Sustainable drainage systems

Introduction

The role of sustainable drainage systems (SUDS) in adapting and mitigating the effects of flooding has been highlighted as one potential benefit of urban green space. Trees intercept and capture rain, reducing and slowing down the rate and volumes of runoff. SUDS can comprise many green features including ponds, wetlands, drainage ditches, green roofs and swales. These are designed in such a way that they reduce runoff and the volumes of water that traditional drainage systems might normally receive. The major benefits of incorporating SUDS into new and existing developments are:

- The risk of overloading the drainage system with consequent flooding is greatly reduced
- Water quality risks are reduced.

This in turn creates huge economic savings both to the government, and to business and the public. It also enhances the appearance and ecological aspects of urban areas.

Benefits

Benefits of SUDS include:

- Reduced flood risk
- Improved water quality through reduced runoff of polluted water
- Increased water resources through groundwater and aquifer recharge.

Economic evidence

- The economic cost to the national economy due to urban flooding is estimated to be £270 million a year in England and Wales, where 80 000 homes are at risk (Parliamentary Office of Science and Technology, 2007). A foresight report suggests that if no action is taken the cost of urban flooding could rise to between £1 – 10 billion a year by the 2080s (Evans *et al*., 2004).

- As a result of urban diffuse pollution such as runoff from contaminated land, poor drainage and accidental spills, 15% of rivers and 22% of groundwaters are at risk of not achieving the water framework directive objectives. Estimates of the cost of environmental damage due to pollutants is between £150 and £250 million per year based on 2004/05 values (Environment Agency, 2007)

- Duffy *et al*. (2008) produced a cost analysis which supports SUDS and indicates that well-designed and maintained SUDS are more cost effective to construct, and cost less to maintain, than traditional drainage solutions which are unable to meet the environmental requirements of current legislation.

Evidence linked to sustainable urban drainage systems

- Green roofs increase interception, storm water storage, evaporation and transpiration, and work well for small storm events (Carter and Butler, 2008).

- A literature review on green roofs concluded that rainfall retention capability on a yearly basis may range from 75% for intensive green roofs to 45% for extensive green roofs. The magnitude of the retention depends on substrate depths, climatic conditions and amount of precipitation (Mentens *et al*., 2006).

- A wide variety of insects were found on the Ford Motor Company's green roof which is dominated by Sedum (Coffman and Davis, 2005).

- SUDS integrated into the design of a new urban extension at Upton, Northampton, UK demonstrated that aquatic fauna had colonised the new site and that over a two-year period the SUDS had operated as backwater habitats for aquatic and wetland species dispersed from the River Nene Valley (Jackson and Boutle, 2008).

- Using Stockholm as an example: lawns and parks, urban forest, cultivated land and wetland all contribute to drainage but they also contribute to noise reduction, air filtering, microclimate regulation and recreational and cultural values. Wetland also seems to be a valuable ecosystem type since it contributes to all services (Bolund and Hunhammar, 1999).

- One benefit of green roofs over traditional green space is that they make use of previously unused space and do not limit the demands of the people for open space on the ground (Mentens *et al*., 2006).

- Green roofs as well as many green components of SUDS help to lower urban air temperatures and combat the heat island effect. Energy savings can be made with green roofs when incorporated into a life cycle cost as well as improving air quality in densely populated areas (Carter and Keeler, 2008).

Practical considerations

Green space provision may need to be considered alongside increased storage (Gill *et al*., 2007) thus using sustainable drainage techniques.

Not all sites have the potential for open green spaces and trees, especially in highly urbanised areas where soil conditions restrict the amount of urban canopy cover (Day and Dickinson, 2008).

Drainage is a continual problem in highly urbanised areas and with space at a premium green roofs can be implemented as an alternative measure to reduce rainwater runoff (Mentens *et al*., 2006)

Flat green roofs are considered the most practical for implementation, then areas targeted for retrofit installations should be zoned commercial, industrial, or institutional centres which are known to contain large flat-roofed buildings (Carter and Jackson, 2007).

A study in Sacramento's urban forest concluded that floods usually occur during and after major storm events well after canopy storage has been exceeded and although trees reduce runoff they are not effective at flood control (Xiao *et al*., 1998).

Soil type is important as sandy soils have lower runoff coefficients than slower infiltrating soils such as clays (Gill *et al*., 2007).

Links to climate change

The effects of climate change include rising sea levels, heavy rains, tropical cyclones in the North Atlantic and more precipitation during autumn, winter and spring. Temperatures will increase in winter and summer with more extreme/hazardous summer heat waves. Winters will become wetter with more days of rain and greater volume of precipitation. This can lead to an increased flood risk by up to 200%. Summers will become drier with less rain on fewer days. In addition to climate change, Britain is still feeling the effects of the last ice age. The north of the island continues to rise following the retreat of the ice sheet, while the south is still sinking. Climate change effects will combine with this isostatic adjustment to produce regional variation in the amount of sea level rise (Bartens, 2009). All these climate changes make future stormwater management very important for all parts of the UK.

