

## Scottish SUDS retrofits to address pollution from industrial estates

B. D'Arcy<sup>1</sup>, J. Gillard<sup>2</sup>, J Clayton<sup>2</sup>, E Hamilton<sup>2</sup> N McLean<sup>3</sup>

<sup>1</sup>Environmental consultant, Kinnesswood, Kinross KY13 9JR, UK

<sup>2</sup>SEPA, Heriot Watt Research Park, Avenue North, Edinburgh EH14 4AP, Scotland, UK

<sup>3</sup>Creative Drainage, Ferryton by Clackmannan, FK10 4BW, Scotland, UK

**Keywords:** industrial estates; SUDS retrofit; housekeeping, proprietary systems; treatment train; ecological monitoring.

### Abstract

Industrial estates have been recognised in a variety of published studies, as well as investigations in the UK, as a significant source of water pollution. Ecological monitoring has been shown to be more cost effective than trying to measure chemical contaminants that can vary hour by hour and day by day. On that basis a number of impacted watercourses have been identified as priorities for pollution abatement actions in Scotland. The Scottish Environment Protection Agency, SEPA, introduced policies to require urban BMPs or sustainable urban drainage systems as they have become known in Scotland (SUDS) to manage diffuse pollution loads from new developments, and subsequent legislation in Scotland gave the national water utility, Scottish Water, the remit for public SUDS features that comply with their specifications. The combined efforts of both organisations have established a retrofit programme to address existing pollution from industrial estates. A variety of practical problems have been encountered in trying to establish an effective SUDS retrofit programme.

### **Introduction: Urban diffuse pollution impacts in Scotland**

Scotland is a small country and drained by relatively small watercourses, but most of the population live in and around the central belt where those modest streams are often polluted. Issues of social justice and public well-being associated with loss of amenity, as well as economic considerations associated with Scotland's reputation as a tourist venue, have been drivers for clean-up efforts for many years. In 1999, the Scottish Environment Protection Agency, SEPA, identified 500km of watercourses that were adversely impacted by urban drainage – urban diffuse pollution. Within that total, some 150km, typically showing the most severe impacts, were associated with contaminated runoff from industrial estates (SEPA 1999). Industrial estates in the UK became a feature of almost every town and city in the UK from the 1950s onwards, typically being drained on a separate sewer system on the more recent developments, from 1960s. The surface water sewers, draining directly to watercourses, quickly became pathways for pollution (D'Arcy and Bayes 1995). Decades of pollution investigations by SEPA, and by river purification boards previously, had sought improvements by 'housekeeping' measures. These included: actions related to diversion of steam cleaning wash waters and other minor effluents to foul sewer, bunding oil and chemical storage areas, advocating contingency planning and other similar clean up and prevention actions. But ecological monitoring showed that adverse impacts often continued, despite reductions in the frequency of major spills or the presence of visible oil contamination. The evidently unavoidable levels of surface drainage contamination represented severe diffuse source impacts, with the probability that every new estate would be a new pollution problem. Accordingly in 1996, SEPA adopted on its inception, a policy requiring the use of surface water treatment best management practices, subsequently known in UK and elsewhere as SUDS, (CIRIA 2000, and CIRIA 2007). The aim was to prevent the problem increasing in extent.

