground water environments or vegetation to enable a suitable aquatic habitat to develop and to support ecological enhancement.

Table 9. Relationships between biotic scores and species types and numbers

Species type	Numbers within different species types	Biotic scores
No organisms or those not requiring DO e.g. *Eristalis tenax*		0 - 0.5
Oligochaetes and Tubicid worms; Chironomid larvae (midges); Hirudinea (leeches)	1 species >1 species	0.5 – 1.0 1.0 – 3.0
Asellus species; Coleoptera (beetles); Lymnea (snails); Glossiphinidae and Erpobdellidae (leeches)	1 – 2 species 3 – 4 species > 4 species	1.0 -- 2.0 2.0 – 3.5 3.5 – 5.0
Gammarids (shrimp); Hydracarina (water mites); Hydrophilidae, Dryopidae and Heliodidae (beetles); Gerridae (water striders); Hydropsychidae (nymph flies)	1 – 2 species 3 – 4 species >4 species	3.0 – 4.0 4.0 – 5.5 5.5 – 7.0
Trichoptera larvae (caddis flies); Caenidae (mayflies); Limnephilidae (caddis flies); Viviparidae and Neritidae (snails)	1 species 2 – 4 species >5 species	4.0 – 5.0 5.0 – 6.5 6.5 – 8.5
Ephemeroptera (mayflies); Lestidae and Agridae (damselflies); Gumphidae (dragonflies); Astacidae (crayfish); Ecdyonuros (mayflies)	1 – 5 species >5 species	5.0 – 6.0 6.0 – 9.5
Plecoptera (stoneflies); Leptophleidae (mayflies); Phryganedae and Leptoceridae (caddisflies)	1 – 5 species >5 species	6.0 - 8.0 8.0 – 10.0

Table 10. Characteristics of different SUDs/BMPs which can contribute to ecological benefits to receiving surface waters and allocation of utility scores.

SUDs/BMP	Ability to contribute to ecological improvement	Utility score (level of impact)
Swale	Can provide limited above ground storage in a vegetative environment but capable of supporting only a transient aquatic habitat	0.4 (L/M)
Filter strip	Can provide limited above ground storage in a vegetative environment but capable of supporting only a transient aquatic habitat	0.4 (L/M)
Filter drain	Does not provide an above ground aquatic environment in which a beneficial habitat could be established	0.2 (VL/L)
Soakaway	N/A	
Infiltration trench	N/A	
Detention basin	Provides above ground storage but only on a temporary basis therefore not allowing a sustainable aquatic habitat to develop despite a possible vegetated environment	0.5 (M)
Extended detention basin	Provides above ground storage for periods of 24 to 48 hours which in a vegetated environment will facilitate the development of a limited aquatic habitat	0.6 M/H)
Retention pond	Provides a permanent aquatic environment enabling aquatic habitats to form and survive, particularly in the presence of vegetated margins	0.7 (H)
Constructed wetlands	Provide the ideal conditions for the establishment of a thriving aquatic habitat which can be of great benefit to receiving waters	0.9 (VH)
Infiltration basin	Capable of providing above ground storage but only on a temporary basis therefore not allowing a sustainable aquatic habitat to develop despite a possible vegetated environment	0.5 (M)
Porous surfacing (without storage)	Does not provide an above ground aquatic environment in which a beneficial habitat could be established	0.1 (VL)
Porous surfacing (with storage	Provides underground storage but not capable of making a significant contribution to surface water ecology	0.2 (VL/L)

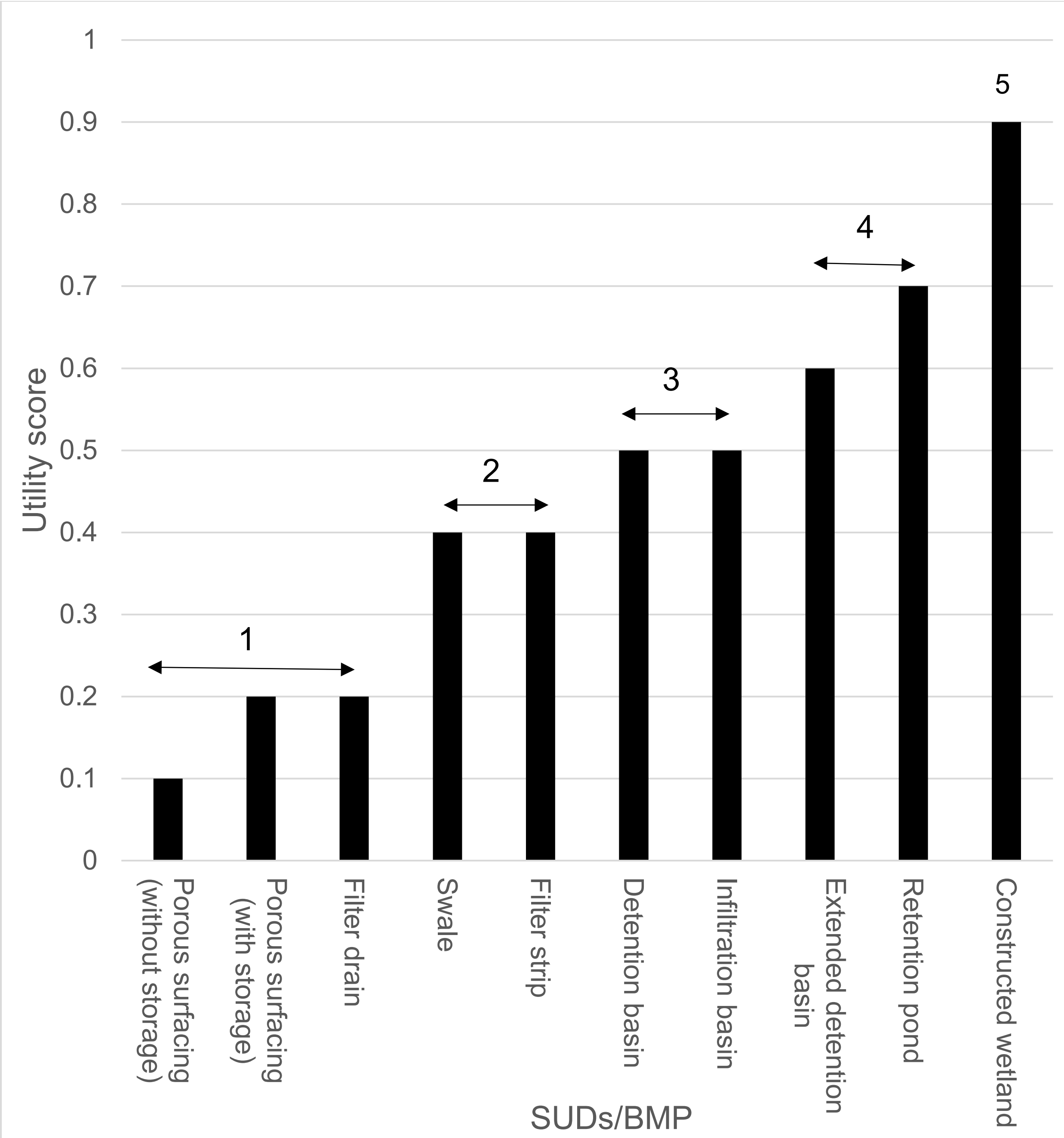


Figure 11. SUDs/BMP rankings and allocated scores based on their contribution to the ecological benefits in surface waters.

Groundwater

The Groundwater Directive (EU-GWD, 2006) identified the need for research to be conducted in ecological studies of groundwater, but despite the EU requirement for the provision of better criteria for ensuring groundwater ecosystem quality, progress has been slow to emerge. The emphasis in the PROPER DSS is on the ecology in the deeper, saturated zone as opposed to less deep unsaturated zone where the ecological characteristics will be more closely aligned to those on the surface. Aquifers can be established in different types of rocks although the most common are in porous, permeable (sandstone) or sedimentary rocks with the water able to move through the voids which define the aquifer's porosity and permeability. The original perception was that aquifers would be lifeless due to presence of limited spaces inhibiting the establishment and reproduction of underground faunal populations. However, the intergranular spaces which exist in sands (0.05 – 2 mm) and gravels (2 – 75 mm) provide a suitable habitat for a large diversity of organisms such are bacteria and aquatic invertebrates that belong to different taxonomic groups the majority being crustaceans (e.g. Copepoda, Ostracoda, Amphipoda, Isopoda, Syncarida and Oligochaeta (Annelida), Nematoda (roundworms) and Mollusca (snails) (Gibert et al., 1994). These specialised groundwater invertebrates are known as stygofauna and are characterised by a body-size of between 0.05 and 5 mm and an elongated, cylindrical shape which enables them to move and disperse actively over distances of up to hundreds of metres assisted by the groundwater flow within an aquifer (Danielopol, 2003).

In addition, there are species living exclusively in groundwater which are termed stygobites (Gibert et al., 1994). These species have specifically adapted to underground environmental conditions, characterized by the absence of light, limited food resources and relatively constant temperature. The particular adaptations of morphological order (size and shape), physiology, metabolism (reduced metabolic rate) and reproduction (low fertility) provide evidence of the evolution and persistence of these organisms in an extreme environment for life. Groundwater fauna act as indicators of groundwater quality through the ratio between stygobites (species adapted to live and reproduce only in groundwater) and non-stygobites (species able to live both underground and at the surface) play a significant role. A high incidence of stygobite species is associated with a good chemical status of an aquifer whereas a high diversity of non-stygobites, is associated with a low to moderate chemical status of an aquifer.

Because of the limited similarities between groundwater ecology and surface water ecology it is unlikely that infiltration waters discharged from SUDs/BMPs will have any significant impact, either negative or positive, on the ecological characteristics of deep aquifers. Additionally, the extensive route taken by infiltrating waters following their release from SUDs/BMPs prior to arrival at their aquifer destination will enable gradual changes in the ecological aquatic environment any mitigate any possible biological impact. Therefore mid-range grades of 3 are allocated to all those SUDs/BMPs which discharge infiltration waters as shown in Table 11.

Table 11. Allocation of grades to those SUDs/BMPs which discharge infiltration waters to groundwater

SUDs/BMP	Allocated grade
Swale	3
Filter strip	3
Filter drain	3
Soakaway	3
Infiltration trench	3
Infiltration basin	3
Porous surfacing (with storage)	3
Porous surfacing (without storage)	3

The benchmark grade values for the various SUDS/BMPs as derived from Figure 11 and Table 11 appear as default values in the DSS matrix for the "Receiving Water Ecology" indicator within the Environmental criteria section. It is possible for end-users to modify these gradings to take account of local design conditions or in negotiation with specific stakeholder interests and issues. Re-grading of the utility score plots can be achieved using the guidelines for surface waters and groundwaters in the discussion provided above.

References

Boxall, A. B. A. and Maltby, L. 1997. The effects of motorway runoff on freshwater ecosystems: 3. Toxicant confirmation. Archives of Environmental Contamination and Toxicology, 33, 9-16.

Danielopol, D.L., Griebler, C., Gunatilaka, A., Notenboom, J. 2003. Present state and future prospects for groundwater ecosystems. Environmental Conservation 30: 104-130.

Environment Agency. 1996. Assessing Water Quality. General Quality Assessment (GQA) scheme for Biology. (accessible at http://environmentdata.org/archive/ealit:1649).

EU Groundwater Directive (2006) Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration https://www.eea.europa.eu/policy-documents/groundwater-directive-gwd-2006-118-ec

EU WFD (2000) Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field ofWater Policy. Available online: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32000L0060:EN:HTML

Gibert, J., Danielopol, D. L., Stanford, J.A. 1994. Groundwater ecology. San Diego, California, USA. Academic Press

OPERATION AND MAINTENANCE CRITERION

incorporating

MAINTENANCE AND SERVICING REQUIREMENTS INDICATOR

MAINTENANCE & SERVICING REQUIREMENTS INDICATOR

Although systematic and regular maintenance should be a basic design criterion if highway SUDS/BMPs are to function at their optimum design efficiency throughout their operational lifetimes, surface water control structures only fairly recently have received specifications or effective management and servicing strategies to ensure their continued benefits to the responsible authorities and the receiving environment. The design principles of SUDS/BMP structures are reasonably well established and have a large range of supporting guidance material and manuals available on a national basis throughout Europe and overseas. The concerns which exist about long term highway SUDS/BMP operation and maintenance (O&M) have been highlighted in PROPER Deliverable D3.2. Highway drainage servicing and management does have both a national (e.g. in the UK, HMEP, 2012 and Roads Liaison Group, 2005; in the US, McGee et al., 2009; in Ireland, DEHLG, 2004) and a regional/local (e.g. in the US, NYS, 2009; in the UK, Hertfordshire County Council, 2017) documentation profile which is increasing progressively with working experience.

The flood, pollution and ecological component functions of highway SUDS/BMPs need to have O&M servicing that minimises performance risks in terms of:

- safety and incident management to mitigate standing floodwater and spillage impacts
- regular and effective maintenance of SUDS/BMP ancillary structures (inlets, outlets, silt traps, flow controls and storage structures, headwalls, low flow channels, bypass etc..)
- management of litter, sediment, vegetation and herbicide/pesticide applications etc..
- protection of local habitat/ecological benefits with associated landscape management.

Safety and serviceability are clearly key O&M performance indicators for highway authorities and effective sustainable management of the network will support these prime objectives. Many highway authorities are developing (or already have in place) drainage asset management plans (DAMPs) for their high speed, restricted access highways and there is evidence for the pro-active management of drainage infrastructure risks (e.g. Highways Scotland, 2014).

