SUDS Treatment Train Assessment Tool

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ABSTRACT
This paper outlines a rationale and scoring system for the stormwater treatment train assessment tool (STTAT) which is a proposed regulatory tool for Sustainable Urban Drainage Systems (SUDS). STTAT provides guidance and regulatory consistency for developers about the requirements of planners and the Scottish Environment Protection Agency (SEPA). The tool balances the risks of pollution to the receiving water body with the treatment provided in a treatment train. It encourages developers to take SUDS into account early, avoiding any misunderstanding of SUDS requirements at the planning stage of a development. A pessimistic view on pollution risks has been adopted since there may be a change of land use on the development in the future. A realistic view has also been taken of maintenance issues and the 'survivability' of a SUDS component. The development of STTAT as a response to the requirements of the Water Framework Directive is explored, the individual scores being given in tabular format for receiving water and catchment risks. Treatment scores are proposed for single SUDS components as well as multiple components within treatment trains. STTAT has been tested on a range of sites, predominantly in Scotland where both development and receiving water information was known. The operational tool in use by SEPA is presented.

KEYWORDS
Environmental Risk, Guidance, Regulation, Sustainable Urban Drainage, Treatment Train

INTRODUCTION
The publication of the SUDS design manual in 2007 (CIRIA 2007) resulted in greatly improved guidance for SUDS. This was consolidated in Scotland with the release of Sewers for Scotland 2nd Edition (WRc 2007). While these provide design guidance, no rules have yet been formalised as to the level of treatment required to address diffuse pollution (Campbell et. al. 2004) at a particular application. While this gives flexibility to the designer, the lack of guidance results in a wide variety of sequential treatment of the quality of surface runoff (collectively known as the treatment train) and there is still a considerable degree of misunderstanding.

The water quality aspects of SUDS are becoming increasingly understood at an individual process level (Jefferies et. al. 2004, Lampe et. al. 2005) but knowledge of integrated processes within treatment trains is limited and there is never likely to be evidence-based guidance which points to the pollutant removal in one SUDS component followed by a second or a third due to the resources required to obtain sufficient data. In contrast to the lack of clear rules for water quality, the hydrological and hydraulic parameters are considerably better understood both scientifically and through the regulatory process (e.g. Scottish Executive 2003).

The maintenance of SUDS components is critical for long term operation, as it depends on a range of factors including location, soil, construction details, ownership and the imposed pollution load. Some types of components are easier to maintain than others. Yet a further issue is the robustness, or 'survivability' of the SUDS design and concept for the site. Systems which have a number of stages in sequence where pollutants (particularly sediment) are progressively removed, are generally more robust. Pollutants should be deposited where removal is easiest and the key treatment units are protected from damage – in other words they are more likely to 'survive' in the long term.

OUTLINE OF THE STTAT TOOL

Rationale

STTAT is a scoring system in which the number of SUDS components in the proposed treatment train and their specification is assessed using scores which match the pollution risks of the development. Scores are allocated to different designs incorporating both individual SUDS components and the same components arranged in treatment trains. This gives a scoring system which is complementary to hydrological design and gives clarity to the water quality requirements.

To address water quality issues, the SUDS system should have an appropriate treatment capture potential which is commensurate to the risks of pollution on the site. The SUDS system installed should also be capable of being maintained in an operational condition at an economic cost. Various studies (e.g. CWP 1997, Lampe et. al. 2005) have shown the robustness of some types of SUDS in contrast to the vulnerability of others. For example, the ease of maintenance of a detention basin located in an industrial estate means that it is more likely to operate in the long term than a filter drain, presuming similar pollutant loadings at both locations.

In addition to the risks of applied pollution, the nature of the receiving water poses further constraints on a development to be addressed in the treatment train. For example;

- a sensitive inland stream will require a much greater degree of protection than a stretch of tidal water where there is significant dilution.
- a nutrient-sensitive water body liable to eutrophication will demand nutrients in the runoff to be managed in addition to control of a range of other pollutants, and this will most probably only be possible in a retention pond.
- In contrast, a fast moving river close to an upland area, not being nutrient sensitive, might only require protection from hydrocarbons and other toxic compounds, although discharges should not be sediment laden.