Tools

CITYgreen toolkit
This toolkit calculates the volume of runoff coming from the land cover, based on a 2-year, 24 hour rain event. CITYgreen also reports the runoff volume and economic value in US$ associated with removing any excess storm water that results from changes in land cover, such as constructing a retention or detention pond. The effects of climate change on urban drainage have been modelled by the University of Manchester, which uses a classification of land cover classes, and models storm water runoff (Gill *et al*., 2007).

i–Tree Hydro
Developed by USDA Forest Service, this package is in the final stages of development and is due to be released in 2010. It simulates the effects of changes in tree and impervious cover characteristics within a watershed on stream flow and water quality. Model results can be used to improve urban forest management and urban planning and design to help improve water quality and reduce the risk of flooding.

HYDRUS 1D, 2D and 3D computer programmes
This is a Microsoft Windows based modelling environment for the analysis of water flow and solute transport in variably saturated porous media. HYDRUS can accurately predict runoff especially for small rain events.

Case studies

Ekostaden Augustenborg, Malmö, Sweden.
http://www.cabe.org.uk/case-studies/ekostaden-augustenborg

Bristol Business Park.
http://www.cabe.org.uk/public-space/sustainable-urban-drainage

Green Streets, Portland, USA.
http://www.cabe.org.uk/case-studies/green-streets

CIRIA – SUDS case studies

Lamb Drove - SUDS residential scheme
Hopwood Motorway Service Area
Matchborough First School
Bognor Regis Sports Centre
Dunfermline Eastern Expansion
Wessex Water Operations Centre, Claverton Down
Bristol Business Park

Bourne Stream Partnership. Poole, Dorset. http://www.bournestreampartnership.org.uk/

Defra - Integrated Urban Drainage Pilots
The link can access all 15 pilot studies across England.
http://www.defra.gov.uk/environment/flooding/manage/surfacewater/urbanrisk.htm

Knowledge gaps

Research is needed on: the interception of precipitation by trees and soil infiltration rates aiding storm water management; economic benefits of implementing SUDS; models integrating SUDS components for more accurate runoff data. Long-term monitoring on the performance and benefits of SUDS will help local and central government form clear policy and guidance.

Appropriate training should be given at a local level so SUDS can be sited correctly, used more frequently and maintained properly.

Citations of national policies/priorities

European Water Framework Directive (2000)
http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0060:20090113:EN:PDF

Environment Agency Policy - Sustainable Drainage Systems (SUDS)
http://www.environment-agency.gov.uk/static/documents/Business/suds_policy.pdf

Draft Flood and Water Management Bill (2009)
http://www.official-documents.gov.uk/document/cm75/7582/7582.pdf

Flood Risk Management (Scotland) Act 2009
http://www.opsi.gov.uk/legislation/scotland/acts2009/pdf/asp_20090006_en.pdf

The Water Environment (Controlled Activities) (Scotland) Regulations 2005
http://www.opsi.gov.uk/legislation/scotland/ssi2005/20050348.htm

Planning Policy Statement 25: Development and Flood Risk (2006) (Communities and Local Government)
http://www.communities.gov.uk/documents/planningandbuilding/pdf/planningpolicystatement25.pdf

References

Bartens, J. and The Mersey Forest Team (2009). *Green infrastructure and hydrology.* Accessed 26th January 2020.

Bolund, P. and Hunhammar, S. (1999). Ecosystem Services in Urban Areas. *Ecological Economics* **29**, 293–301.

Carter, T. and Butler, C.M. (2008). Ecological impacts of replacing traditional roofs with green roofs in two urban areas. *Cities and the Environment* **1** (2), article 9.

Carter, T. and Jackson, C. (2007). Vegetated roofs for stormwater management at multiple spatial scales. *Landscape and Urban Planning* **80**, 84–94.

Carter, T. and Keeler, A. (2008). Life-cycle cost-benefit analysis of extensive vegetated roof systems. *Journal of Environmental Management* **87** (3), 350–363.

Day, S.D, and Dickinson, S.B., eds (2008). *Managing stormwater for urban sustainability using trees and structural soils*. Virginia Polytechnic Institute.

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.

Environment Agency (2007). Response to Royal Commission on Environmental Pollution consultation ‘Urban Environment’. (Accessed: 15th February 2010)

Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Saul, A., Sayers, P., Thorne, C. and Watkinson, A. (2004a). *Foresight. Future flooding. Scientific summary: Volume I: Future risks and their drivers*. Office of Science and Technology, London.

Evans, E., Ashley, R., Hall, J., Penning-Rowsell, E., Saul, A., Sayers, P., Thorne, C. and Watkinson, A. (2004b). *Foresight. Future flooding. Scientific summary: Volume II: Managing future risks*. Office of Science and Technology, London.

Gill, S.E., Handley, J.F., Ennos, A.R. and Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built Environment* **33**, 115–133.

Jackson, J. I. and Boutle, R. (2008). Ecological functions within a sustainable urban drainage system. *11th International conference on urban drainage*. Edinburgh.

Mentens, J., Raes, D. and Hermy, M. (2006). Green roofs as a tool for solving the rainwater runoff problems in the urbanized 21st century? *Landscape and Urban Planning* **77**, 217–226.

Parliamentary Office of Science and Technology (2007). *Urban flooding*. Postnote Number 289. POST, London.

Xiao, Q., McPherson, G., Simpson, J. and Ustin, S. (1998). Rainfall interception by Sacramento’s urban forest. *Journal of Arboriculture* **24** (4), 235–244.