Institution: University of Abertay Dundee

Unit of Assessment: 7

Title of case study: Sustainable Urban Drainage Systems (SUDS)

1. Summary of the impact (indicative maximum 100 words)

Research and knowledge exchange led by Prof. Jefferies in sustainable urban drainage systems (SUDS) has driven the design and integration of SUDS into urban environments, into urban planning and everyday practice in the UK, Europe and worldwide. This research has contributed to the development of policies and established guidelines that have informed the set-up of operational and monitoring systems and the reduction of a training manual which is impacting widely on the sector (downloaded >40.000 times). Evidence gathered through this research has supported drainage policy nationally and now underpins important parts of urban infrastructure, improving environments and their resilience to flooding.

2. Underpinning research (indicative maximum 500 words)

Sustainable Urban Drainage systems (SUDS) involve a range of structural components (ponds, basins, swales, infiltration systems) and non-structural responses (cleaning programmes, changed regulations) designed to ameliorate the otherwise degrading effects of older, conventional drainage systems. Underpinning research assisted in determining the principles by which SUDS could be successfully implemented in the UK by evaluating hydrological, environmental chemistry, cost and socio-economic parameters of a number of prototype SUDS (an unproven technology) in a step-by-step programme (McKissock et al., 1999). This research was undertaken at Abertay where the team led by Prof. Jefferies coordinated groups at a number of other UK universities. More recently this researcher also extended to the Mediterranean region (Casal-Campos et al., 2012).

Initial research focused on information gained from on-site performance monitoring of a range of SUDS types - filter drains and infiltration trench systems, permeable paving systems, swales, basins and ponds (McKissock et al., 1999). Performance results were evaluated, using bespoke scoring systems, giving indications of the varied behaviour of systems in Scotland which was the only region of the UK where SUDS were being built at the time. Hydraulic monitoring enabled comparisons of performance in attenuating flow rates. The key hydraulic parameters examined included percentage runoff, initial runoff loss, peak flow reduction and lag time. In the case of in-ground systems, it was found that existing hydraulic models were not adequate and an improved model was developed based on the finite-volume-method and Darcy's law (Schlüter et al., 2002). This model, which uses the acronym FVD was validated using site data and was incorporated into the industry-standard software, Infoworks Version 6.5.

It was found that the systems studied also performed well in removing certain pollutants from urban runoff and in attenuating peak concentrations of others (Napier et al., 2009). Pond water quality data were interpreted by means of a water quality index which was modified from an existing index for Scottish watercourses and is parameter weighted. Later work showed that pollutants from motor vehicles presented serious risks (Napier et al., 2008). The mass of lead, copper, zinc and polycyclic aromatic hydrocarbons (PAHs) being released by automobiles in the UK was estimated and showed that as other pollution sources are reducing, automobiles have become a major source of environmental pollution with copper, zinc and PAHs all trending upwards. A lab and field study used twelve lysimeters, a laboratory based degradation study and field studies on motorway SUDS installations to study the risks to groundwater from passing highway drainage on to soil based SUDS. The vast majority of heavy metals, PAHs and petroleum hydrocarbons (TPH) were

found to be retained in the top 10 cm of soil, thereby impacting on soil function with time and with potential implications for long term maintenance (Napier et al., 2009).

Parallel but equally significant strands of the overall research programme examined cost and social/perception issues. Costs were addressed by examining and reviewing specific sites in the UK and a much larger set from the USA (Duffy et al., 2008). The perception of open-access stormwater systems within residential areas, and in particular ponds, and river management schemes was examined through survey techniques. Amenity, recreational value and aesthetics of new schemes were found to be of major importance for public acceptability, while function, efficiency, and maintenance are primarily important in areas facing flooding problems.

3. References to the research (indicative maximum of six references)

- McKissock, G., Jefferies, C. and D'Arcy, B. J. (1999), An Assessment of Drainage Best Management Practices in Scotland. Water and Environment Journal, 13: 47–51. DOI: 10.1111/j.1747-6593.1999.tb01004.x
- Casal-Campos A., Jefferies C. and Perales Momparler S. (2012) Selecting SUDS in the Valencia Region of Spain. Water Practice & Technology 7 No 1. DOI:10.2166/wpt.2012.001
- Schlüter W. & Jefferies C. (2002) Modelling the outflow from a porous pavement Urban Water 4, Issue: 3, Pp: 245-253. DOI: 10.1016/S1462-0758(01)00065-6
- Napier F., Jefferies C., Heal K. V., Fogg P, D'Arcy B. J. and Clarke R. (2009) Evidence of traffic-related pollutant control in soil-based Sustainable Urban Drainage Systems (SUDS). Water Science & Technology. 60.1 2009. DOI: 10.2166/wst.2009.326
- Napier, F., D'Arcy, B. and Jefferies, C. (2008). A review of vehicle related metals and polycyclic aromatic hydrocarbons in the UK environment. Desalination. 226: 143-150. doi:10.1016/j.desal.2007.02.104
- Duffy A., Jefferies C., Waddell G., Shanks G., Blackwood D.J. and Watkins A. (2008) A Cost Comparison of Traditional Drainage and SUDS in Scotland. Water Science and Technology. 9, volume 57 2008. DOI: 10.2166/wst.2008.262.

The research is underpinned by £1,565,095 worth of projects from a range of sources, namely research councils and FP6 (£208,610), industry (£941,567), and KTP's and training (£414,918). A detailed list of projects can be made available.