- Discharges into a stream from a large number of existing or anticipated developments are putting water quality at risk. The need to protect this type of water body may require enhanced levels of SUDS treatment.

These principles all drive the extent of the treatment train required and are addressed by the STTAT scoring system. A similar on-line methodology to address treatment level in relation to catchment and water-body risk has been proposed by HR Wallingford (2008), although this procedure has less scope for definition of receiving water characterisation.

The Water Framework Directive and Controlled Activities Regulations (Scotland)
To meet the terms of the Water Framework Directive it is important to recognise diffuse pollution which will include elements that the SUDS treatment train can manage. Thus the transposition of the European directive into Scots Law, the Water Environment and Water Services (Scotland) Act (2003) (WEWS 2003), allowed for regulations to see SUDS constructed for new developments. This brought about regulations, the Water Environment (Controlled Activities) (Scotland) Regulations 2005, commonly known as CAR (CAR 2005) requiring SUDS to be constructed for nearly all new developments in Scotland whose surface water runoff discharged to the water environment. 2 exceptions exist – for a single dwelling (house) and for discharges made directly to coastal waters. CAR also requires treatment of surface water discharges during the construction phase of the development, often a stage that can offer a high risk of pollution to receiving waters.

For inner city developments, within a combined sewer catchment, SUDS need not be a requirement as the discharge should go to the waste water treatment works, but the likelihood is that under most circumstances attenuation of surface runoff would be required to reduce the frequency of spill from combined sewer overflows. SEPA regulates surface water discharges by one of two forms of authorisation;

- General Binding Rules 10 and 11 (GBRs) (Schedule 3 of CAR). Examples of these rules are a no pollution condition and a requirement for SUDS for new developments. No application for a GBR is required, but applications must comply with the statutory conditions of the GBRs.
- Licences where more prescriptive and site specific requirements are required.

The type of authorisation required is determined by the risk to the environment. For high risk situations such as very large developments, industrial estates, lengths of major highways (draining >1 km) or, in exceptional situations, sensitive receiving waters, authorisation via a licence is required. For all other situations authorisation of surface water discharges is via GBR 10.

STTAT allows for the desired transparency by the regulator and also flexibility in choice of SUDS for developers. Both regulator and regulated will know what “reasonable” steps should be taken to protect the environment.

The STTAT Procedure and Scoring System
Sufficient level(s) of treatment must be provided so that the STTAT Equation is satisfied before development should be permitted to proceed;

Treatment Train Scores > Σ Risk Score - ***STTAT Equation***

The receiving water risk score is selected from Table 1 and this should be added to the catchment risk score from Tables 2 or 3 to give a total score (***Σ Risk Score***) representing the risks to the water environment. The polluting potential represented by this score requires to be balanced by the protection provided by the SUDS, taking into account the quality of treatment provided in an individual unit, and the extent of the treatment train.

Receiving Water Risk Scores

The scores for the different types of receiving water are given in Table 1 and the rationale for these is given in the following paragraphs;

Table 1 Receiving Water Score

Receiving Water	Score
Sea water	0
Normal rivers	20
Significant existing / anticipated development / pollution pressures already on stream	30
Sensitive receiving environments e.g. SSSI; limited dilution watercourses; groundwater	30
Nutrient sensitive water bodies	50

Sea Water: Attenuation of surface runoff for marine discharges is not required, consequently, water quality is the only interest. Where there are no particular concerns in the sea water (e.g. no designated Bathing or Shellfish Waters), then the score allocated is zero with no SUDS required (in accordance with CAR).

Normal: The term 'Normal' river is intended to represent the majority of rivers in the UK. The 'normal' river allows reasonable dilution and there are normally no specific water quality concerns. A score of 20 is assigned.

