Project: Sustainable Hydro Assessments and Groundwater Recharge Projects
Project acronym: SHARP

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APPENDIX: Long version of good practices to be adapted report

GPA 5	SuDS and Groundwater

Involved Project Partners:
International Resources and Recycling Institute (IRRI)
Saxon State Office for Environment, Agriculture and Geology (LfULG)

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1. Concise description of the adapted good practice

1.1 Introduction

Surface runoff in the urban environment is caused by precipitation falling upon impermeable surfaces such as roads and rooftops, and traditionally the general practice of urban water management was to transfer this water as quickly as possible from the point of origin to a local water course. Whilst this is an effective strategy at source it can cause fluvial flooding further downstream along with other negative impacts such as increased river channel/bank erosion, increased pollutant loads reaching water courses and resultant decrease in urban river biodiversity. In addition, the increased stress upon often aging piped sewer networks leads to leakage of these same polluted waters within the subsurface and subsequent contamination of groundwater.

Attempts to mitigate these flooding and water quality issues now focus mainly around the implementation of Sustainable Drainage Systems or SuDS (the equivalent of Best Management Practices in Europe). The rationale for these systems is the use of infiltration and retention structures that act to delay and reduce runoff volumes and associated contaminant concentrations that would cause a risk to the urban water environment. It is envisaged that they be implemented in a "management" or "treatment train" comprised of a number of complimentary systems in series that function to trap colloidal material and other pollutants, and infiltrate a proportion of the runoff water generated to ground, in order to mitigate the problems surrounding excessive urban runoff.

SuDS were effectively introduced to the UK through Scotland when SEPA started to apply Best Management Practices (BMPs) during the 1990's which had been pioneered in the United States and Europe (Primarily Germany and the Netherlands) (CIRIA Report 2009). Experience in this field amounts to only 10-15 years and so European nations employ different strategies to regulate, encourage and install the various SuDS they employ. This report aims to contrast the UK experience to European examples, especially Germany where knowledge is advanced, in order to summarise general advice and guidance emerging with regard to SuDS and groundwater protection.

1.2 Legislation

In Germany the Federal Environment Agency funded a study to set up emission requirements for storm water discharges. These requirements dictate that discharge into receiving waters is to be limited by quantity as well as by solids load. Groundwaters have to be protected according to the soil conservation act (Grottker, 2003). On the Federal State level, only a few municipalities have separate storm requirements, and discharge of polluted storm water should be permitted only after its treatment. States such as North Rhine-Westphalia and Baden-Wurttenberg demand that storm water infiltration is used as an important source control measure in new built properties and has to be preferred in comparison to conventional drainage systems. In North Rhine-Westphalia infiltration SuDS have to be considered retroactively in already existing drainage master plans (Ristenpart, 2003).

In nine German states ordinance for self surveillance of sewerage systems are already realised, with municipalities responsible for the operation and self –supervision of their sewerage system and are obliged to report on this to the water authorities. The main focus of this self surveillance is to monitor the structural integrity of the sewer system and the accurate operation of overflow structures.

Constructed wetlands are presently the strongly favoured type of treatment structure in North Rhine-Westphalia and as such the local authority has developed design guidelines for their construction and operation (Ristenpart, 2003). Along with these wetlands, swales, infiltration trenches and detention basins are very popular; whereas in the UK, the most important types of SuDS are detention basins, ponds and permeable pavements (CIRIA report, 2009)

Funding programmes were set up for some technical measures in Germany. For instance storm water management measures (infiltration SuDS) are funded by some German states, municipalities or water associations. Funding ranges from 5 – 20 Euros per square meter of runoff producing area that is disconnected from the sewer system. North Rhine-Westphalia also fund the construction of wetlands to a significant degree. Emschergenossenschaft, like many other water associations charge a fee for connection to their trunk sewer network, which can be avoided by infiltrating or discharging the runoff water directly into the local river, provided the quality is satisfactory (Jefferies et al., 2008). In this way, incentives are provided for disconnecting runoff producing areas from the piped sewer network.