The maintenance regime of flow/treatment devices for most authorities appears to be based on asset type and matched against their presumed performance. In this respect, the maintenance schedules are therefore based on standardised generic SUDS/BMP performance parameters and as such carry the liability that the servicing regime becomes contract dependent rather than being strictly performance prescriptive. In addition, many of the available inspection manuals are essentially focused on short-term O&M needs in order to maintain or protect the design level of serviceability (Highways Agency, 1999). Irrespective of this, the development and application of appropriate vulnerability indicators remain challenging to measure in any rigorous manner. In addition, it might be argued that many current management action plans overly focus on data and work practices rather than infrastructure mitigation works. It should nevertheless be accepted that such a data focus can serve to identify drainage condition “hotspots” in terms of performance specification.

Table 12 illustrates the type and nature of highway drainage impacts that can be expected from future changes in precipitation patterns as a result of climate change and the consequent need for pro-active servicing and management guidelines in order to maintain an effective control performance.

Table 12. Highway drainage impacts resulting from climate change

FACTOR	OUTCOME	DRAINAGE IMPACT	MANAGEMENT IMPACT
Higher winter precipitation	Increased pluvial flooding	Surface flooding and standing water; Drainage capacity overloaded	More frequent O&M; Unplanned capital works to enhance capacity
Lower summer precipitation	Low receiving water flows; low minimum water levels	Increased toxic discharges; Drainage dilution levels	Endangering receiving water environmental objectives; remedial control works
Extreme rainfall events	Increased pluvial flooding; extreme short-term volumes	Surcharging and surface flooding; Drain blocking/scouring; High first-flush	Damage/loss of drainage network; Sediment build-up; Disruption/delays; Unplanned remedial/control capital works

An O&M management plan should have specifications detailing how, when and by whom servicing is to be undertaken with schedules of work itemizing both regular and periodic maintenance together with data monitoring and potential remedial requirements. Table 13 summarises the general basic O&M servicing requirements associated with the main groups of SUDS/BMPs forming the basis for identifying qualitative O&M levels and in developing utility scores in respect of individual SUDS/BMP devices. Each of the SUDS/BMP groupings (Basins & Wetlands; Filter strips and Swales; Infiltration Systems; Porous surfacing) have discretely similar (if overlapping) maintenance requirements. However, the individual SUDS/BMP devices within each group place differing demands on these maintenance parameters which provide the basis for the benchmark utility scores allocated to each of the controls shown in the table. The Annex to these O&M Indicator pages provides additional guidance on the qualitative derivation of the utility scores developed for each highway SUDS/BMP type itemised in Table 13.

Given the fundamental importance of Regular O&M activities, this component has been more heavily weighted than the Periodic O&M and Monitoring/Data components, and the overall average utility scores shown in the final column of Table 13 have thus been derived by applying a 3:2:1 weighting ratio respectively, to these components. The allocation of utility scores to the descriptive values follows the distribution adopted for other benchmarks (Table 14) with a single descriptive value being allocated the mid-utility score e.g. Medium (M) = 0.5 and border line descriptive values taking the upper or lower limit of the utility score range e.g High/Very High (H/VH) = 0.2. The lower utility scores and grades reflect the higher SUDS/BMP O&M demands required to maintain their serviceability both in terms of regular and periodic inspection, maintenance and data monitoring. For example, the high servicing requirements indicated for Basins and Wetlands in Table 13 reflects the wider range and more intensive maintenance work activities required to retain their performance capabilities in comparison to most Infiltration systems.

Table 13. SUDS/BMP O&M service requirements and utility scores

SUDS/BMP Type	Regular O&M	Periodic O&M	Monitoring and Data	Weighted Average Utility Score
Basins & Wetlands	- Landscape maintenance and grass cutting (3/4 x year) - Litter removal (2/3 x year) - Inlet/Outlet cleaning (2 x year) - Oil/sediment control (annually; after storms)	- Clearance of bankside vegetation - Control/Removal of weeds etc - Vegetation removal and re-planting/re-seeding - Sediment removal (1 x 3 years; sediment disposal 1 x 10 years) - check wetland substrate porosity (1 x 5/10 years) - Shut-off valve check (1 x year) - Aeration if eutrophic	- Inlet/outlet inspection (2 x year; after large storms) - Sediment accumulation (1 x year) - Screen check (1 x year; after large storms) - Erosion damage	
Detention Basin	*Medium/High; 0.4*	*Medium; 0.5*	*Medium/Low; 0.6*	***0.47***
Retention Ponds	*High; 0.3*	*High; 0.3*	*Medium/High; 0.4*	***0.32***
Extended Detention Basin	*High/Very high; 0.2*	*High; 0.3*	*Medium/High; 0.4*	***0.27***
Wetland	*Very High; 0.1*	*Very High; 0.1*	*High; 0.3*	***0.13***
Filter Strips & Swales	- Grass and vegetation maintenance (3/4 x year) - Debris/Litter removal (2/3 x year) - Inlet/Outlet checking and cleaning (1/2 x year) - Check/clean; ponding, soil compaction (2 x year) - Check gradients (1 x year)	- Control/removal of shrubby growth and weeds etc. - Re-turfing/re-seeding eroded areas. - Surface raking and removal of any accumulated sediment (1 x 3/4 years) - Remove oil/petrol residues	- Inlet/outlet inspection (1/2 x year; after large storms) - Inspection of check dams and any gravel strips/distributor edges (annually) - Monitor erosion/gullying and silt deposits - Excessive waterlogging or standing water	
Filter Strip	*Medium; 0.5*	*Medium/Low; 0.6*	*Low; 0.7*	***0.57***
Swale	*Medium; 0.5*	*Medium/High; 0.4*	*Low; 0.7*	***0.50***
Infiltration SUDS/BMPs	- Removal of surface debris/litter/silt (1/2 x year) - Landscape maintenance and grass cutting of larger I/Bs and I/Ts (2/3 x year) - Cleaning of oil/grit chamber facilities if fitted (1x year) - Buffer strip maintenance if fitted (annually) - Check for blockage, clogging, standing water (1 x year)	- Removal/cleaning of surface gravel infill (1 x 10/15 years) - Removal of any shrubby growth (annually) - Repair/replacement of geotextile/perforated pipework (1 x 10/15 years) - Sump cleaning and/or forebay sediment removal (1 x 4/5 years) - Inlet/outlet cleaning (1 x 3/4 year) - Replace/clean void infill (1 x 10 years)	- Observation well inspection (1 x year) - Surface ponding and drain-down time (as required) - Overflow pipe inspection (1 x year) - Inlet/outlet inspection (1 x year) - Oil/grit chamber inspection (1 x year if fitted)	
Filter Drains	*Low; 0.7*	*Low; 0.7*	*Low; 0.7*	***0.70***
Soakaways	*Medium/Low; 0.6*	*Low; 0.7*	*Medium/low; 0.6*	***0.63***

Infiltration trench	*Low; 0.7*	*Low; 0.7*	*Low; 0.7*	***0.70***
Infiltration basin	*Low/Medium; 0.7*	*Low; 0.7*	*Low; 0.7*	***0.70***
Porous Surfacing	- Check and repair block paving/ alignment (1 x year) - Surface brush/vacuum cleaning and high pressure hosing, especially following ice/snow (annually) - Check/clean major oil spills	- Renewal of filter course (as required) - Inlet/outlet cleaning (1 x 3/4 years) - Repair cracks/potholes/ruts and missing/loose blocks (as required) - Weed/grass control (1 x 2 years)	- Surface ponding inspection (annually) - Check/clean overflow (1 x 3/4 years) - Check drain time (1 x 4/5 years)	
Porous Surfacing (without sub-structure)	*Low/Medium; 0.6*	*Low; 0.7*	*Very Low; 0.9*	***0.68***
Porous Surfacing (with sub-structure)*	*Medium; 0.5*	*Medium; 0.5*	Low; 0.7	***0.53***

*See description in Annex (see page 90)

It must be emphasised that Table 13 does not represent the full or detailed maintenance specifications which may need to be worked out on a specific site basis and which can be obtained from national/local guidance such as listed in the references. Further detail on both regular and periodic maintenance/remedial actions recommended for each of the SUDS/BMP facilities is given in the Annex and in PROPER Deliverable 3.2 ("*Sustainable Assessment of Measures and Treatment Systems for Road Runoff: Survey of Guidelines"*). The utility scores allocated in Table 13 are in line with the maintenance guidelines presented in Deliverable 3.2 which can be referred to in respect of detailed support of the tabulated scorings incorporated into the current benchmarking methodology.

Table 14. Utility score ranges used for descriptive values

Descriptive Value	Utility Score Range
Very High (VH)	0 – 0.2
High (H)	0.2 – 0.4
Medium (M)	0.4 – 0.6
Low (L)	0.6 – 0.8
Very Low (VL)	0.8 – 1.0

In addition, it is difficult to foresee the nature, type and extent of remedial maintenance which will be required during the SUDS/BMP lifetime as this will depend on factors such as extreme storm event damage, accidents, inadequate design etc.. Table 15 provides some general indication of the type of remedial/restorative activities that may be required by the various SUDS/BMP groups from time to time. However, no descriptive value or utility score has been allocated for this remedial O&M component given the unforeseen nature and scale of such restorative rehabilitation.

Table 15. Examples of possible remedial O&M activities which may be required by different SUDS/BMP types

Basins & Wetlands	Filter Strips & Swales	Infiltration SUDS/BMPs	Porous Surfacing
- Erosion damage - Inlet/outlet damage - Riprap replacement or re-alignment - Replacement of vegetation - Headwall, bypass damage etc	- Erosion damage e.g. channeling, check dams - Inlet/outlet damage - Swale slope stability - Check dam repair - Replacement of "level-spreader" gravel strip trench - Rehabilitation and turf/grass replacement	- Debris/sediment blockage - Cleaning and/or replacement of infill and geotextile - Repair and/or replacement of perforated under-drain pipes - Installation of sediment forebay or pre-settling facility	- Renewal of clogged sub-surface stone reservoir - Repair/replacement of any geotextile liner(s) - Repair/renewal of any under-drain piped system - Sediment clearance from any pre-filtering system - block/asphalt displacement; surface rutting

The overall average weighted SUDS/BMP utility scores shown in Table 14 have been directly plotted for each individual SUDS/BMP on Figure 12 as a basis to define the default grade values to be entered into the PROPER DSS matrix.

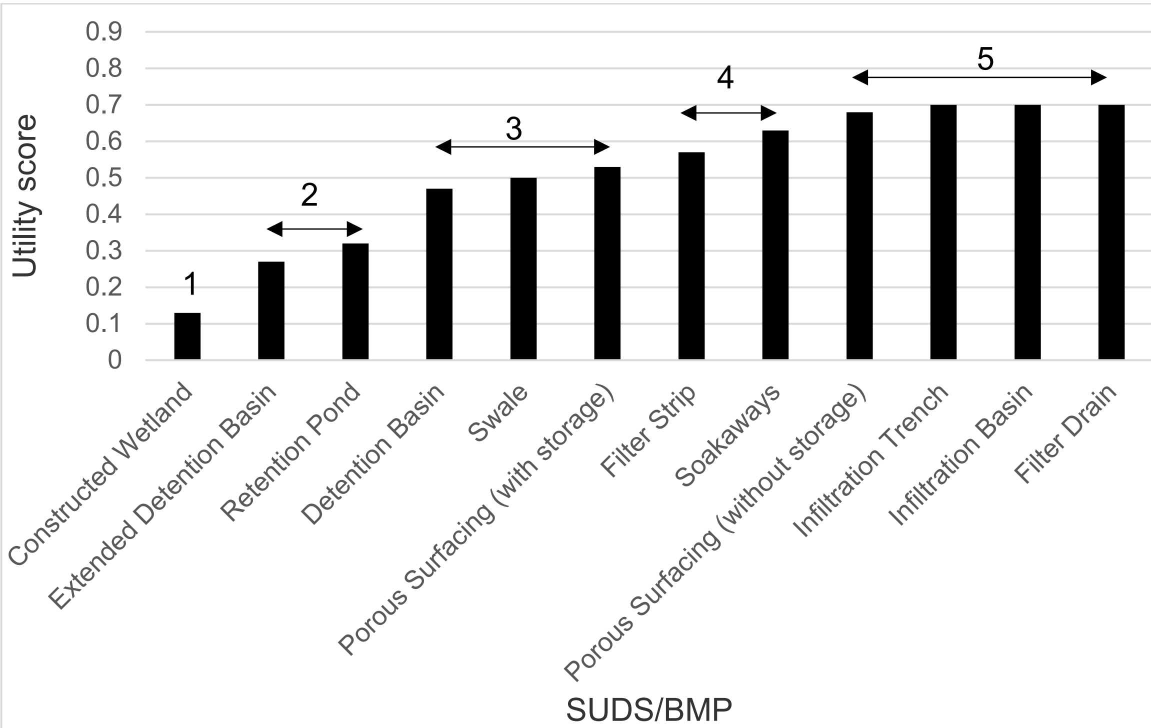


Figure 12. Utility Scores and Default Grade Values for the Maintenance and Servicing Requirements Indicator.

If new weightings wish to be applied to the three O&M servicing parameters, the modified average utility score for each SUDS/BMP must be re-calculated and re-plotted with a new set of default grade values defined and entered into the DSS matrix.

References

DEHLG. 2004. Guidelines for Road Drainage. Department of Environment, Heritage & Local Government (DEHLG). Dublin. Ireland.

Revitt, D.M., Ellis, J.B and Lundy, L. 2019. Sustainable Assessment of Measures and Treatment Systems for Road Runoff: Survey of Guidelines. Deliverable D.3.2. CEDR PROPER Project. Middlesex University. London. UK.

Hertfordshire County Council. 2017. Highways Service Guide. Hertfordshire County Council, County Hall, Hertford. UK.

Highways Agency. 1999. Trunk Road Maintenance Manual. HMSO. London. UK.