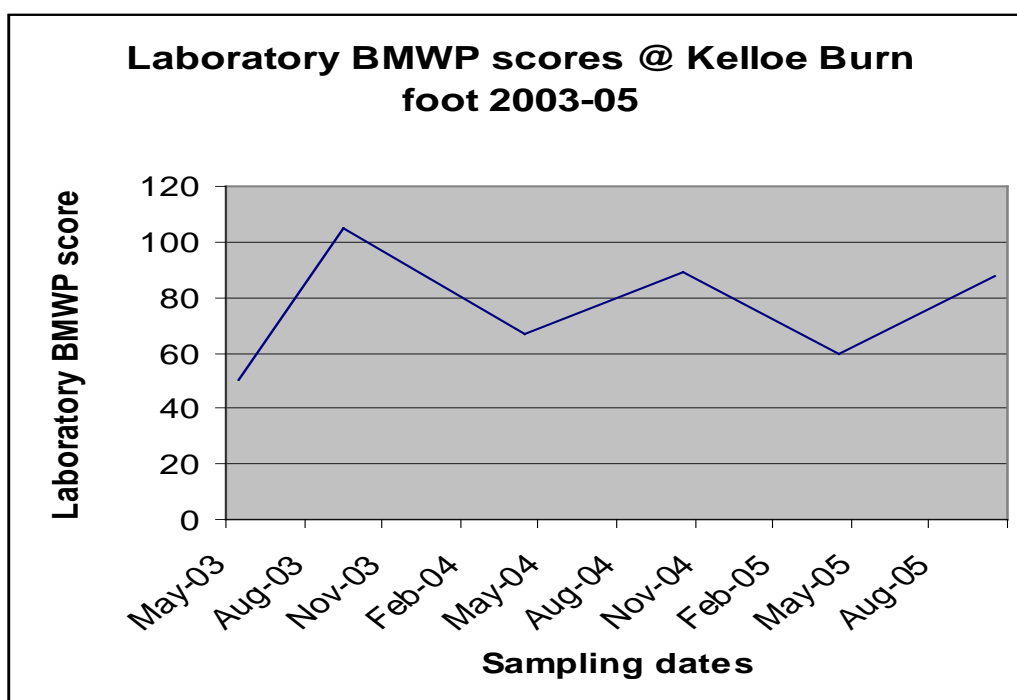
### **Evidence Based action**

In many countries best management practices (BMPs) have been required for decades as basic measures to prevent diffuse pollution from industrial and commercial estates (as well as roads and residential areas) having an impact on the local water environment. Internationally, over many years scientific studies have reported higher EMC (event mean concentration) values for industrial and sometimes commercial land uses, than for other urban areas, for a range of pollutants (e.g. as

far back as Stenstrom *et al* 1984, Fisher *et al* 1999, Walker *et al* 1999). UK Environment agencies rarely undertake the storm event monitoring required for such estimates however, relying on infrequent spot samples that often miss storm events. Consequently, ecological monitoring (Hawkes 1997) has been preferred as a cost effective basis for urban pollution assessment. It is often able to detect pollution events missed by chemical monitoring, as the impacts on the aquatic environment persist for some time after dispersal or sedimentation of the pollutant, which may also not be detected by infrequent spot samples. Discharges may also be missed by chemical sampling in dry weather when there is minimal flushing of pollutants from the industrial estate and its surface water drainage system, leading to concentrations building up within the drainage system or its catchment.

Evidence for this in Scotland is exemplified by measurements of water quality below industrial estates. In contrast to classic water pollution impacts below a point source effluent discharge, when low flows are most susceptible to steady effluent discharge impacts due to limited dilution, for the industrial estate impact the water quality is sometimes best at low flows, with poorest flows after wet weather. An example is given in figure 1, which shows ecological data from the Kelloe Burn, a small stream below Duns Industrial estate that drains into the Blackadder Water; the autumn samples, that follow summer lower flows/runoff, have greater diversity/scores than the spring samples taken after the winter high flow/runoff period (a consistent run of weather patterns and other influences is required to demonstrate the effect).

**Fig. 1 Kelloe Burn (tributary of Blackadder) below Duns industrial Estate.**

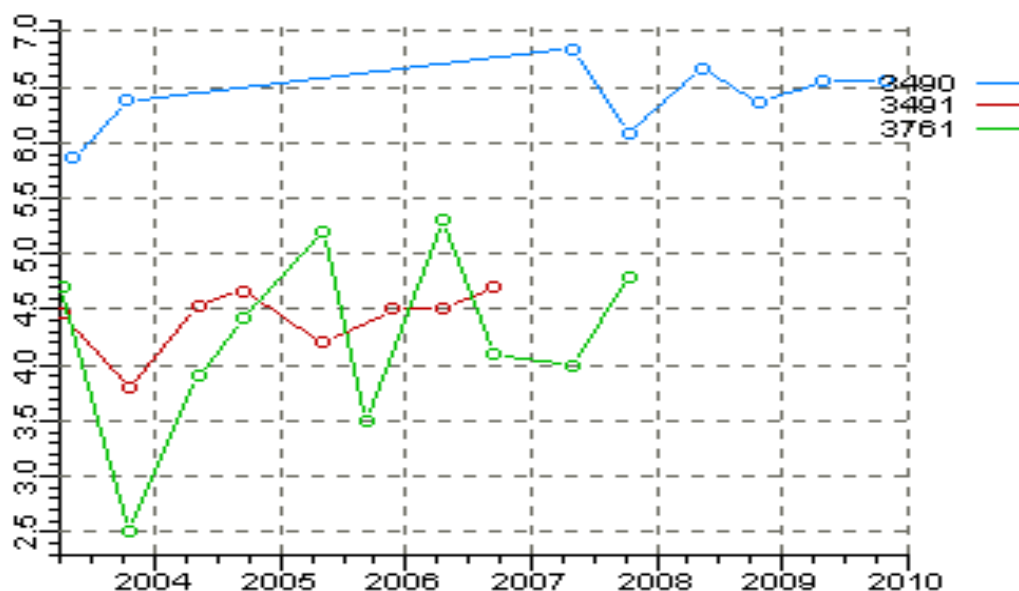


That is consistent with pollutant inputs driven by storm events. In dry weather the pollutants are still on the ground and in the soil; a classic diffuse pollution characteristic.

Long term monitoring data is available for the Red Burn, which drains part of Cumbernauld, and the catchment includes a cluster of large industrial estates. The burn was one of the watercourses included in the industrial estate impacted reaches documented in the SEPA State of the Water Environment report (SEPA 1999) and provides a well investigated and documented case study.

Decades of intensive pollution prevention action brought about many individual changes on various premises, and persistent interactive engagement with the businesses on the industrial estates involved inspections of premises and even court actions to “stop the pollution”. But the basic poor quality of the Red Burn showed insufficient progress towards good quality. Figure 2 shows the continuing poor quality as monitored by ecological indices since 1999.