SuDS are a very popular topic in urban drainage in Germany. Beginning with the first exemplary projects in the late 1980's, which already included investigations of impacts on groundwater quality, SuDS are now widely used in drainage planning. This approach is now being pursued in other European countries such as France, Switzerland and the UK.

In the UK, the use of SuDS as an alternative to these traditional water management techniques has been promoted by Policy Planning Statement25 (HMSO, 2010b) since its publication in 2001. However it wasn't until the exceptional rainfall events of 2007, during which 48000 homes were flooded that changes to legislation were considered. The Pitt review into the causes and consequences of the flood events identified that surface water was the primary cause of the flooding. As a result of this review, DEFRA launched the Government's 'Future Water' strategy for England and Wales in 2008 (HMSO, 2008). This called for sustainable management of surface water, which included facilitating water re-use, storage and infiltration into the ground to decrease the reliance upon traditional drainage systems. To facilitate this change, the strategy advocated a shift in policy to withdraw the automatic right for developers to connect to the drainage system and also to provide clarification on the ownership and maintenance responsibilities for sustainable drainage systems (Dearden, 2010).

The 'Future Water' and the preceding 'Making Space for Water' (DEFRA, 2005) strategies led on to the Floods and Water Management Act 2010 (HMSO, 2010a), which has partly been driven by the necessity for adaption within the changing climate. The Act included provision for the implementation of Sustainable Drainage Systems (SuDS) and National Standards for their design and performance. In 2011 DEFRA published these National Standards, which provide guidance on the suitability of sustainable drainage techniques for particular site conditions and/or development types and provide further framework by which SuDS Approval Bodies (SAB) should operate. The National Standards contain a drainage hierarchy that states the types of drainage techniques that must be considered in order of priority, namely that the installation of infiltration SuDS should be prioritised, followed by those that discharge to a water course and finally, by those that discharge to the sewer network. This effectively requires that every new development considers infiltration to the ground before other SuDS techniques (Dearden, 2010). It also states that drainage plans will need approval from the local authority and that the local authority will then adopt and maintain the approved SuDS.

In Scotland the sustainable drainage legislation was adopted ahead of that in England and Wales. Scottish legislation was prompted by the EU Water Framework Directive 2000 that requires water quality in the environment be maintained and improved. To meet this target, the Scottish Government passed the Water Environment (Controlled Activities) (Scotland) Act 2005 (Scottish Statutory Instruments, 2005), which contains a specific requirement for sustainable drainage. It requires that new developments should pass their drainage water through sustainable drainage systems, where surface water is released to the water environment (with exception for single dwellings and discharges to coastal waters).

Legislation is similar between Germany and the UK, in that the switch in emphasis from pipe based sewers to infiltration systems is now enshrined in law, but there are some important differences. UK legislation only applies to new developments (or redevelopments of brown field sites) whereas German law, at least in a few federal states, demands the retroactive consideration of SuDS to already existing drainage solutions.

2. Description of adaption process

2.1 Examples of success

As mentioned above, SuDS ponds are an important type of sustainable drainage solution in the UK, particularly in Scotland where they have been constructed since the mid 1980's, due to the widespread occurrence of low permeability soils that limit the rate of infiltration and the wet climate. These SuDS are regional scale, end of pipe solutions that are difficult to retrofit due to their large land take. The design lifetime of a SuDS pond is typically 25-30 years.

SuDS ponds are primarily designed to attenuate runoff, and an example discussed by McLean (1998) demonstrates the success of these structures in fulfilling this role within an urban drainage context.