Highways Scotland. 2014. Trunk Road Inspection Manual. Transport Scotland. Edinburgh. Scotland.

HMEP. 2012. Guidance on the Management of Highway Drainage Assets. Highway Maintenance Efficiency Programme (HMEP). Department of Transport, London. UK.

McGee, H.W., Nabos, D and Baughman, P.E (Edits). 2009. Maintenance of Drainage Features for Safety. Report FHWA-SA-09-024. Federal Highway Administration, US Dept. of Transportation. Washington, DC. US.

NYS. 2009. Highway Maintenance Guidelines. Department. of Transportation, Office of Transportation Maintenance. New York. US.

Roads Liason Group. 2005. Well Maintained Highways: Code of Practice for Highway Maintenance Management. Roads Liason Group, Department. of Transport. HM Stationery Office (TSO). London. UK.

SOCIO-ENVIRONMENTAL AWARENESS CRITERIA

incorporating

SUSTAINABLE DEVELOPMENT (BIODIVERSITY) INDICATOR

AESTHETICS AND PUBLIC AWARENESS INDICATOR

SUSTAINABLE DEVELOPMENT (BIODIVERSITY) INDICATOR

The EU Sustainable Development Strategy (EU SDS, 2001) which was originally adopted in June 2001, and subsequently reviewed in 2009 (EU SDS, 2009) set out as one of its goals to reconcile environmental protection with social cohesion/equity and economic development. The protection and enhancement of natural resources and the environment strongly underpin the strategic policy guidelines. The principles of sustainable development contained in the EU guidelines and practised by all member states can be summarised by the following bullet points.

- Living within environmental limits
- Achieving a sustainable economy
- Using sound science responsibly
- Ensuring a strong, healthy and just society
- Promoting good governance

Within the context of these guiding principles, the evaluation of SUDs/BMPs in effectively supporting the development of a healthy and sustainable environment needs to address their contribution to promoting biodiversity potential and to minimising both energy and resource use. Biodiversity potential is concerned with the protection, restoration and enhancement of priority species and habitat status. This includes providing a diverse habitat and landscape whilst reducing habitat fragmentation and isolation. Highways authorities now place an important emphasis on preserving biodiversity within the highway environment as indicated by a recently published Biodiversity Action Plan on behalf of Highways England (Highways England, 2015).

The establishment and effective management of mixed terrestrial, marginal and aquatic habitats can contribute to fulfilling environmental legislation and the achievement of sustainable development objectives. Hence, those SUDs/BMPs which help to reduce fragmentation or isolation of habitats and barriers to animal and avian movement will have high biodiversity potential. Positively managed ecological habitats and hydrological regimes also help to maximise the biodiversity impact particularly where they are consonant with existing biodiversity legislation and regulation. Ponds and basins score highly in this respect with wetlands offering the very highest biodiversity potential. SUDs/BMP infiltration facilities have a lower potential although they do have some biodiversity potential by virtue of reducing discharge and pollutant impacts on receiving watercourse habitats.

Energy and resource use are important sustainable development benchmarks which seek to minimise the future impact of existing and future activities on environmental compartments. With specific reference to the highway environment, Highways England have published their approach to a sustainable development strategy which identifies how they plan to continue to reduce the impact of their activities to ensure a long-term and sustainable benefit to the highway environment (Highways England, 2017). Ideally SUDs/BMPS should utilise minimum energy consumption during construction, operation and maintenance thereby requiring low electro-mechanical costs. Similarly, SUDs/BMPs which utilise minimum material consumption in their implementation, operation and maintenance will have high sustainable development potential and ensure that they do not exceed the “carrying-capacity” of the local environment. Source material use should be low with resource re-cycling potential being practised where at all feasible. Reduced manufacturing and transport costs together with the associated emissions is an advantage particularly in terms of a reduced carbon footprint. SUDs/BMPs requiring heavy material usage during construction as well as material transport will have low utility score values, particularly if there is a continued energy demand during their operation and maintenance lifetimes. However, infiltration facilities have potential for resource re-cycling through groundwater recharge whilst surface water SUDS/BMPs may offer some potential for additional use as irrigation water if their location within the highway environment permits this.

Table 16 identifies the factors which influence the ability of individual SUDs/BMPs to influence the development of biodiversity potential and allocates utility scores on the basis of this. The utility scores correspond to the descriptive values shown in Table 17 with very high (utility score range: 0.8 – 1.0) indicating that the SUDs/BMP has the potential to make a very strong contribution to biodiversity and very low (utility score range: 0 – 0.2) suggesting a very minimal biodiversity contribution. Table 18 identifies the factors which address sustainable development by assessing the ability of individual SUDs/BMPs to influence the reduction of energy and resource usage and allocates utility scores on the basis of this.

Table 16. Characteristics of different SUDs/BMPs which can contribute to biodiversity potential and allocation of utility scores.

UDs/BMP	Ability to contribute to biodiversity potential	Allocated utility score
Swale	Ability to support some habitat development in both aquatic and terrestrial compartments	M/H; 0.6
Filter strip	Limited potential for habitat development although this can cover both aquatic and terrestrial environments	L/M; 0.4
Filter drain	Minimal potential for habitat development although possibility where grassed surface exists	VL/L; 0.2
Soakaway	Possible presence of some grassed surface providing limited habitat enhancement; can provide habitat protection within receiving watercourse due to pollutant discharge reduction	L; 0.2
Infiltration trench	Possible presence of some grassed surface providing limited habitat enhancement; can provide habitat protection within receiving watercourse due to pollutant discharge reduction	L; 0.2
Detention basin	Possess the potential for both aquatic and terrestrial habitat development but limited by alternating wet and dry conditions	M/H; 0.6
Extended detention basin	As for detention basin but with greater possibility for development of aquatic habitat due to longer retention of wet conditions	H; 0.7
Retention pond	Able to successively support an aquatic habitat and potential exists for productive marginal habitat development	H/VH; 0.8
Constructed wetland	Combined water and vegetated environment supports the existence of a thriving aquatic habitat	VH; 1.0
Infiltration basin	Development of a terrestrial habitat possible but little possibility for a sustained aquatic habitat.	M; 0.5
Porous surfacing (with storage)	No surface habitat enhancement; can only provide habitat protection within receiving watercourse due to pollutant discharge reduction	VL; 0.1
Porous surfacing (without storage)	No surface habitat enhancement; can only provide habitat protection within receiving watercourse due to pollutant discharge reduction	VL; 0.1

Table 17. Utility score ranges corresponding to the different descriptive values awarded for SUDs/BMPs performance against specific criteria.

Descriptive value	Utility score range
Very high (VH)	0.8 – 1.0
High (H)	0.6 - 0.8
Medium (M)	0.4 – 0.6
Low (L)	0.2 – 0.4
Very low (VL)	0 – 0.2

Table 19 collates the utility scores allocated for ability to promote biodiversity potential and ability to reduce energy and resource usage and combines them on an equal weighting to derive an overall utility score for sustainable development (biodiversity). These scores are plotted against the individual SUDs/BMPs in Figure 13 to determine a grade for each treatment system.

The distribution of overall utility scores indicates that all 12 SUDs/BMPs fall within the range of 0.15 to 0.65 for the sustainable development (biodiversity) indicator. Because the highest utility score is only 0.65, the highest grade value of 5 is not allocated and the range is from grade 1 to grade 4 according to the distribution shown in Figure 13. Although some SUDs/BMPs score evenly between the biodiversity potential and energy/resource usage indicators (e.g. swales) some are much less consistent as demonstrated by constructed wetlands which achieve a maximum utility score for biodiversity potential compared with a much lower utility score of 0.3 for ability to minimise energy and resource consumption.

The benchmark grade values for the various SUDS/BMPs as derived from Figure 13 appear as default values in the DSS matrix for the “Sustainable Development” indicator within the Socio-environmental Awareness criteria. It is possible for end-users to modify these gradings to take account of local design conditions or in negotiation with specific stakeholder interests and issues. Re-grading of the utility score plots can be achieved using the guidelines in the discussion provided above.

Table 18. Characteristics of different SUDs/BMPs which can lead to the minimisation of energy and resource use and allocation of utility scores.

SUDs/BMP	Ability to contribute to minimisation of energy and resource use	Allocated utility score
Swale	No energy utilisation during operation; construction requirements mainly involve earth works with no major material input	H; 0.7
Filter strip	No energy utilisation during operation; construction requirements mainly involve earth works with no major material input	H; 0.7
Filter drain	No energy utilisation during operation; requires trench excavation and infilling with material transported to site.	M; 0.5
Soakaway	No energy utilisation during operation; involves substantial manufacturing cost and subsequent transport to prepared site	L; 0.3
Infiltration trench	No energy utilisation during operation; requires trench excavation and infilling with material transported to site	M; 0.5
Detention basin	No energy utilisation during operation; main construction task involves substantial earth works and normally requires additional materials for inlet/outlet structures	M; 0.5
Extended detention basin	No energy utilisation during operation; main construction task involves substantial earth works and normally requires additional materials for inlet/outlet structures	M; 0.5
Retention pond	No energy utilisation during operation; main construction task involves earth works but normally requires additional materials for inlet/outlet structures; typically fitted with sediment forebay	L/M; 0.4
Constructed wetland	No energy utilisation during operation; main construction task involves substantial earth works; additional materials needed for inlet/outlet structures including sediment forebay; sub-surface flow type requires substantial amount of gravel substrate.	L; 0.3
Infiltration basin	No energy utilisation during operation; main construction task involves substantial earth works and normally requires additional materials for inlet/outlet structures; material demand for construction of infiltration area	L; 0.3
Porous surfacing (with storage)	No energy utilisation during operation; construction is part of highway preparation works; no inlet/outlet structures required but heavy demand in terms of transported in construction materials	L/VL; 0.2
Porous surfacing (without storage)	No energy utilisation during operation; construction is part of highway preparation works; no inlet/outlet structures required but heavy demand in terms of transported in construction materials	L/VL; 0.2

Table 19. Overall utility scores derived from individual utility scores for biodiversity potential and minimisation of energy and resource usage.

SUDs/BMP	Utility score for biodiversity potential	Utility score for reducing energy and resource usage	Overall utility score
Swale	0.6	0.7	0.65
Filter strip	0.4	0.7	0.55
Filter drain	0.2	0.5	0.35
Soakaway	0.2	0.3	0.25
Infiltration trench	0.2	0.5	0.35
Detention basin	0.6	0.5	0.55
Extended detention basin	0.7	0.5	0.60
Retention pond	0.8	0.4	0.60
Constructed wetland	1.0	0.3	0.65
Infiltration basin	0.5	0.3	0.40
Porous surfacing (with storage)	0.1	0.2	0.15
Porous surfacing (without storage)	0.1	0.3	0.15

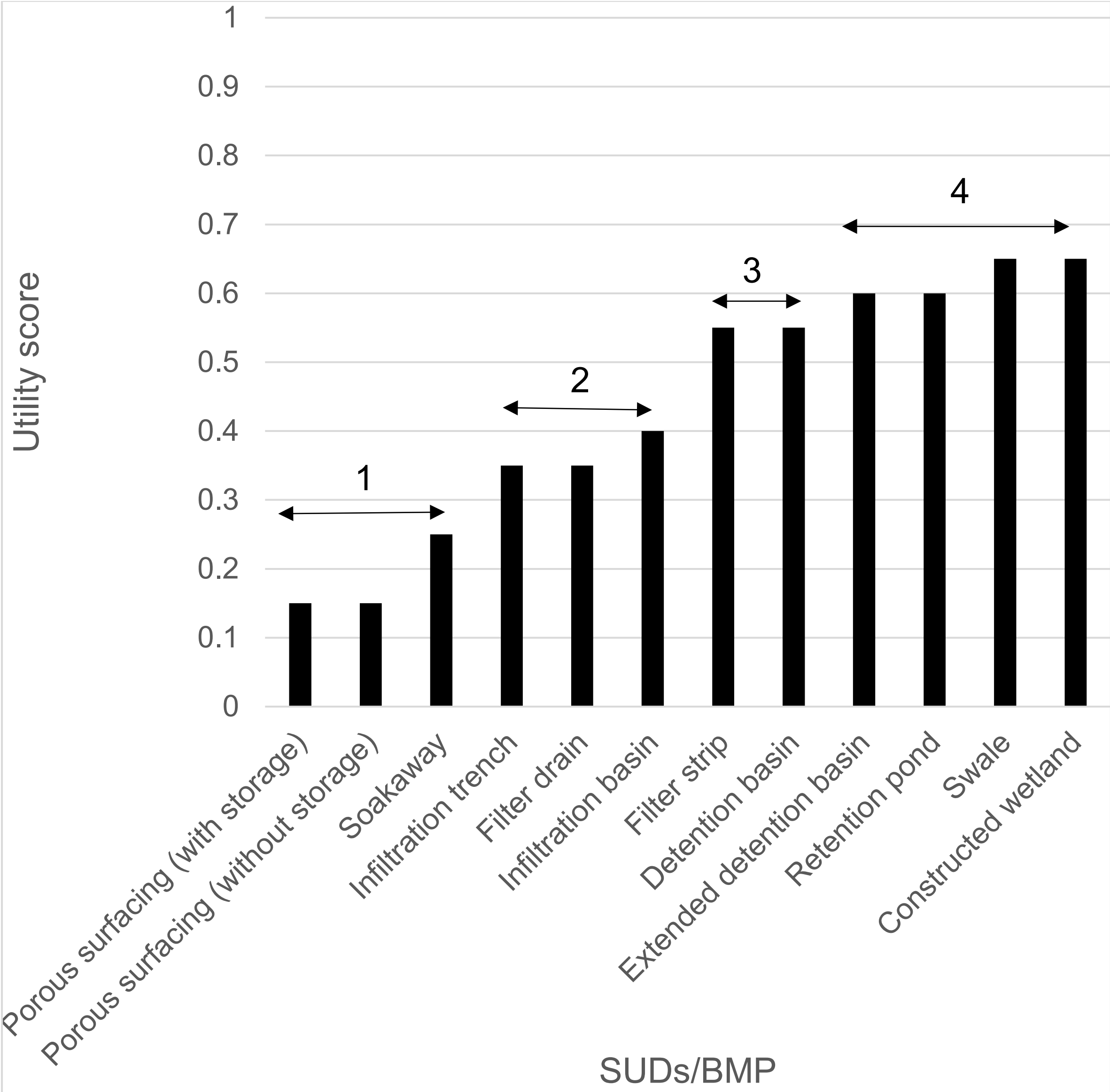


Figure 13. Allocated grading scores for SUDs/BMPs for sustainable development (biodiversity indicator.