Significant existing / anticipated development / pollution pressures: Large scale development in catchments can cause degradation of the receiving waters. This is of particular concern where dilution is limited and further uncontrolled surface runoff will add to existing stresses on the receiving waters. A score of 30 is assigned where there are significant existing or anticipated developments on the watercourse.

Sensitive: There are many reasons to classify the receiving water as sensitive. These include designated water dependent conservation sites e.g. Sites of Special Scientific Interest (SSSI), Special Protection Areas (SPA) downstream, local biodiversity action plan (LBAP) site, or alternatively where the discharge is to groundwater. A score of 30 is assigned.

Nutrient Sensitive Water Bodies: Certain sensitive water bodies will suffer from nutrient enrichment and the treatment train should potentially have phosphorus removal. This can be achieved in retention ponds having a treatment volume of 4Vt principally due to better sedimentation in the larger permanent water volume. A score of 50 is assigned.

Catchment Risk and Treatment Train Scores

The generation of pollution from an area is related to its land use. The rationale for the land use scores is given in Table 2 for residential sites and in Table 3 for non-residential. Table 4 gives the treatment train scores.

Table 2 Catchment Score: Residential

No of Houses	Score	CAR Guidance
5-25	5	Score relates directly to size of development
25-50	10	
50-100	20	
100-500	45	
500-1000	70	
> 1000	95	Large developments are always considered high risk and new or enlarged developments should be licensed by a simple licence, regardless of the receiving environment.

Table 3 Catchment Score: Non-Residential (table is not exhaustive and other combinations may be permissible)

	Land Use	Score	CAR Guidance (Indicative only)
a	Offices & Parking (<20 Cars)	10	GBR
	Offices & Parking (20-100 Cars)	25	GBR
	Offices & Parking (100-500 Cars)	25	GBR
	Offices & Parking (500-1000 Cars)	50	GBR
	Offices & Parking (>1000 Cars)	75	Simple licence
b	Local Shops	25	GBR
	Retail Park / Distribution Park	50	GBR/ Simple licence if >1000 car parking spaces
	Supermarket / Commercial	50	GBR
	Industrial Estate	75	Simple licence
c	Rural road junction	25	GBR
	Rural Motorway/ major road	50	Simple licence (if outfall drains >1 km)
	Motorway/major road Interchange	75	Simple licence (if outfall drains >1 km)

Table 4 Treatment Train Score assuming that designs follow the current best practice in CIRIA (2007). Revised scores are for use in practice

Description of Treatment Train combination	Original Score	Revised Score
Permeable paving	25	40
Lateral inflow filter drain and infiltration trench	25	25
Swale with lateral inflow	25	40
Filter strip	25	40
Detention basin (no permanent water)	30	40
Detention Pond (with permanent pool of water with volume 1 x Vt)	45	50
Retention Pond (with permanent pool of water with volume 4 x Vt)	45	50
Permeable paving & underground storage	35	40
Infiltration trenches and basin	50	65
Filter strip or swale & detention basin	55	75
Permeable paving & detention basin	55	75
Permeable paving or swale & (1 x Vt) detention pond	70	90
Swales and (4 x Vt) retention pond	100	120
Filter strips or swales & detention basin & retention pond	120	140

USING THE TOOL

The planning officer of the environmental regulator requires to have an understanding of the pressures on the receiving waters in their area to be able to apply STTAT appropriately. The tool communicates these pressures in an understandable form to the developer. In operation, the developer will provide evidence of the type of land use for the development and this information will generally not be controversial. In contrast, the scores attributed to different land uses may be the source of some debate. In particular, a pessimistic view of industrial estates is taken since these are one of the most polluting forms of land use.

Assembling SUDS Components into a Treatment Train

The treatment train scores are compromises for a range of different influences on SUDS performance. In most cases the scores of the different components can be added to give the total score. However, scores for retention ponds should not simply be added since, although retention ponds provide the best treatment, there are significant concerns regarding the disposal of accumulated sediment from a pond. Consequently, a retention pond with no treatment train upstream is assigned a reduced score (50) since sediment will be deposited under water leading to increased costs for sediment removal and disposal. With a protecting treatment train upstream, the full score of the pond (120) applies.