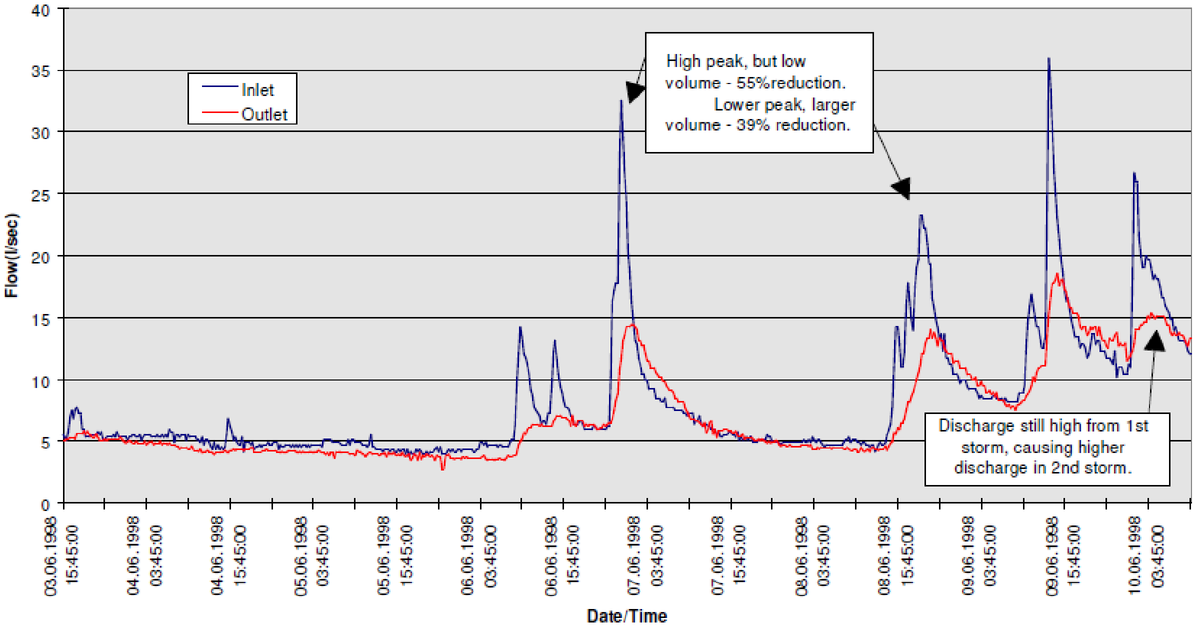

Fig. 1: Flow attenuation during a storm event at Claylands Pond, Edinburgh (after McLean, 1998).

However, evidence also exists to show ponds can improve runoff water quality both in terms of heavy metal concentrations and microbiological content, as described in measurements taken from sites in and around Dunfermline (Heal, 2004.).

Heal et al., (2004) point to the lack of evidence of groundwater pollution being caused by SuDS. They cite work conducted by Yousef and Yu (1992) into heavy metal mobility in bottom sediments of six detentions ponds in Florida which received high runoff. They discovered that most metals were retained within the top 15-20 cm of the sediment and recommended that removal of the bottom sediments every 25 years would be sufficient maintenance to minimise the risk of contamination of the underlying groundwater.