References

EU SDS. 2001. A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development. COM/2001/0264 final. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52001DC0264

EU SDS. 2009. Review of the EU Sustainable Development Strategy COM (2009) 400. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52009DC0400

Highways England. 2015. Our plan to protect and increase biodiversity. Available at https://www.gov.uk/government/publications/biodiversity-plan

Highways England. 2017. Sustainable development strategy: our approach. Available at https://www.gov.uk/government/publications/highways-england-sustainable-development-strategy

AESTHETIC AND PUBLIC AWARENESS INDICATOR

Table 20 outlines a general quality assessment for receiving waters and identifies how this is impacted upon by aesthetic condition and public awareness potential. These functional characteristics are of concern in terms of the visual pollution and landscape character encountered on many watercourses and channels. In the highway environment, it is important to assess how SUDs/BMPs contribute to aesthetic condition and public awareness potential to the benefit of the general quality grade classification achieved by receiving waters.

Evaluation of the SUDs/BMP aesthetic condition is primarily based on the occurrence of litter (gross litter and general litter), oil scums, foams and fungus as well as prevailing colour and odour. An important emphasis for the aesthetic classification in the highway environment will be the consequences of oil pollution in the form of surface sheens, slicks, scum and foam. Public awareness potential is evaluated in terms of the ability of SUDs/BMPs to support a varied and thriving habitat which makes a positive contribution to the landscape which will be visible to passing motorists

Table 20. General quality grade classification in terms of aesthetic condition and public awareness potential

Class		Aesthetic Condition	Public Awareness Potential
A	Very good	No smell; surface water colourless; no evidence of oil pollution; no gross solids or general litter.	Provision of thriving aquatic and/or terrestrial habitats; very high landscape value and visual attraction
B	Good	No or only occasional smell; surface water generally colourless; no evidence of oil pollution; little if any gross solids or general litter.	Provision of good aquatic and/or terrestrial habitats; high landscape value and visual attraction
C	Fairly good	Faint smell (musty/earthy); surface water very pale colour; some (0 – 5%) oil sheen/slicks; some general litter and scum	Moderate habitat and associated ecological value; good landscape value and some visual attraction
D	Fair	Faint smell (musty/earthy); surface water pale colour; some (5 – 10%) oil sheen/slicks; some general litter and scum	Modest habitat and associated ecological value; fair landscape value and limited visual attraction
E	Poor	Obvious smell; surface water pale/greyish colour; obvious (5 - 25%) oil sheens/slicks; presence of some gross solids; general litter present; some scum and foam	Only a few suitable habitats with minimal ecological value; poor landscape potential
F	Bad	Strong smell; surface water dark colour; considerable (>25%) oil sheen/slicks; considerable gross solids; considerable general litter; heavy scums and foam.	Very poor habitat and no landscape value; typically overgrown site.

The relationships between the classes described in Table 20 and the utility scores developed in Table 22 (for aesthetic aspects) and Table 3 (for public awareness potential) are shown in Table 21. Tables 22 and 23 identify the utility scores allocated to individual SUDs/BMPs based on the two functional parameters of aesthetic condition and public awareness potential.

Table 21. relationships between general quality grade classifications and utility scores.

Class	Utility score range
A; Very good	0.8 – 1.0
B; Good	0.6 - 0.8
C; Fairly good	0.4 – 0.6
D; Fair	0.2 – 0.4
E; Poor	0.01 – 0.2
F; Bad	0

Table 24 collates the utility scores allocated for aesthetic condition and public awareness potential and combines them on an equal weighting to derive an overall utility score for aesthetic and public awareness. These scores are plotted against the individual SUDs/BMPs in Figure 14 to determine a grade for each treatment system.

Examination of Table 24 shows that the utility scores for individual SUDs/BMPs are reasonably consistent for aesthetic condition and public awareness potential. The resulting overall utility scores cover a range of 0.3 to 0.8 to which the grades of 1 to 5 are allocated as shown in Figure 14. The lowest grade of 1 is awarded to two infiltration treatment systems (soakaways and infiltration trenches) with a poor potential awareness potential being a major influencing factor. Permanent water containing treatment systems, such as constructed wetlands and retention ponds, achieve the highest grade (5) by scoring consistently well for both aesthetic condition and public awareness potential.

Table 22. Characteristics of different SUDs/BMPs which can contribute to aesthetic condition and allocation of utility scores.

SUDs/BMP	Ability to contribute to aesthetic condition	Allocated class/utility score
Swale	When present, surface water is flowing which counteracts discolouration and odour development; possibility of oil deposits, sediments and litter on grass sward.	B/C; 0.6
Filter strip	Presents a substantial grassed area which is susceptible to oil deposits, sediment accumulation and litter collection; some flowing surface water with little potential for discolouration or odour development.	C; 0.5
Filter drain	No prolonged presence of surface water and associated problems; limited surface area can be contaminated with oil, sediment and litter but this may be a sacrificial gravel layer.	C; 0.5
Soakaway	No problems or benefits associated with surface water; small visible surface area susceptible to oil coating and sediment accumulation	C; 0.5
Infiltration trench	No problems or benefits associated with surface water; small visible surface area susceptible to oil coating and sediment accumulation	C; 0.5
Detention basin	Alternating wet and dry appearance; limited storage of water preventing development of colour/odour problems; when dry, large exposed area can be contaminated with deposited sediment and oils.	B/C; 0.6
Extended detention basin	Longer wet storage periods than for detention basins but not sufficient to allow discolouration/odour problems; when dry, large exposed area can be contaminated with deposited sediment and oils.	B/C; 0.6
Retention pond	Aesthetic benefits provided by stored surface water which in the presence of repeated water movements will not become discoloured/odorous; oil sheens possible and litter accumulation can occur in vegetated margins	B; 0.7
Constructed wetland	High potential for aesthetic appeal due to presence of varied aquatic species; this can be moderated by possibility of trapped litter and dieback of vegetation in non-growing season	A/B; 0.8
Infiltration basin	Same characteristics as detention basins but presence of infiltration zone will be particularly susceptible to accumulation of oils and sediment	C; 0.5
Porous surfacing (with storage)	Ideally no surface water present; oil and sediment accumulation possible in porous surfacing but continuous traffic movement will counteract any odour development and litter accumulation	C; 0.5
Porous surfacing (without storage)	Ideally no surface water present; oil and sediment accumulation possible in porous surfacing but continuous traffic movement will counteract any odour development and litter accumulation	C; 0.5

Table 23. Characteristics of different SUDs/BMPs which can contribute to public awareness potential and allocation of utility scores.

SUDs/BMP	Ability to contribute to public awareness potential	Allocated class/utility score
Swale	Potential to blend in with and enhance local landscape providing visual impact	B; 0.7
Filter strip	Ability to provide contribution to local landscape but only modest visual impact	C; 0.5
Filter drain	Only minimal visual impact and landscape contribution	D; 0.3
Soakaway	No landscape or visual enhancement	E; 0.1
Infiltration trench	No landscape or visual enhancement	E; 0.1
Detention basin	Provides landscape improvement benefits; visual attraction when both wet and dry.	B; 0.7
Extended detention basin	Provides landscape improvement benefits; visual attraction when both wet and dry;.	B; 0.7
Retention pond	Provides good landscape improvement benefits with associated visual potential.	A/B; 0.8
Constructed wetland	Provides good landscape improvement benefits with associated visual potential.	A/B; 0.8
Infiltration basin	Provides landscape improvement benefits; visual attraction when both wet and dry.	B: 0.7
Porous surfacing (with storage)	Component of highway environment and therefore contributes to man-made landscape; visual restrictions apply.	D; 0.3
Porous surfacing (without storage)	Component of highway environment and therefore contributes to man-made landscape; visual restrictions apply.	D; 0.3

Table 24. Overall utility scores derived from individual utility scores for aesthetic condition and public awareness potential

SUDs/BMP	Utility score for aesthetic condition	Utility score for public awareness potential	Overall utility score
Swale	0.6	0.7	0.65
Filter strip	0.5	0.5	0.5
Filter drain	0.5	0.3	0.4
Soakaway	0.5	0.1	0.3
Infiltration trench	0.5	0.1	0.3
Detention basin	0.6	0.7	0.65
Extended detention basin	0.6	0.7	0.65
Retention pond	0.7	0.8	0.75
Constructed wetland	0.8	0.8	0.8
Infiltration basin	0.5	0.7	0.6
Porous surfacing (with storage)	0.5	0.3	0.4
Porous surfacing (without storage)	0.5	0.3	0.4

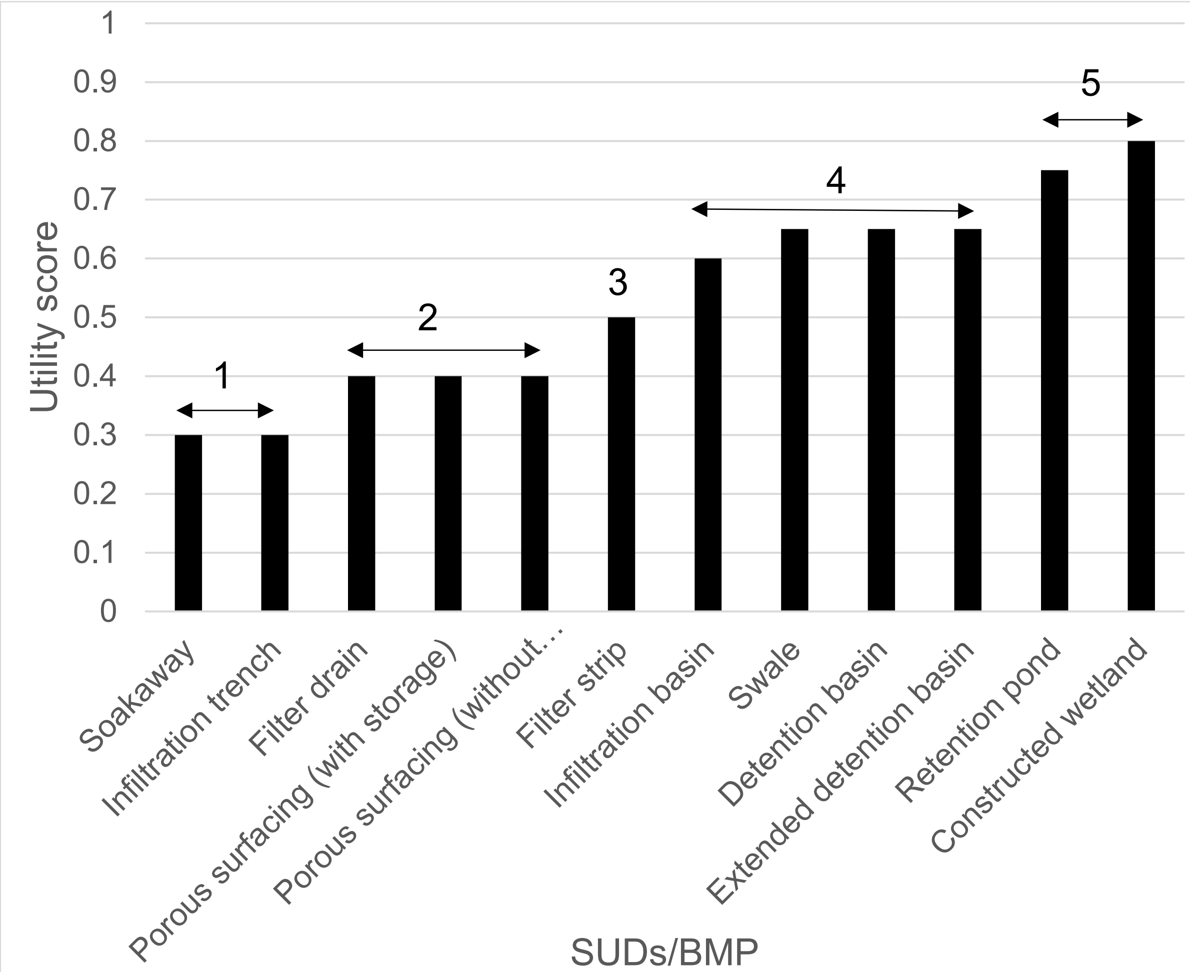


Figure 14. Allocated grading scores for SUDs/BMPs for aesthetic and public awareness indicator.

The benchmark grade values for the various SUDS/BMPs as derived from Figure 14 appear as default values in the DSS matrix for the “Aesthetic and Public Awareness” indicator within the Socio-environmental Awareness criteria section. It is possible for end-users to modify these gradings to take account of local design conditions or in negotiation with specific stakeholder interests and issues. Re-grading of the utility score plots can be achieved using the guidelines in the discussion provided above.