A SUDS treatment train is a logical combination of SUDS components. Treatment train requirements have developed out of operational experience and observations at key sites and good and basic guidance may be found in CWP (1997). The individual treatment train units are assembled so that they have a logical order, give sequential treatment and provide backup should one element become ineffective. Of particular importance, treatment trains should trap sediment from the contributing catchment without impairing performance. Some very good examples can be seen at motorway service areas (e.g. Heal et. Al. 2009). The key aspects of scoring a treatment train include:

- The basic pollutant removal performance of the SUDS component.
- Ease & cost of maintenance.
- Targeting specific pollutants.
- Survivability in the long term.

These principles are articulated in Table 5;

Table 5 Justification of Treatment Train Score (Vt is the basic component of treatment volume in SUDS systems)

Type	Score	Commentary
Permeable paving & underground storage	40	Permeable Paving has been shown to remove a range of pollutants. The paving will protect the storage provided it is the only inlet route to the storage.
Swales and 4xVt retention pond	120	Sediment will be removed in the swale, an easily inspected and maintained component, and this will enable the pond to function correctly in the long term.
Filter strips or swales + detention basin + retention pond	140	This train has three stages of treatment with the pond providing final ‘polishing’ prior to discharge.

The above examples show that a high treatment train score is as much related to its survivability as it is to the treatment potential of the individual components. The most important factor in survivability is the control of sediment which must be removed from the runoff and stored where it a) is easy and cheap to remove; and b) does not block or clog a flow route or flow control device.

SEPA Operational STTAT Tool

SEPA has incorporated the principles of this research in its planning guidance for SUDS (SEPA 2008) which is reproduced here as Table 6.

Table 6 SEPA SUDS Selection Table

No. of houses/car park spaces	Water body sensitivity		
	Low	**Med**	**High**
<25	Source control	Source control	Source control
25-49	Source control	Source control	Source control plus detention basin
50-99	Source control	Source control plus detention basin	Source control plus detention basin
100-249	Source control plus detention basin	Source control plus 1Vt pond*	Source control plus 1Vt pond*
250-1000	Source control plus 1Vt pond	Source control plus 1Vt pond*	Source control plus 1Vt pond*
>1000	Source control plus 1Vt pond	Source control plus detention basin and 1Vt pond*	Source control plus detention basin and 1Vt pond*

* where a water body is nutrient sensitive, consideration should be given to increasing the size of the pond to 4Vt or using an additional SUDS component in the treatment train installed.

TESTING STTAT ON STUDY SITES

Study Site Details

The scoring approach was tested on sample sites where SUDS had already been installed and relevant details were available. Twenty two study sites were identified with a mixture of components totalling 16 treatment trains (≥ 2 SUDS in series) and 18 standalone SUDS. Seven discharge to waters with raised ecological requirements including sites of special scientific interest (SSSI), those forming parts of LBAPs or other nature conservation areas. The receiving waters for the study sites were predominantly rivers with a water quality classification ranging from Class C to A1. River classifications have been translated into STTAT risk scores where Class C rivers are assigned a risk score of 30 (significant development already on stream / low flow river) and Class B to A1 rivers are assigned a risk score of 20 (normal river).

The SUDS at the study sites included a variety of source, site and regional controls. Land use of the sites was entirely housing with two exceptions; one site had a commercial area in addition to housing, and the second an industrial area and housing. The age of the

SUDS designs within the study group ranged from one to ten years. The standalone SUDS served sub-catchments with from 29 to 160 houses, the treatment trains served sub-catchments ranging from 46 to 500 houses.

STTAT Results – Using initial scores
The STTAT tool was applied to the study sites, with the results grouped into three categories: standalone detention basins, standalone retention ponds and treatment trains. All sites with standalone detention basins failed (risk score > treatment train score), with the exception of one site, all sites with standalone retention ponds failed but all sites with treatment trains passed. A retention pond without an upstream treatment component represents a significant operational risk due to potentially high cost of sediment removal and this is reflected in a lower treatment score.