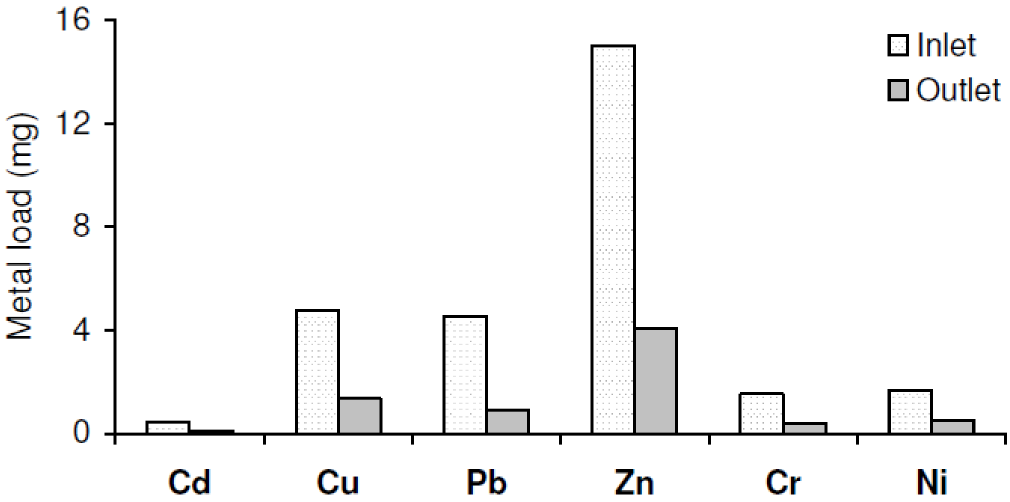

Fig. 2: Heavy metal loads at the inlet and outlet of Stenton Pond, near Dunfermline (Heal, 2004).

Ellis ,(2006) provided a summary of studies into European infiltration performance and highlighted the work of Mikkelsen et al. (1997) in Denmark who showed an inverse relationship between contaminant mass recharging groundwater and soil depth, and concluded there was little risk of contamination to groundwater from pollutants at the site. A study by Deschesne et al. (2004) in France reported high topsoil (upper 10cm) retention of heavy metals and hydrocarbons with rapid concentration decrease with depth to background levels by 50 cm depth. Examples Ellis cited from the UK include work by Wild et al. (2002) who assessed the performance of highway filter drains in Edinburgh and reported ranges in mean runoff values of 42%, and although pollutant removal rates were highly variable, solids were reduced by 75%; and a study by Newman et al. (2002) into the removal of grease and oil by a porous paving system and found effective hydrocarbon degradation (up to 90%) over a 4 year operational period. However, they noted this required appropriate design and levels of operation and maintenance for successful and sustained performance.

A German example by Dierkes et al. (1999) examined the distribution and fate of highway pollutants on adjacent verges and embankments. They found the highest concentrations were located within the uppermost 5cm of soil and within 2m of the highway. Mineral hydrocarbons were noted to have degraded but Poly-aromatic hydrocarbons accumulated within the upper 10cm of soil. Their recommendations were for the removal of the upper soil layer as hazardous waste.

2.2 Examples of failure

The above evidence points to the successful implementation and operation of SuDS throughout the UK, and indeed wider Europe. However, a body of evidence exists for examples of failed SuDS schemes, and infiltration SuDS that have not functioned as intended by design. In a study by Schluter and Jefferies (2005) where they assessed the performance of SuDS systems at 43 sites in Eastern Scotland, they found that almost 50% of the systems were unsatisfactory, and over half of these were rated as having failed. Fewer than 20% of the systems assessed demonstrated good performance in terms of flow attenuation, pollutant retention, and minor additional required maintenance.

Reasons for this poor performance were found to be partial or complete blockages caused by poor or absent maintenance and construction runoff. Also highlighted was the presence of high level bypass or overflow mechanisms. Fig 3 shows problems encountered as a result of inappropriate installation or maintenance techniques including: a) Filter material disturbed onto carriageway. b) Blockage of the inlets leading to local flooding and c) Damage to lateral kerbside inlets.

Fig. 3: Issues with SuDS systems in East Scotland (Schluter and Jefferies, 2005).

Work conducted in Ireland indicated that already existing 'French' drains used to convey water from highways to surface water bodies were becoming clogged with debris, diverting a significant volume of runoff water away from the intended concrete drain and causing it to become recharge to groundwater. In Scotland in 1999, 22% of the total SuDS constructed were of the 'French' filter drain system or similar. Ellis (2006) goes on to point out that infiltration systems give effective volume reduction but rather more variable performance in terms of retaining and degrading urban pollutants, a statement supported by the legacy of unsuccessful infiltration SuDS installations as recorded in the Scottish SuDS database (D'Arcy and Wild, 2002).