ECONOMIC CRITERION

incorporating

UNIT RATE COSTING INDICATOR

UNIT RATE COSTING INDICATOR

An appreciation of the financial implications are important when considering the overall costs of individual sustainable drainage (SUDS/BMP) best management practice devices given the contention that exists as to their alleged reduced costings compared to conventional drainage systems (Lampe et al., 2004; Environment Agency, 2015). Capital costs may be lower than conventional piped systems, but operational and maintenance costs may well be higher. An appreciation of and tools for costing enables appropriate comparisons to be made between potentially different drainage design solutions and also allows comparison with conventional and proprietary alternatives. There are also costs related to risk, residual value and on-going environmental benefits which need to be considered in any long term cost comparison.

A whole life cost methodology is summarised in Figure 15 which identifies the various data components needed to undertake a meaningful appraisal. ***Capital costs (CAPex)*** include: planning and site investigation costs; design and project

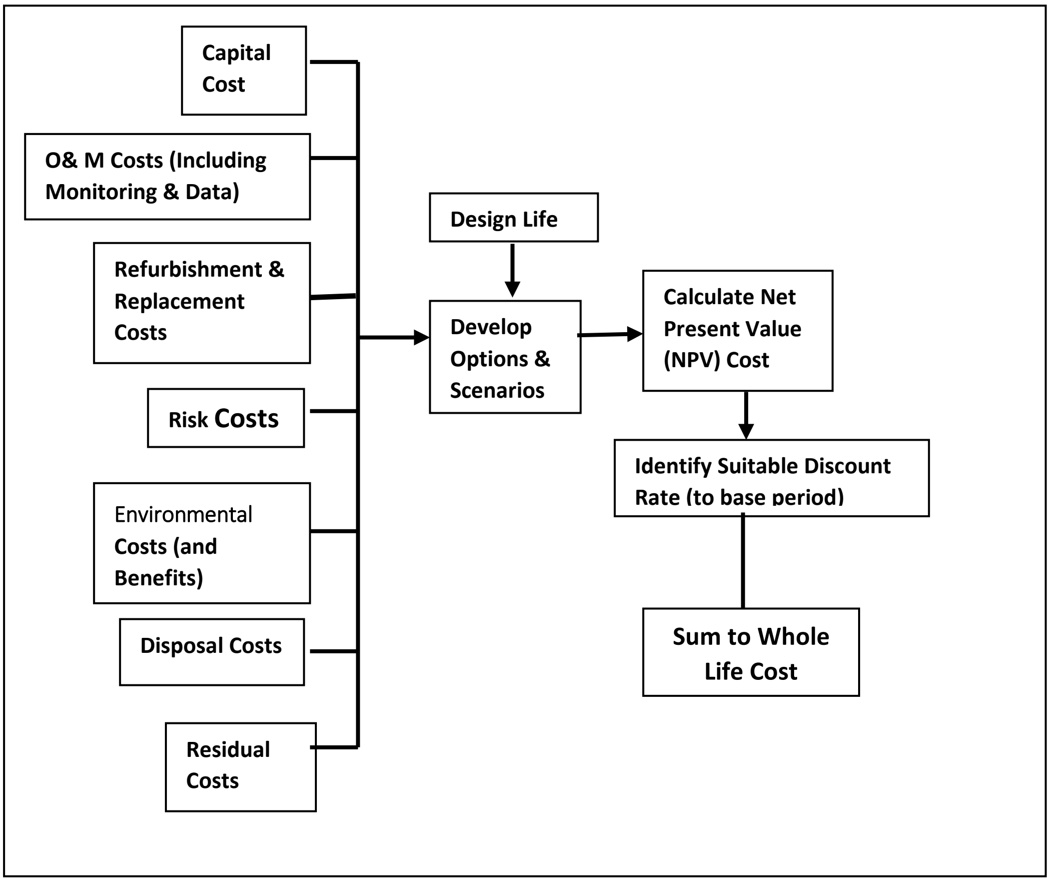


Figure 15. Whole Life Cost SUDS/BMP Appraisal

management/site supervision costs; clearance and land preparation costs; material costs; construction (labour and equipment) costs; planting and post-construction landscaping costs; and land-take costs. ***Operation and Maintenance (O&M) costs*** include monitoring and data; planned (regular) maintenance; periodic unplanned maintenance. ***Refurbishment and Replacement costs*** include rehabilitation (resolving problems such as blocked culverts and screens) and/or replacement (such as plant replacement). ***Risk costs*** cover residual costs not directly covered by any agreement clauses which might include exceptional legal costs associated with liability action, flood damage or pollution incidents etc. Such costs tend to be highly site-specific. ***Environmental costs*** are "off-set" costs to recognise the direct (and indirect) local community and environmental benefits that can accrue from the introduction of SUDS/BMPs including ecological and aesthetic enhancements, aquifer recharge as well as flood control and receiving water quality improvements. ***Disposal costs*** include requirements for disposal of vegetation (grass mowings, turfing, vegetation etc), sediment (which may need de-watering and safe disposal as well as toxicity testing), geotextile, contaminated infill and permeable materials. ***Residual costs*** (or more appropriately ***residual value***) recognize the final net present value (NPV) following the assumed operational lifetime of the site used for drainage control and treatment.

All these component costs are extremely difficult to evaluate in direct monetary terms with some such as environmental costs requiring specialist contingent valuation methodologies. Receiving water quality improvements and biodiversity enhancement are clearly relevant cost benefit elements but it is not an easy task to derive meaningful or robust economic values for these components in respect of highway drainage. Such externalities are therefore not considered in the current methodological framework proposed here but consideration is given for biodiversity and sustainable development in a separate Indicator page under the heading of 'Socio-environmental Awareness' criteria. If required, reference in terms of habitat and safety impacts can also be made to Biggs (2003) and to the working experience recorded for Scottish highways in respect of potential receiving water quality and amenity value (Wolf et al., 2015; Duffy et al., 2008).

It must be recognized that identifying overall average costs for each of the above components will be difficult as SUDS/BMP costs are inherently variable even when conducted on a unit (volume or area) basis as they must depend on local site and traffic conditions. In addition, indirect factors such as style and effectiveness of management and supervision practices, rigour of O&M schedules and drainage scale will all affect the costing regime. In this respect it is not surprising that large differences can be noted between different costing studies or between individual tendering estimates for the same drainage infrastructure work. Quotations provided for SUDS/BMP O&M for example, can vary considerably as evidenced by the UK M40 Oxford Motorway Service Area SUDS/BMP treatment train and associated landscaping which received whole site quotations ranging from £20,000 to £40,000 per annum (Heal et al., 2008). There is therefore considerable uncertainty and lack of experience in appreciating the requirements of these systems and a resulting costing variability is to be expected even where specifications and schedules have been clearly provided.

Some sub-elements of the individual whole life cost components do have useful data and background information particularly in respect of capital costs per unit storage volume and surface area. For example, such cost functions have been developed for retention ponds and infiltration trenches/basins (e.g. see Ellis and Aftias, 2008; Tarnaras *et al*., 2004). However such unit rate cost function analysis rarely extends to biofilters, wetlands or porous surfacing and also normally excludes consideration of post-construction landscaping costs, land-take costs or other components such as risk, disposal and residual costs. Figure 16 illustrates the inherent variability and underlying uncertainty in cost function methodology based on capital costing data for wet retention pond storage derived from the UK (Woods Ballard *et al*., 2003), Europe (Tarnaras *et al*., 2004), Australia (Tucker *et al*., 2000) and the US (Schueler, 1997).

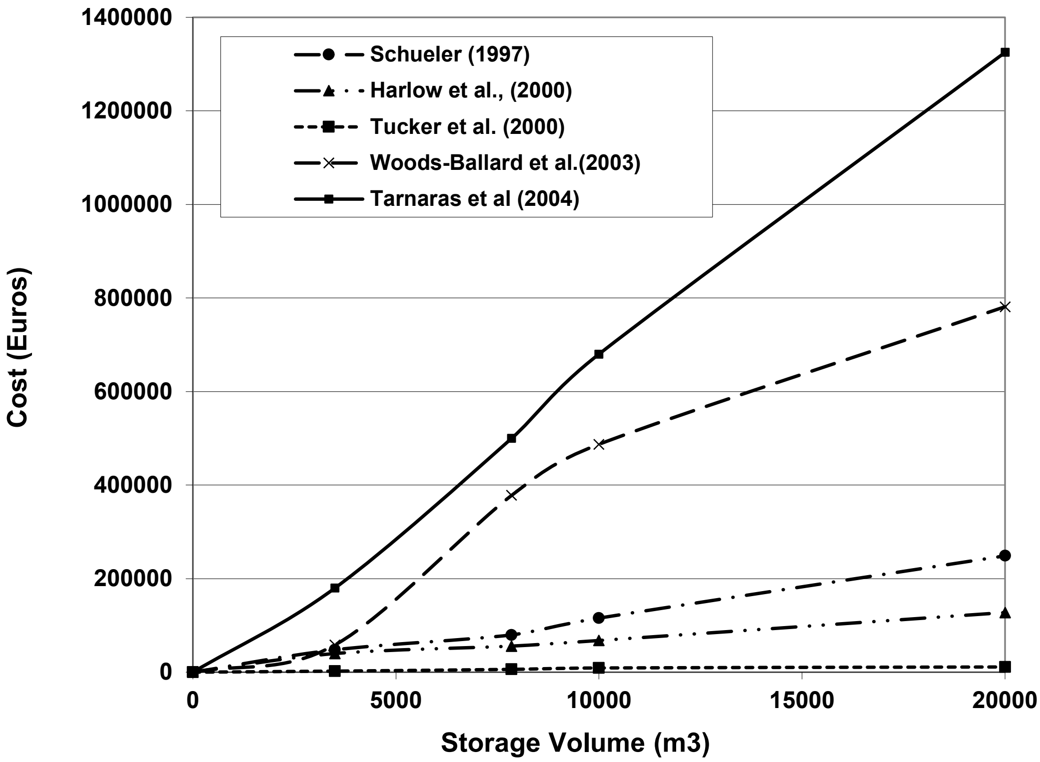


Figure 16. Costs for Retention Basin Storage.

The continental European data are based on theoretical values derived from unit cost prices primarily related to the Greek market whilst all other data are derived from real turn-out construction costs and costed operations collated from contractors and industry. The UK field data is the nearest to the theoretical European data and illustrates economy of SUDS/BMP scale up to about 8000 m^3 storage volumes which is also reflected to some extent in the US and Australian data. The latter data set suggests extremely low costing values operating in the Australian market and the same low costing regime has been noted to operate in N Ireland which is some 40% lower than that of the Greater London region (Bray and HR Wallingford, 2004). The high costing shown for the US Texas Department of Transportation data may possibly be related to high traffic disruption and associated safety costs. Despite the clear deficiencies exhibited by Figure 16 in terms of inherent variability, it is still nevertheless possible to utilise the cost function approach for at least the Capital Costing (CAPex) and O&M (OPex) components of the whole life cost index approach by selecting appropriate curves as shown in Figure 16 and scaling the cost in terms of utility scores. The essential problem with this approach is that there is very little similar cost data for SUDS/BMPs other than retention basins and only limited data specifically for highway drainage controls. However it has been shown that there is surprisingly little apparent difference between UK, European and US outcomes for SUDS/BMPs in terms of total unit rate costs although some material and labour costs tend to be somewhat higher in the UK (Bray and HR Wallingford, 2004).

As indicated in Figure 15, SUDS/BMPs have different design life spans and thus their economic comparison has to be estimated for the same life duration. Estimation of life time capital costs uses a timeframe equal at least to the longest lasting option and Table 25 illustrates net present value (NPV) coefficients which have been used as a basis for a 50 year reference with the coefficient (f) derived as: $f = 1 / (1 + i)^n$ where i is the rate of interest (taken as a standard historic 6% high discount rate rather than a declining 3.00% lower long term discount rate), and the exponent n is the estimated life duration of each SUDS/BMP.

Table 25. SUDS/BMP Net Present Value Coefficients for a Lifetime Duration of 50 years

SUDS/BMP	Estimated Life Span (years)	Net Present Value Coefficient
Swale	10	2.14
Porous Surfacing (without sub-structure)	10	2.14
Filter Drain	15	1.66
Soakaway	15	1.66
Infiltration Trench	15	1.66
Porous Asphalt (with sub-structure)	30	1.50
Detention Basin	50	1.00
Extended Detention Basin	30	1.17
Infiltration Basin	30	1.17
Retention Basin	50	1.00
Constructed Wetland	30	1.12

The recommended UK treasury long term discount rate for a drainage asset having a 50 – 75 year design lifetime is 3.00%, but the choice of an appropriate discount rate is a highly contentious issue. The lower 3.00% rate significantly downgrades capital costs compared to long term O&M costs. Thus the present value capital cost (CAPex) over 50 years for a swale having an average 10 years lifetime duration i.e. replaced every 10 years, would be equal to:

C_{total} (50 years) = C_{total} (10 years) x f
where:

$$f = 1 + [1/(1 + i)^{10}] + [1/(1 + i)^{20}] + [1/(1 + i)^{30}] + [1/(1 + i)^{40}] = 2.14$$

It is evident from the Greek examples (Tarnaras *et al.*, 2004) that reduced capital CAPex cost is associated with increasing storage volume and the 50 year cost formula has been developed as a generic basis for the calculation of capital costs and the construction of unit cost function graphs. The Operation & Maintenance costs (OPex) are based on the 15.76 NPV value of £1 per year capitalized over 50 years at 6% discount which is the multiplier used to derive the equivalent 50 year lifetime O&M cost.

Figure 17 summarises estimated average SUDS/BMP unit lifetime costs (£/m^3) based on a combination of the Greek, French, German and UK data as reported in the listed references with unit costs upgraded to a base 2013 dating. The data includes reference to Capital, O&M, Disposal, Replacement and Risk (+20%) costs although the data for Wetlands and Porous Surfacing (shown as hatched histogram bars in the figure) are based on very limited and tentative information and thus must be regarded with a substantial degree of uncertainty.