4. Details of the impact (indicative maximum 750 words)

The main impact of this research has been achieved through a series of recommendations applicable to design engineers, developers, and authorities, by contributing significantly to achieving optimum long-term performance of SUDS in terms of outflow quality, flow attenuation, maintenance and perception of their acceptability. Recommendations from this research programme underpinned a range of guidance manuals targeted at different professions. This research will continue to improve urban environments in terms of greater resilience to flooding and improved environmental quality, as SUDS become more widespread in the UK and internationally.

A policy change driven by the Water Framework Directive in favour of more sustainable drainage was implemented early in Scotland. With the encouragement of the Scottish Government, Scottish Environment Protection Agency (SEPA) and Scottish Water (SW), a Scottish Centre of SUDS excellence was established. This group was led by Professor Chris Jefferies of Abertay, involved staff from six Scottish Universities and had the purpose of informing users of the effects of decisions taken in urban drainage. Strategically, urban development was being constrained because appropriately sustainable solutions could not be found to meet societal and regulatory

issues concerning environmental quality and flooding. The initial objective of the research funded by stakeholders and undertaken by the SUDS Scottish Centre of Excellence was to determine the principles by which SUDS could be implemented most successfully in Scotland and this was later extended to the remainder of the UK, to other European countries and even more broadly from 2013 onward. Since 2005, National (Scotland) policy has required all new developments to adopt and/or change their drainage approach and methodologies to include the use of SUDS. However, prior to this, evidence of benefit and practical implementation was not obvious and compelling to the number of different stakeholder organisations involved in the requisite adoption of SUDS. Therefore a series of prototype systems had to be constructed, their performance monitored and results assessed. Once this stage was underway, guidance was prepared, professionals trained and a wide public debate commenced. There were three phases to Abertay's impact;

- 1998 to 2005 - a series of PhD and Masters field research programmes, predominantly at Abertay, but also at partner universities benchmarking performance of SUDS that was require for the implementation and policy change
- 2005 to 2008 - the work was consolidated into guidance driven by policy.
- 2008 - 2013 The group engaged with international programmes to disseminate the outcomes nationally (UK) and internationally.

Specific impacts on public policies and services are as follows (numbers refer to sources of evidence listed in section 5);

i) Public policy enabled through the monitoring programme. New methods and monitoring techniques were developed by the research at Abertay to support the policy changes [1].

ii) SUDS are required by the Water Environment and Water Services Act (2006) but the method of implementation was not clear. Our research informed the approach of SEPA to regulate SUDS through the Controlled Activities Regulations and of SW in the development of a corporate approach [1, 2].

iii) Delivery of a public service (by Scottish Water) has changed through the development of a roll-out process and by means of costing the public element of SUDS which are now part of 'normal business' in Scottish Water. The research was delivered into Scottish Water through KTP projects KTP7116 and KTP7784. Of specific societal importance, the 'reasonable cost' of drainage has been defined. [2, 6].

The impact on international development policies is;

i) The impact continues through Abertay's involvement in the EU project E2STORMED which commenced in early 2013 focusing on stormwater and energy management using SUDS in six Mediterranean countries.

ii) Professor Jefferies presented a paper based on our research to the 24th Council of UN-Habitat early in 2013, which passed a resolution on strengthening basic urban services [7]. Work with UN-Habitat continues with a SUDS workshop in Kigali, Rwanda in May 2013 and the commissioning of a drainage strategy for UN-Habitat [3].

The impact on practitioners and professional services are;

i) The SUDS design manual (CIRIA 2007) which was significantly informed by our research is used by all practitioners in the field both in UK and internationally (more than 40,000 downloads since publication in 2007). [4, 5]

ii) SUDS for Roads – This design manual is targeted at road planners and designers. [8]

iii) A community interested in bridging the gap between research and practice (SUDSnet) was created as a vehicle to disseminate the research of the group. This practitioner/ stakeholder network is still very healthy 6 years after the EPSRC grant (GR/S76816/01) finished.

5. Sources to corroborate the impact (indicative maximum of 10 references)

Sources who can be contacted

[1] Former SUDS adviser for SEPA – Monitoring programme and SUDS for Roads

[2] SUDS coordinator, Scottish Water – Implementation of SUDS by Scottish Water

[3] Chief Technical Adviser, Water for African Cities Phase II UNHABITAT (Water, Sanitation and Infrastructure Branch), Nairobi Kenya

[4] Research Manager Construction Industry Research and Information Association (CIRIA).

Supporting documents

[5] Construction Industry Research and Information Association 2007. The SUDS Manual. CIRIA Report C697 ISBN 0-86017-697-5. Construction Industry Research and Information Association, Classic House, 174-180 Old Street, London EC1V 9BP, UK. 2007.

[6] Sewers for Scotland 2nd Edition (2007) Water Research Centre. ISBN: 9781898920601.

[7] HSP/GC/24/L.3/Rev.1 Draft resolution on strengthening UN-Habitat's work on urban basic services. Passed on 17th April 2013. At http://www.unhabitat.org/list.asp?typeid=18&catid=744

[8] SUDS for Roads. At http://scots.sharepoint.apptix.net/roads/General%20Publications/SuDS%20for%20Roads/20100805%20SUDS%20for%20Roads%20-%20FINAL%20Version.pdf