Swan (2010) describes a water company in Norfolk, UK opting for a conventional in-sewer option to rectify flooding problems within the catchment, at the same time that planning permission was given by the local authority for redevelopment of a site with a large impermeable area for a retail development. This redevelopment will include a runoff solution involving sub-surface storage that will be sited immediately adjacent to the water authority's in-sewer solution; a potential inefficient use of resources and a missed opportunity to implement a single infiltration-based system to serve both purposes within the catchment. The author points to the importance of all local stakeholders working together to address urban drainage issues and advocates the large scale master planning as a means of providing better opportunities for the implementation of sustainable drainage techniques, allowing for the consideration of SuDS at the early design phase as building and street layout are still being formulated.

2.3 Recommendations

These examples of failures of SuDS systems provide lessons that can be learned and transposed into recommendations for ways installation, operation and maintenance of these structures can be improved to ensure continued optimal working efficiency for the lifetime of the SuDS.

One of the key lessons emerging from the experiences of practitioners in the UK, Germany and other European countries, is that maintenance of SuDS is a key aspect of their continued efficiency that is currently being overlooked. Legislation in the UK has recently been enacted that will aid in removing uncertainty as to who's responsibility it is to manage and maintain installed SuDS structures, and in European countries like the

Netherlands, guidance documents giving practical advice on maintenance regimes have been brought in over the past 5 years. This should ensure that current and future SuDS systems continue to function optimally and carry out their role in mitigating flooding and reducing contaminant flux into the water environment.

A number of authors have called for continued research into key areas of SuDS systems, in particular, the long term function of these structures and the maintenance activities and frequencies required to maintain optimum working efficiency. Concerns in terms of water quality performance include the potential for basal accumulation of contaminants in infiltration SUDS to surpass the sorption properties of the subsurface, leading to risk of contamination of groundwater. Issues with flood attenuation have been raised regarding catchments in which too many SuDS systems designed to attenuate flow have been installed, which could effectively merely delay the hydrograph peak. Continued monitoring of current SuDS sites over the decade time scale will provide us with answers to these questions, and is ongoing across the EU.

Finally a key message from the literature in this area is the call for a more holistic approach to SuDS design and operation. The example given above of the overlap and inefficient application of resources in Norfolk, UK point to the current lack of communication between the various concerned parties involved in drainage issues (civic planners, water and drainage utilities, local authorities). There is an increasing appreciation of the importance of early involvement of council planning representatives for the successful implementation of these schemes, particularly when considering retrofit SuDS, and steps are now being taken in the UK to recognise and promote this type of integrated approach (Swan, 2010; Todorovic et al., 2008). Jefferies et al. (2008) point to work carried out under the Urban Water project funded by Interreg IIIB where the locations that have enjoyed the most success in reducing the quantity of contamination reaching watercourses demonstrated integrated policies where excess water was just one of a number of economic, social and environmental drivers for a project. This integrated response lead to the pooling of resources and reduction of total costs ensuring effective delivery of solutions that satisfy the projects aims. It is evident that this holistic approach is being pioneered in areas of Europe and that it achieves results, and increasingly it is being recognised that an integrated approach to the management of sewer systems, treatment plants, surface and ground waters, agriculture and the morphology of waters are required to facilitate the successful implementation of SuDS in the future (Ristenpart, 2003). This will be a strategically directed political process that will need to be maintained over the medium term.

Some differences exist between Germany and UK in terms of the types of SuDS used and the legislation enacted in order to protect groundwater, but both are now striving for development along very similar lines. Namely, the promotion of the importance of SuDS maintenance to ensure maximum operational efficiency; the advocacy of more long term study into the performance of SuDS structures in order to fully understand the performance and maintenance requirements of these systems; and perhaps most importantly, the need to move toward a more holistic, integrated approach to the planning, development, and implementation of urban drainage solutions in order to mitigate the negative impacts urban runoff can have on the water environment.

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