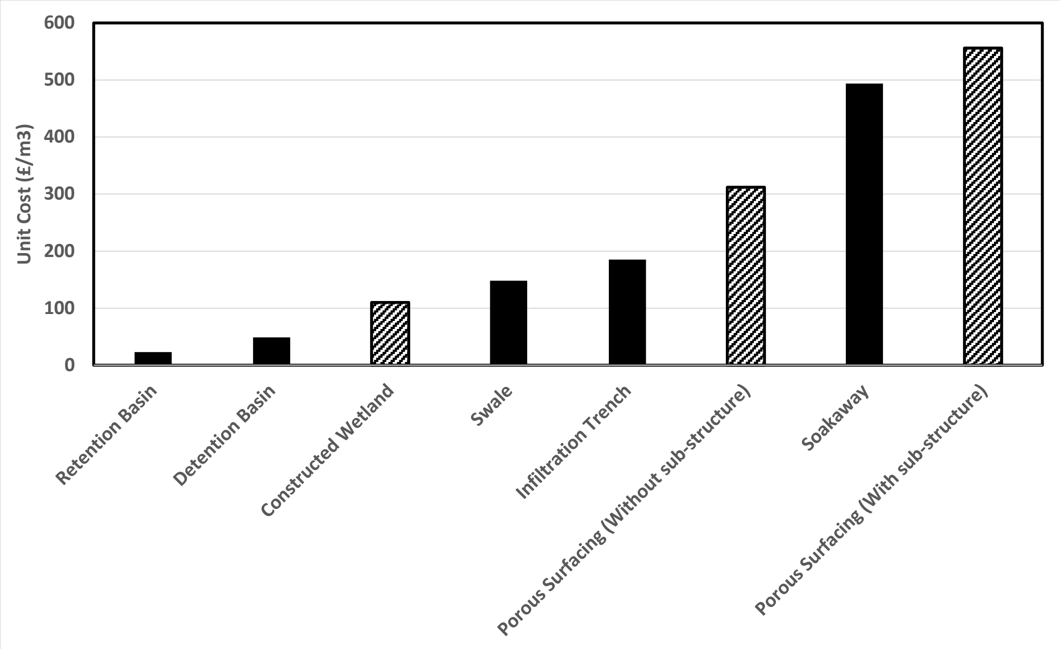


Figure 17. SUDS/BMP Lifetime Cost Distribution.

The data has been sourced from studies employing differing pricing approaches which only serves to exacerbate the data uncertainty. The Greek unit costs are primarily derived from commercial Bills of Quantity with the French and German data based on field examples whilst the UK costing data (Ellis, 2005; Bray and HR Wallingford, 2003) is averaged from data supplied by five consulting engineer and development companies from field/tendering work (and originally expressed in terms of m^3 storage or m^2 surface area). All SUDS/BMP capital costs have been costed to the equivalent timeframe for the longest lasting option i.e. over 50 years and the UK Capital Cost data includes an initial design and project management overhead of 25%. No allowance has been made for land-take costs, sediment/vegetation disposal or off-set environmental benefits. A recent US/UK joint project has suggested that land-take costs (SUDS/BMP plan area, access/easement and any amenity/recreation area) can be as much as 40% of the total SUDS/BMP whole life cost (Garden *et al*., 2005). However, this is likely to be favourably balanced by the residual value at the end of the SUDS/BMP lifetime.

It has not been possible to identify sufficient information on costing regimes for a number of highway SUDS/BMP units including filter strips, filter drains, extended detention basins and infiltration basins. The data ranges shown in Figure 17 therefore reflect not only differing EU national costing regimes but also the effects of SUDS/BMP scale, as the larger the unit in terms of storage capacity, the more economical the overall costing. In addition, the data does not include reference to any specific highway site being exclusively related to SUDS/BMPs located within an urban setting and which frequently are much larger than the majority of highway SUDS/BMP facilities. Given the limited data and lack of information on highway SUDS/BMP whole life costs, no attempt has been made to delineate gradings for the distribution shown in Figure 17, However, it may be possible for users who have full working knowledge and field experience of specific SUDS/BMPs to enter their own grade values using within the DSS matrix, as explained in the User Guide.

Faced with this problem of identifying robust data relating to highway SUDS/BMP whole life costs, an alternative semi-quantitative approach based on direct Capital and O&M costs only has been adopted. There is still relatively little field/site data available even for this more limited approach so recourse has been made to incorporate itemized bills of quantity as derived from national engineering pricing rates such as the UK Spon's Highway Works volume (AECOM, 2018). The unit rates, process and outputs derived from these sources relate mainly to small-medium sized highway schemes of up to £20M and for sites having no acute ground condition problems which is largely applicable in the UK context. The approach is based on bills of quantity and resource costing arising from detailed engineering construction records which have been updated to a 2013 price time. The data however, exclude items costed within "preliminaries" (e.g. site surveys), financing/loan charges, office overheads etc.. As such, the bills of quantity approach may not necessarily reflect the true capital/O&M costing of highway SUDS/BMP drainage but at least provide a standardized and unit rate costing methodology that can be applied in a uniform and structured manner for all SUDS/BMP control devices as a basis for national/regional comparisons. In addition, the unit rate costings provide a convenient and appropriate basis for transposing the unit costs to the utility scoring and grading procedure developed for other Indicator benchmarks in the current DSS methodology. In this regard the alternative methodology comprises a reasonable and robust procedural framework for SUDS/BMP unit rate costing as an alternative to a much more uncertain whole life costing estimate.

Table 26 shows the range of unit rates for capital and O&M costs for highway SUDS/BMP facilities as compiled from Spon's Highway Works volume (AECOM, 2018), construction data relating to motorway service stations (Bray and HR Wallingford, 2003) and Scottish highway SUDS/BMPs (Scottish Water 2013; Duffy et al., 2008). The sourced costing data has been discounted to a 2013 pricing time base and unitized in terms of cost per m^2 surface area or m^3 storage/detention volume. Relative descriptive values have been allocated to the unit costs following the procedure adopted for other Indicators as shown in Table 27 and these values form the basis for benchmarking the utility scores.

Table 26. Unit Price Costing and Utility Scoring of Highway SUDS/BMPs

SUDS/BMP	Cost Component	Unit Cost (£)	Costing Unit	Descriptive Relative Cost	Utility Score	Overall Average Utility Score
Filter Drain	Capital Cost	160 -224	m^3 storage	VH	0.1	0.3
	O&M Cost	0.48 – 2.56	m^2 surface area	M	0.5	
Infiltration Trench	Capital Cost	88 – 104	m^3 storage	H	0.3	0.4
	O&M Cost	0.32 – 1.88	m^2 surface area	M	0.5	
Soakaway	Capital Cost	>100	m^3 storage	H/VH	0.2	0.45
	O&M Cost	0.40	m^3 storage	L	0.7	
Porous Surfacing (Without sub-structure)	Capital Cost	56 – 64	m^2 surface area	M	0.5	0.5
	O&M Cost	1.28 – 2.56	m^3 storage volume	M	0.5	
Porous Surfacing (With sub-[structure)	Capital Cost	>58	m^2 surface area	M/H	0.4	0.4
	O&M Cost	1.34 – 3.48	m^3 storage volume	M/H	0.4	
Infiltration Basin	Capital Cost	16 – 24	m^3 detention volume	L	0.7	0.65
	O&M Cost	0.32 – 1.28	m^2 surface area	L/M	0.6	
Detention Basin	Capital Cost	24 – 32	m^3 detention volume	M/L	0.6	0.55
	O&M Cost	0.64 – 2.72	m^3 detention volume	M	0.5	
Extended Detention Basin	Capital Cost	64 – 80	m^3 detention volume	M/H	0.4	0.4
	O&M Cost	0.77 – 3.2	m^3 detention volume	M/H	0.4	
Wetland	Capital Cost	40 – 48	m^3 treatment volume	M	0.5	0.6
	O&M Cost	>0.48	m^2 surface area	L	0.7	
Retention Pond	Capital Cost	24 – 32	m^3 treatment volume	M/L	0.6	0.5
	O&M Cost	1.28 – 3.2	m^2 surface area	M/H	0.4	
Filter Strip	Capital Cost	4 – 7	m^2 surface area	VL	0.9	0.9
	O&M Cost	0.2 – 0.26	m^2 surface area	VL	0.9	
Swale	Capital Cost	16 - 28	m^2 surface area	L	0.7	0.7
	O & M Cost	0.16	m^2 surface area	VL	0.7	

Table 27. SUDS/BMP Utility Score Ranges and Descriptive Values

Descriptive Value	Utility Score Range
Very High (VH)	0 – 0.2
High (H)	0.2 – 0.4
Medium (M)	0.4 – 0.6
Low (L)	0.6 – 0.8
Very Low (VL)	0.8 – 1.0

The two components of the costing methodology (capital and O&M costs) have been given equal weighting and the final column of Table 26 shows the overall weighted score for each of the SUDS/BMPs. Only filter drains and soakaways demonstrate any significant difference between capital and O&M costs in terms of relative weighting with both having much higher capital costs in comparison to their O&M costs. O&M costs appear to average between 0.5% to 2.0% of capital costs with the Bray & HR Wallingford (2004) work on motorway service station SUDS/BMP schemes suggesting O&M costs to vary between 2% - 10% of total construction costs. However, the lowest overall unit costs relate to at-source filter strips and swales with filtration controls such as filter drains, infiltration trenches, soakaways and porous surfacing (with deep sub-structures) having the highest unit costs.

Figure 18 shows the utility score distribution for the highway SUDS/BMP unit rate pricing which is rather different to that exhibited in Figure 17 where retention, detention basins and wetlands were shown to have lowest unit cost prices. This most probably is related to the difference imposed by scale where the larger sizing of the average urban SUDS/BMP facility offers diminishing unit costs. The poor utility scoring and associated gradings of soakaways, infiltration trenches and porous surfacing with deep sub-structures is confirmed in both Figures 17 and 18.

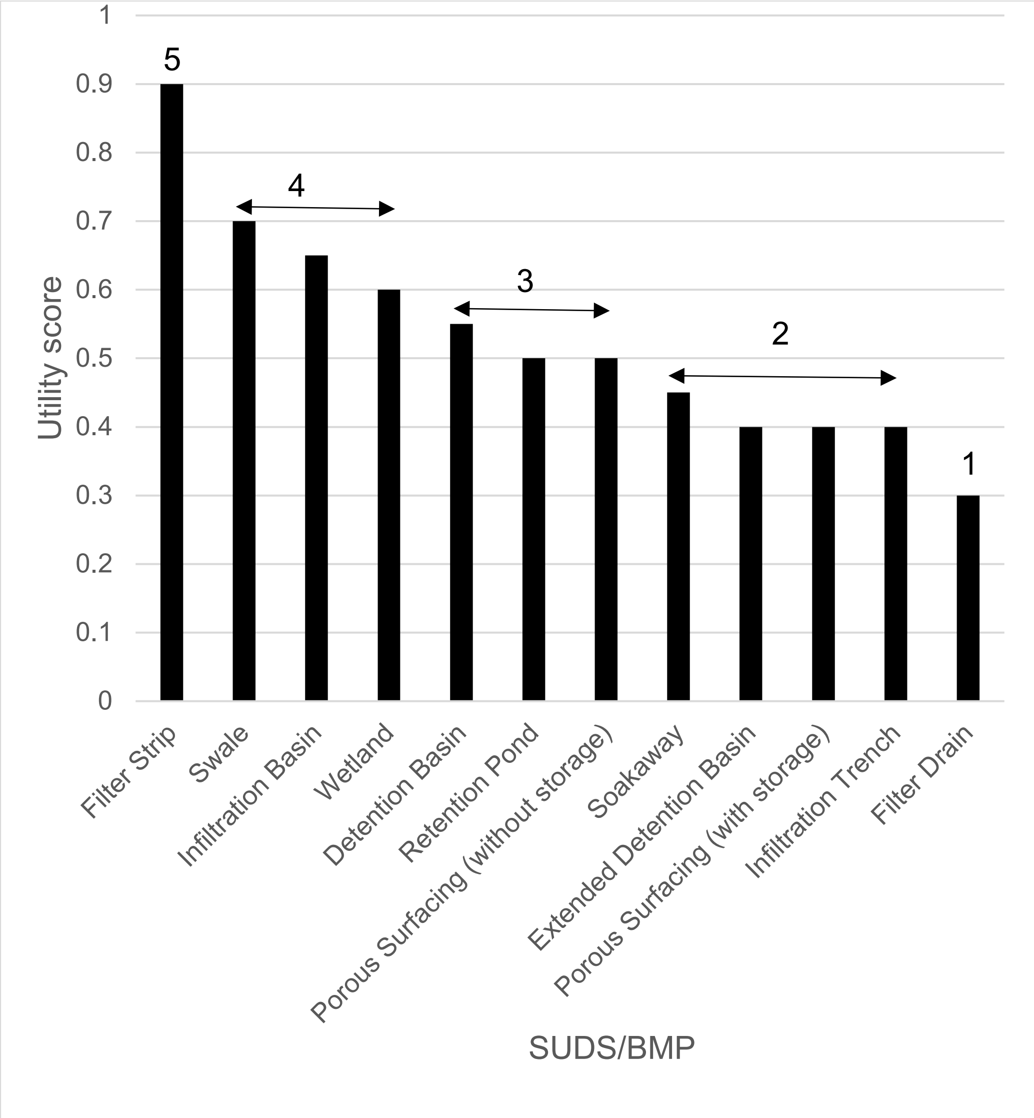


Figure 18. SUDS/BMP Costing Utility Score Distribution

References

AECOM. 2018. Spon's Civil Engineering and Highway Works. Taylor & Francis (CRC Press). Abingdon, Oxon. UK. ISBN 9751138612020.