The initial scoring used indicated an apparent inadequacy of the SUDS which had been installed. While this was not impossible, it was unexpected, since these were operational sites which have been in existence for a number of years. While some may not necessarily have been highly specified, there were no known detrimental impacts to the receiving watercourses and it would have been surprising if they all were shown by STTAT to be inadequate. Housing represents the lowest risk category within urban catchments and where there are less than 100 houses which discharge to a "normal" watercourse it is reasonable to assume that a detention basin is sufficient protection of the water environment. However the initial scoring did not concur with this and adjustments to the scores were deemed necessary. Furthermore, SEPA now require source control in addition to a basin in this scenario to simplify decision making.

Where standalone retention ponds were used, all sites failed using the initial scores but in contrast to the results for the detention basins this was expected. All sites with treatment trains achieved satisfactory STTAT scores. This result was acceptable and it reflects the approach of STTAT to ensure that surface water runoff is adequately treated prior to final discharge to the water environment.

Sensitivity Testing
The sensitivity of the scoring mechanism was tested to gain a better understanding of the scores to ensure they were appropriate for the various risks within a catchment. Incremental adjustments and combinations of adjustments were applied to the risk scores for land use, treatment train, and receiving water to identify scenarios where the majority of the standalone detention basins would achieve a satisfactory STTAT score (where the treatment score exceeds the sum of the risk scores. A total of 18 combinations were assessed.

The analysis identified three scoring adjustments where all basins achieve a satisfactory STTAT result apart from the three basins with the highest risk scores - two serving areas greater than 100 houses discharging to normal rivers and one with 50-100 houses discharging to a river with significant development on stream. The adjustment of scoring was that two combinations with decreased weighting for land use scores and increased weighting for treatment scores, and that decreases in the weighting for land use and receiving water scores and an increased weighting for treatment scores.

STTAT Result – Outcome after adjustment

Adjustment of the scoring system to achieve a suitable result for the detention basins influenced the scoring of the standalone retention ponds and treatment train groupings. The scores of some of the standalone retention ponds are now acceptable. This is appropriate as less than 100 houses are served and discharge to Class C rivers. Treatment train scores were inflated. However this had little impact as all sites had initially achieved a positive result.

To test the implications of the adjusted scores further, the three combinations identified were assessed using all possible variations of land use, and receiving water scores. This comparison identified a number of anomalies between different SUDS arrangements. Three notable changes to the scores allocated to certain treatment components were identified by the adjustment of scoring for given risk conditions:

i. One level of (dry) treatment is appropriate in some situations. In the initial scoring, two (dry) stages (or one standalone wet SUDS) were required.
ii. One standalone wet SUDS is suitable in some situations compared with the initial scoring where a minimum of two (dry) SUDS were necessary.
iii. Two (dry) stages of treatment are suitable in some situations. Initially, a two stage treatment train incorporating one wet SUDS was necessary.

Since the STTAT score incorporates the survivability of SUDS, filter/infiltration trenches are assigned a lesser score due to their propensity to failing (Schlüter & Jefferies 2005). These components, unless used with pre-treatment, have a propensity to fail (due to influx of sediment) with consequentially higher costs of refurbishment than swales and filter strips.

CONCLUSIONS

As the Water Framework Directive's requirements are being implemented, the use of legislation will be fundamental in addressing urban diffuse pollution. Guidance and advice on what steps have to be taken to satisfy the regulatory framework and provide protection to the water environment will become more necessary and STTAT has been developed to meet this requirement. STTAT provides guidance on the appropriate level of SUDS depending on development type/scale and nature of receiving water. This will provide greater consistency in meeting the regulator's requirements for SUDS.

The STTAT tool and scoring system effectively communicates the SUDS requirements at a development site. The approach has been robustly evaluated by comparing the STATT recommendations with actual SUDS installations at a range of residential sites, predominantly in Scotland. Sensitivity testing has shown that, following adjustment, it is robust in a variety of situations. The approach outlined in the paper is being used in a simplified form by the Scottish Environment Protection Agency.

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