Biggs, J. 2003. Maximising the Ecological Benefits of Sustainable Drainage Systems. Report SR625. HR Wallingford. UK.

Bray, R and HR Wallingford. 2004. Whole Life Costing for Sustainable Drainage. Report SR627. HR Wallingford. UK.

Duffy, A., Jefferies, C., Waddell, G., Shanks, G., Blackwood, D and Watkins, A. 2008. A cost comparison of traditional drainage and SUDS in Scotland. Water Science and Technology, 57 (9), 1451 – 1459.

Ellis, J.B. 2005. UK BMP CAPex and OPex Cost Data. Daywater WP5, Hydropolis, BMP Catalogue. EU 6th Framework Programme. www.daywater.org.

Environment Agency. 2015. Cost Estimation for SUDS: Survey of Evidence. Report SC080039/R9. Delivering Benefits Through Evidence. Environment Agency. Bristol. UK.

Garden, M., Woods Ballard, B and Taylor, L. 2005. Whole life costing of SUDS in Practice. 164 – 173 in Newman, A.P., Pratt, C.J., Davies, J.W and Blakeman, J.M (Edits): Proceedings of the 3rd National Conference on Sustainable Drainage, June 2005. Coventry University, Coventry. UK.

Heal, K.V., Bray, R., Willingale, S.A.J., Briers, M., Napier, F., Jefferies, C and Fogg, P. 2008. Medium term performance and maintenance of SUDS: A case study of Hopwood Park Motorway Service Area, UK. Proceedings of the 11th International Conference on Urban Drainage, Edinburgh, Scotland. 1 – 10. IWA Publishing, London. UK.

Lampe, L., Barrett, M., Woods-Ballard, B., Martin, P., Glass, C., Weinstein, N and Jefferies, C. 2005. Post-project Monitoring of BMPs/SUDS to Determine Performance and Whole Life Costs. IWA Publishing. London. UK. ISBN 1843397161.

Schueler, T. 1997. Costs and Benefits of Stormwater BMPs. Final Report, Centre for Watershed Protection, Ellicott City Maryland, United States.

Scottish Water. 2013. SUDS for Roads. Working Party SUDS. WSP Development & Transportation. Edinburgh. Scotland.

Tarnaras, I., Papavasiliou, C., Papatzani, S and Aftias, E. 2004. Best Management Practices Cost Estimates. Daywater WP6, Deliverable 2. EU 6th Framework Programme. www.daywater.org.

Harlow, C., Landphair, P.D., McFalls, J.A and Thompson, D. 2000. Design Methods, Selection and Cost Effectiveness of Stormwater Quality Structures. Report FHWA/TX-01/1837-1, Texas Department of Transportation, Austin, Texas, US.

Tucker, J., Rozis, N and Rahman, A. 2000. A simple method for life cycle cost assessment of water sensitive urban design. In Strecker, E.W and Huber, W.C (Edits): Global Solutions for Urban Drainage. Proceedings of the 9th International Conference on Urban Drainage, September 2002, Portland, Oregon, US

Wolf, D.F., Duffy, A.M and Heal, K.V. 2015. Whole life costs and benefits of SUDS in Dunfermiline, Scotland. 419 – 427 in Barrett, M. (Editor): Proceedings of the International Conference on Low Impact Development. American Society of Civil Engineers (ASCE), Reston, Virginia, USA. ISBN 97807784479025.

Woods Ballard, B., Malcolm, M and Kellagher, R. 2003. Whole Life Costing for Sustainable Drainage Schemes. HR Wallingford, Oxon. [See also 181 – 192 in Pratt, C.J, Davies, J. W., Newman, A. P and Perry, J. L. (Edits)., Proceedings of the 2nd National Conference on Sustainable Drainage, June 2003, Coventry University, Coventry, UK].

LEGAL AND HIGHWAY PLANNING CRITERION

incorporating

ABILITY TO COMPLY WITH THE EU WATER FRAMEWORK DIRECTIVE OBJECTIVES

ABILITY TO COMPLY WITH THE EU WATER FRAMEWORK DIRECTIVE OBJECTIVES

Each country has its own national highway legislation and regulations, which additionally can be interpreted and implemented in a variety of forms at a local level. Therefore a practicable way to develop default scores for SUDS/BMPs which are applicable on a European basis is to select an issue of general relevance to highway planners, developers and operators, and to use this approach to facilitate a SUDS/BMP comparison. A priority aim within any national planning system is to manage development relative to social and environmental interests. The management of enhanced surface water volumes associated with construction of highways is hence an essential consideration for highway practitioners. The traditional approach to managing stormwater runoff generated by highways has been to directly drain away surface water as quickly as possible to prevent flooding in the local area. However, it is now appreciated that this approach can drastically influence the flooding regime, pollutant loading characteristics, receiving water ecology and hydro-geomorphology of an entire river basin and hence be prejudicial to various EU Directives e.g. the EU Water Framework Directive (EU WFD, 2000), EU Groundwater Directive (2006) and NATURA 2000.

A further major factor influencing highway authorities and practitioners in many areas is the increased awareness of the need to tackle global issues, such as climate change and water scarcity, on a local scale. For example, the generation of surface runoff is increasingly reframed as an opportunity; a resource with the potential to contribute to meeting multiple needs as opposed to its traditional designation as a waste product to be disposed of. Sustainability issues are now at the core of both European and national legislation, with the need to take a more holistic approach permeating through many recent legislative decisions. As they are frequently at the forefront of many planning decisions, highway planners, developers and operators are under increasing pressure to incorporate more and more demanding legislative requirements and policies within their highway development and management plans.

CEDR PROPER Deliverable 2.3 (Evaluation of International, European and national legislative frameworks and approaches) includes a detailed assessment of legislation pertinent to management of surface and groundwater bodies potentially impacted by road and traffic related activities. Drawn from D2.3, Table 28 provides an overview of EU legislation that highway practitioners need to be cognisant of, together with a list of associated GIS files produced by Member States (as part of the various Directives' requirements) which can be used to generate integrated maps which identify areas where highway construction and operation would fall under one or more environmental constraint. The GIS files are freely available from the Water Information System for Europe (WISE), an open access web-based database where users can access information as datasets in excel, interactive maps and shapefiles in GIS, forecasting services etc. (WISE, undated). CEDR PROPER D2.3 proposes a flowchart which sets out a step-by-step approach to support users developing such an integrated map. The generation of such maps – either integrated or on a standalone basis – can also support users of the PROPER Decision Support System (DSS) (CEDR PROPER Deliverable 3.3) in refining default scores identified in the performance matrix by, for example, enabling users to identify areas of poor ecological or chemical status and/or areas identified as NATURA 2000 sites. Specific indicators, which have been used in the development of the PROPER DSS performance matrix (D3.3), to consider aspects relevant to the requirements of the identified European Directives are also listed in the final column of Table 28.

Table 28. Legislation pertinent to management of waterbodies receiving highway runoff, associated WISE files and the DSS indicators within which they have been considered

Legislation	Relevant WISE GIS shape file	DSS indicator
EU Water Framework Directive (2000)	Quantitative status of groundwater bodies	Impact on receiving water quantity
	Chemical status of groundwater bodies	Impact on receiving water quality
	Ecological and chemical status of surface water bodies	Impact on receiving water quality Impact on receiving water ecology
	Areas designated for the abstraction of surface and groundwater intended for human consumption	Presence of sensitive groundwater
	Areas designated for the protection of economically significant aquatic species	Impact on receiving water ecology
EU Groundwater Directive (2006)	Diffuse source emissions	Pollution control
	Point source emissions	Pollution control
EU Nitrates Directive (1991)	Vulnerable zones	Impact on receiving water quality
EU Urban Wastewater Treatment Directive (1991)	Designated sensitive areas	Impact on receiving water ecology
NATURA 2000	Natura 2000 habitats or ecosystem areas	Impact on receiving water ecology; site of special scientific interest staus
EU Floods Directive (2007)	Areas at risk of flooding	Flood control

The increasing importance placed on the use of river basin management approaches has led to renewed emphasis on the use of decentralised stormwater runoff management for both quantity and quality control. For example, highway planners, developers and operators are increasingly required to tackle flood risk reduction on a catchment scale i.e. highway practitioners should aim to minimise flood risk at the local scale without increasing the risk of flooding elsewhere. The use of such a catchment-based approach is also in keeping with the requirements of the EU WFD (2000) and EU Floods Directive (2007), and is incorporated into the majority of individual EU Member State planning legislations. With regard to quality, Article 10 of the EU WFD (2000) specifically refers to the management of diffuse pollution, recommending the use, where appropriate, of best environmental practices. The provision of high quality green areas and open spaces in highway environments is also starting to be recognised as an opportunity to contribute to the delivery of cultural (e.g. aesthetic) benefits and biodiversity targets at a wider catchment scale. Whilst the specific benefits offered by highway green infrastructure are not yet clear, well-maintained green and blue spaces are recognised to offer areas for recreation, amenity and environmental education/awareness, as well as providing key corridor habitats for wildlife and plants. In this way the use of highway SUDS/BMPs can also contribute to the achievement of national sustainable performance indicators and local/regional framework planning strategy objectives. The use of such decentralised approaches also aligns with the objectives of UN Sustainable Development Goals (Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation), particularly indicator 9.4: "*upgrade infrastructure….. make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies…*". (UN SDG, 2015). Hence increasing attention throughout Europe is being focused on the use of SUDS/BMPs in highway environments as an important way to contribute to meeting many of the legislative requirements through the opportunities they can provide in relation to achieving water quality, quantity and socio-amenity targets within highway environments and the wider catchment area.

The ongoing implementation of the Directives identified in Table 28 will require the introduction of and compliance with a range of new and modified legislation and regulations in the highway planning, development and operational arena. Such legislative modifications may include consideration of highway runoff taxes and fees as well as highway usage charges. The potential for each type of SUDS/BMP to contribute towards several legislative requirements has already been evaluated within various PROPER DSS indicators (see Table 28 for an overview of linkages between DSS indicators and various EU Directives). As the overarching framework addressing sustainable water resource management, the potential for SUDS/BMPs to contribute towards legal and highway planning is based on an evaluation of the potential for SUDS/BMPs to make a contribution to EU WFD requirements with respect to their ability to fulfil compliance assessments and/or obtain planning permission. Ease of compliance of SUDS/BMPs is described qualitatively using one of five descriptors ranging from very high (i.e. easy to comply) to very low (i.e. more challenging and likely to require planning permission or detailed compliance assessment). A utility score is then associated with each descriptor (see Table 29) to enable inclusion in the overall performance matrix assessment. The utility score ranges in Table 29 are related to the descriptive value by taking a mid-range value to represent a specific descriptive value (e.g. 0.7 is taken as being equivalent to High (H)) whereas 0.8 would represent the borderline between High (H) and Very High (VH).

Table 29. Relationship between descriptive values and utility scores

Descriptive values	Utility Score Range
Very high (VH)	0.8 – 1.0
High (H)	0.6 – 0.8
Medium (M)	0.4 – 0.6
Low (L)	0.2 – 0.4
Very low (VL)	0 – 0.2

The results of this assessment (as descriptive values and with an associated utility score) are presented in Table 30.

Filter strips are considered the easiest type of SUDS/BMPs to install to comply with WFD requirements, involving minor design and engineering works only. These are followed by soakaways, infiltration trenches, filter drains and porous surfacing without any sub-structure storage, which require limited land take and do not require extensive negotiations to obtain planning consent or to conform to health and safety regulations. At the other end of the scale, results presented in Table 30 indicate that SUDS/BMPs such as retention basins, (extended) detention basins and infiltration basins have a lower ability to comply with existing legislation due to their comparatively larger size and open water volumes which can lead to the need to obtain planning permission and/or demonstrate compliance with health and safety legislation.

Table 30. Comparative SUDS/BMP contribution to the ability to comply with EU WFD requirements

SUDS/BMPs	Contributing to EU WFD requirements	
	Descriptor	Utility score
Filter Drain	H	0.7
Porous surfacing (without sub-structure storage)	H	0.7
Porous Paving (with sub- structure storage)	MH	0.6
Filter Strip	VH	0.9
Swales	MH	0.6
Soakaways	H	0.7
Infiltration Trench	H	0.7
Infiltration Basin	VL	0.1
Retention Pond	VL	0.1
Detention Basin	VL	0.1
Extended Detention Basin	VL	0.1
Constructed Wetland	L	0.3

The utility scores reported in Table 30 are plotted for each of the SUDs/BMPs in Figure 19 in order to facilitate the award of appropriate grades on a 1 to 5 scale, with grades assigned by considering the distributive range shown by the utility scores and allocating grades to reflect variations within this range. Filter drains, which are identified as relatively the easiest type of system of to comply with planning regulations are allocated a grade of 5 followed by those SUDS/BMPs that require minimal planning consent to conform to existing site requirements, which are awarded a grade of 4. SUDS/BMPs which score poorly include the large storage/detention systems (i.e. various types of detention basins/retention ponds), and these are allocated a grade of 1 reflecting the need for more extensive investigations to satisfy compliance assessments. Constructed wetlands (absence of open water bodies), and swales (linear systems) and porous paving with sub-surface storage (complex substructures) are allocated intermediate grades of 3 and 4 reflecting the relatively differing levels of design and planning required for their successful installation.

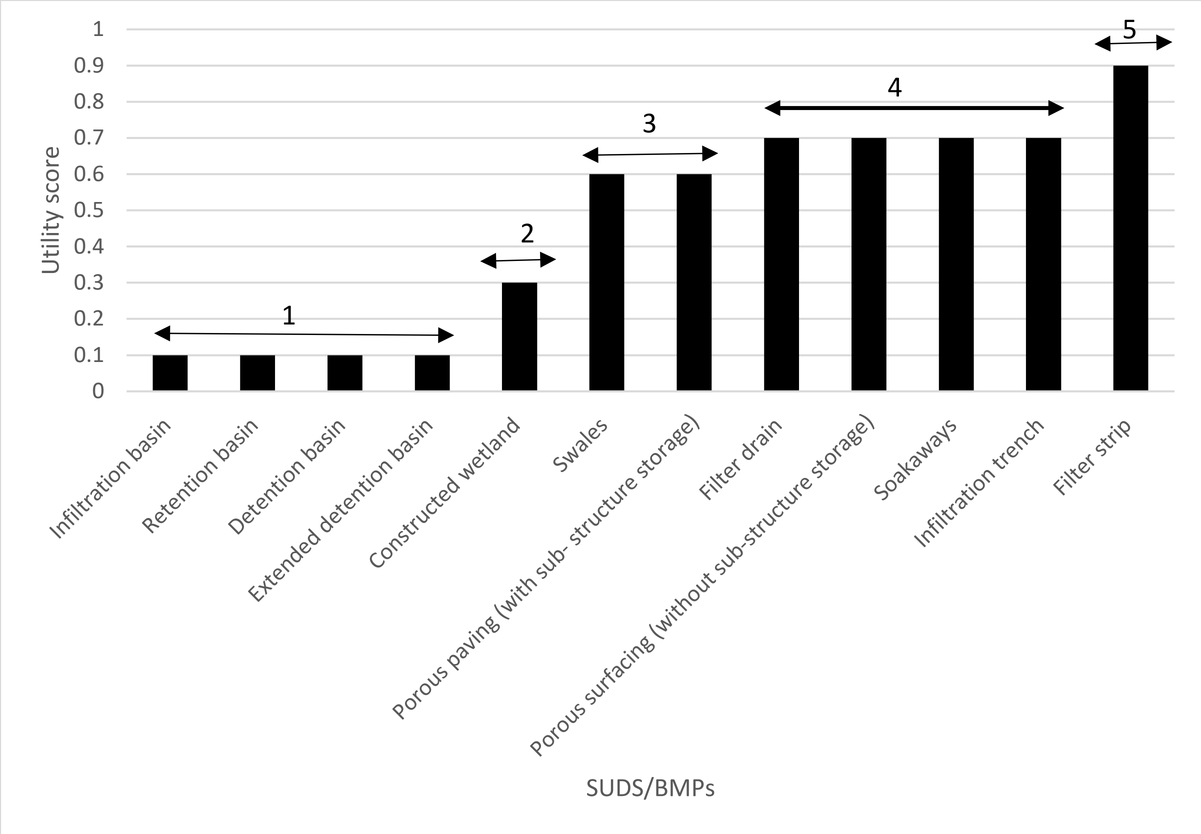


Figure 19. Utility scores and default grade values allocated for the ability of SUDS/BMPs to fulfil legislative and planning requirements

References

CEDR PROPER Deliverable 2.3. 2018. Evaluation of International, European and national legislative frameworks and approaches. http://proper-cedr.eu/outputs.html

EU Floods Directives. 2007. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1567531539168&uri=CELEX:32007L0060

EU Groundwater Directive. 2006. Directive 2006/118/EC on the protection of groundwater against pollution and deterioration https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02006L0118-20140711

EU Nitrates Directive. 1991. Council Directive of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources (91/676/EEC) https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1561542776070&uri=CELEX:01991L0676-20081211

EU Urban Wastewater Treatment Directive. 1991. Council Directive 91/271/EEC of 21 May 1991 concerning urban waste-water treatment. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:31991L0271

EU WFD. 2000. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1567531605743&uri=CELEX:32000L0060

NATURA 2000. NATURA 2000 network viewer. https://natura2000.eea.europa.eu/#

UN SDG. 2015. Sustainable development Goals: Knowledge Platform. https://sustainabledevelopment.un.org/?menu=1300

WISE (undated) The Water Information System for Europe: freshwater https://water.europa.eu/freshwater

SUMMARY OF DEFAULT GRADES DERIVED FROM CONSIDERATION OF EACH INDICATOR

Criteria	Indicator		SW	FS	FD	SO	IT	IB	RP	DB	EDB	CW	PS	PS+
Technical	Flood control		2	2	3	3	3	4	5	5	5	5	1	3
	Pollution control		2	1	3	4	4	5	3	2	4	5	1	5
	Adaptability to highway widening and climate change		2	1	2	3	2	2	3	4	5	5	1	4
Environmental	Impact on receiving waterbody volume	SW	2	2	3	-	-	4	3	4	5	2	1	3
		GW	2	2	3	4	4	5	-	-	-	-	3	4
	Impact on receiving waterbody quality	SW	3	3	4	-	-	5	4	3	4	5	2	4
		GW	2	2	3	3	3	4	-	-	-	-	3	4
	Impact on receiving waterbody ecology	SW	2	2	1	-	-	3	4	3	4	5	1	1
		GW	3	3	3	3	3	3	-	-	-	-	3	3
Operation and Maintenance	Maintenance and servicing requirements		3	4	5	4	5	5	2	3	2	1	5	3
Socio-environmental awareness	Sustainable development (biodiversity)		4	3	2	1	2	2	4	3	4	4	1	1
	Aesthetics & public awareness		4	3	2	1	1	4	5	4	4	5	2	2
Economic	Unit rate costing		4	5	1	2	2	4	3	3	2	4	3	2
Legal & highway planning	Ability to comply with the EU WFD objectives		3	5	4	4	4	1	1	1	1	2	4	3

KEY:
SW = Swale
FS = Filter strip
FD = Filter drain
SO = Soakaway
IT = Infiltration trench
IB = Infiltration basin
RP = Retention pond
DB = Detention basin
EDB = Extended detention basin
CW = Constructed wetland
PS = Porous surfacing with sub-surface storage
PS+ = Porous surfacing without sub-surface storage

ANNEX. Derivation of O&M Utility Descriptive Values for Highway SUDS/BMPs

1. Basins and Wetlands			
SUDS/BMP Component	**Regular Maintenance**	**Periodic Maintenance**	**Monitoring & Data**
Detention Basin	-Regular mowing (1 x month) -Litter/debris removal (after storms) -Inlet/outlet cleaning (1 x year) -Oil sheen/slicks and emulsions (annually; after storms)	-Bankside vegetation -Weed/shrub control -Silt/sediment removal -Bankside erosion -Overflow/inlet/outlet check and rehabilitation	-Inlet/outlet structures -Silt/sediment accumulation -Standing/ponding water (after 48 hours)
	Medium/High	***Medium***	***Medium/Low***
Retention Pond	-Regular mowing (1 x month) -Litter/debris removal (after storms) -Inlet/outlet cleaning (1 x year) -Oil sheen/slicks and emulsions (annually; after storms) -Check/clean screens (after storms)	-Bankside vegetation -Weed/shrub control -Silt/sediment removal -Bankside erosion -Overflow/inlet/outlet check and rehabilitation -Control/removal of aquatic and nuisance plants -Maintain basin configuration	-Inlet/outlet structures -Silt/sediment accumulation -Check water levels -Check overflow/bypass -Dam/rip-rap condition
	High	***High***	***Medium/High***
Extended Detention Basin	-Regular mowing (1 x month) -Litter/debris removal (after storms) -Inlet/outlet cleaning (1 x year) -Oil sheen/slicks and emulsions (annually; after storms) -Check/clean screens (after storms) -Check/clean orifice/overflow device (annually)	-Regular mowing (1 x month) -Litter/debris and weed removal (after storms) -Inlet/outlet cleaning (1 x year) -Oil sheen/slicks and emulsions (annually; after storms) -Check/clean screens (after storms)	Inlet/outlet structures -Silt/sediment accumulation -Check water levels (Two-level operation) -Check overflow/bypass -Dam/rip-rap condition
	High/Very High	***High***	***Medium/High***
Wetland	-Regular mowing (1 x month) -Litter/debris removal (after storms) -Inlet/outlet cleaning (1 x year) -Oil sheen/slicks and emulsions (annually; after storms) -Check/clean screens (after storms) -Check/clean level spreader (annually) -Check/clean sediment forebay (annually) -Regular partial vegetation removal	-Regular mowing (1 x month) -Litter/debris removal (after storms) -Inlet/outlet cleaning (1 x year) -Oil sheen/slicks and emulsions (annually; after storms) -vegetation removal and re-planting/reseeding -Sediment/silt removal -Aeration if eutrophic	-Inlet/outlet structures -Silt/sediment accumulation -Check water levels -Check wetland substrate porosity -Shut-off valve check -Vegetation condition -Monitor erosion and bankside condition -Check overflow if present -Check liner condition -Wildlife habitat and condition
	Very High	***Very High***	***High***

2. Filter Strips and Swales			
SUDS/BMP	**Regular Maintenance**	**Periodic Maintenance**	**Monitoring & Data**

Compone nt			
Filter Strip	-Regular mowing (1 x month) -Litter/debris removal (after storms) -Inlet/outlet check/cleaning (if present) -Check gradient (as needed) -Re-instatement of edgings to hard surfaces (as needed)	-Control/removal of weeds -Re-turfing/re-seeding -Surface raking; scarifying; hollow tining/spiking etc. -Silt/sediment removal as required -Turf/overseed to original design levels	-Erosion, scour, gullying etc -Silt/sediment deposits -Soil/grass condition
	Medium	***Medium/Low***	***Low***
Swale	-Regular mowing (1 x month) -Litter/debris removal (after storms) -Inlet/outlet check/cleaning (if present) -Check gradient and condition of check dams if present (as needed) -Re-instatement of edgings to hard surfaces (as needed)	Control/removal of weeds -Re-turfing/re-seeding -Surface raking; scarifying; hollow tining/spiking etc. -Silt/sediment removal as required -Turf/overseed to original design levels -Control of weeds/shrubs etc -Remove oil/petrol residues -Check soil compaction	-Erosion, scour, gullying etc -Silt/sediment deposits -Soil/grass condition -Excessive basal waterlogging or standing water -Inlet/outlet inspection
	Medium	***Medium/High***	***Low***

3. Infiltration SUDS/BMPs			
SUDS/BMP Component	**Regular Maintenance**	**Periodic Maintenance**	**Monitoring & Data**
Filter Drains	-Litter/debris removal (after storms) -Mow/weed grass edges (3/4 x yr)	-Weed/shrub control -Surface salt check and removal -Stone infill renewal/replacement -Surface silt/sediment -Removal/replacement of geotextile liner	-Regular inspection after storm events -Erosion., scour, gullying- -Tyre rutting and splash-out
	Low	***Low***	***Low***
Soakaways	-Litter/debris removal (after storms) -Remove any surface stones/rocks (after storms) -Trim back tree/shrub side roots (1 x yr) -Check for standing water -Check drain-down time	-Clean/replace surrounding granular infill -Sweep area draining to soakaway to prevent/protect against silt entry	-Check silt/sediment accumulation -Check pre-treatment systems e.g silt traps -Check observation wells/tubes -Check for ground settlement -Check oil interceptors -Check inlet -Check with wildlife ecologist on habitat
	Medium/Low	***Low***	***Medium/Low***
Infiltration Trench	-Litter/debris removal (after storms) -Mow grass surrounds (as needed)	-Weed/shrub control (if required) -Surface salt check and removal -Basal soil compaction.	-Regular inspection after storm events -Erosion, scour and gullying -Tyre rutting and splash-out.

		-Check porosity(especially if standing water present) -Clean/replace basal fill	
	Low	***Low***	***Low***
Infiltration Basin	-Litter/debris removal (after storms) -Regular grass mowing (3/4 x yr) -Clearance of leaves, silt from grass surface (annually)	-Check soil compaction and silt/sediment accumulation -Scarify to remove thatch; aeration and tining -Check/renew basal textile liner -Replace with clean stone to top layer (if necessary)	-Regular inspection after storm events -Erosion, scour and gullying -Tyre rutting; damage to upstream channel
	Low/Medium	***Low***	***Low***

4. Porous Surfacing*			
SUDS/BMP Component	**Regular Maintenance**	**Periodic Maintenance**	**Monitoring & Data**
Porous Surfacing (without Sub-structure)	-Regular suction sweeping of fines to prevent surface clogging (1/2 x yr) -Litter/debris removal (after storms) -Remove any soil/silt verge wash-off from the surface(as needed) -Maintain/mow grass verges (4 x yr)	-Clean/remove oil sheen/slicks from surface -Check gradient -Clean/replacement of bedding material and geotextile (if needed)	-Monitor/measure surface discontinuities, rutting and surface displacement, potholes and cracks -Inspection of adjacent verges and hard surface edging
	Low/Medium	***Low***	***Very Low***
Porous Surfacing (with Sub-structure)	Regular suction sweeping of fines to prevent surface clogging (1/2 x yr) -Litter/debris removal (after storms) -Remove any soil/silt verge wash-off from the surface(as needed) -Maintain/mow grass verges (4 x yr)	-Hydroclean and compressed air purging to clean out voids -Clean/remove oil sheen/slicks from surface -Introduction of front-end pollutant interceptor (if needed) -Check gradient -Replacement of binding/wearing surface and granular layers (as needed) -Clean/remove silt from any inspection chambers	Monitor/measure surface discontinuities, rutting and surface displacement, potholes and cracks -Inspection of adjacent verges and hard surface edging -Standing water -Monitoring of block ice during winter
	Medium	***Medium***	***Low***

***Based on assumption that the highway surfacing is porous asphalt and subject to high traffic volume and not constructed from any individual block type paving/surfacing materials. The designation of porous surfacing with sub-structure refers to permeable asphalt surfacing which has a deep reservoir sub-based such as provided by modular geocellular structures possessing very high void ratios.**