Figure 2. Ecological indices of water quality in the Red burn below industrial estates in Cumbernauld.



Key: Blue trace 3490 Glencryan Burn u/s Red Burn (upstream of Cumbernauld), Mean ASPT: 6.42. Green trace 3761 Red Burn d/s 72" @ culvert , (immediately d/s of Cumbernauld where Red Burn emerges from culvert under the town) Mean ASPT: 4.24; red trace 3491 Red Burn u/s Dunnswood STW, (downstream of Cumbernauld IEs), Mean ASPT: 4.42

In table 1, snapshots of water quality as measured by ecological indices are given for other small watercourses below industrial estates in Scotland. Low diversity and abundance of benthic invertebrate populations, were evident, as measured by the BMWP scoring system<sup>1</sup>. (A watercourse with good water quality would be expected to have a BMWP score >100 and an ASPT of at least 5.0). Impacts are less easy to separate from other influences on larger watercourses, where some unsatisfactory effluents, or issues such as drainage from abandoned mines complicate resolution of pollution problems.

Table 1. Example ecological indices of water quality in example urban streams in Scotland (various dates). For details of BMWP and ASPT, see Hawkes, (1997).

Watercourse	Close to industrial estate discharge	Downstream (d/s)	d/s confluence with another stream	comments
Dechmont Burn below (d/s) Deans Industrial estate, near Livingston	BMWP 16 ASPT 3.3	BMWP 14 ASPT 3.5	Brox Burn: BMWP 54 ASPT 4.9	Brox Burn u/s BMWP 80 ASPT 6.3
Lochty Burn, d/s	-	BMWP 25 – 63	-	Impacts also from

<sup>1</sup> Biological Monitoring Working Party Scoring system used to determine the biological condition of a river by measuring benthic invertebrate populations

D'Arcy BJ, Gillard J, Clayton J, Hamilton E and McLean N (2011). Scottish SUDS retrofits to address pollution from industrial estates. In *Diffuse Pollution and Eutrophication*, Proceedings of 15<sup>th</sup> International conference on Diffuse Pollution, Rotorua, New Zealand.

industrial estates in Glenrothes		ASPT 3 - 4.3		abandoned mine drainage and housing areas
Dedridge Burn d/s Brucefield Industrial estate, near Livingstone (3 sets Samples Sept-Nov. 2010)	BMWP 11-30 ASPT 2.75 – 3.75	BMWP 45 – 84 ASPT 5.00 – 5.25	-	Small estate, but no other significant issues. Samples taken following a fire at one of premises.
Caw Burn d/s Houston Industrial estate, Livingstone	No suitable monitoring at outflow from wetland	<u>Spring 2010:</u> BMWP 20 ASPT 2.86 <u>Autumn 2010:</u> BMWP 50 ASPT 3.85	No monitoring -	Practical difficulties of access have prevented sediment removal
Red Burn d/s Cumbernauld (mean 2003-2010)	Discharge from Culvert u/s Ind. Est. ASPT 4.24	u/s Dunnswood STW: ASPT 4.42	No monitoring	Glencryan Burn u/s Red Burn mean ASPT: 6.42

Wilson *et al* (2005) reported on sediment contamination by toxic metals, PAHs and oil, in 27 sample locations on 9 urban streams across Scotland from Aberdeen to East Kilbride. The consistently significant contamination, especially oil, probably explains the generally poor ecological scores that characterise the watercourses.

### The role of Pollution Prevention and Control: 'housekeeping'

Industrial estates are often misunderstood as a water pollution issue, with a belief that pollution is a function of an effluent discharge (that should be licensed and controlled to prevent pollution), or if there is awareness of the dispersed nature of pollution risks and contamination, then there is a perception that maybe a clean-up approach can prevent pollution sufficiently for the restoration of stream ecology? That mindset pre-dates the modern understanding diffuse pollution, with its recognition of the need for urban BMP or SUDS as part of drainage infrastructure. There will of course always be a need for 'housekeeping' measures as well, such as oil spill and clean-up contingency plans, provision of recycling systems for vehicle wash waters or connections to foul sewer after water utility approved pre-treatment, and bunding of oil tanks and drums, etc. SEPA and Scottish Water are working in partnership to find the most cost effective means of driving forward best practice for housekeeping measures, in parallel with the legal requirements for SUDS.

### SUDS and BMPs

The intensive abatement efforts over many years in the river purification boards that preceded the formation of SEPA in 1996, especially in the 1960s New Towns of Cumbernauld, Glenrothes and Livingston in the Forth catchment, were primary drivers for development of a BMPs and subsequently SUDS policy in Scotland when SEPA was formed. In Livingston for example, the need for retrofit BMPs was specifically identified in the River Almond Catchment Plan, and the first retrofit effort was established as a result, by a Scottish Water predecessor, East of Scotland Water (ESWA) on the Caw Burn, treating drainage from Houston Industrial Estate. The retrofit, despite severe constraints such as lack of space, nevertheless led to a class change improvement in water quality (see Heal *et al* 2005). Subsequently, design and especially sizing criteria for SUDS in Scotland followed Roesner's treatment volume concept (Roesner *et al*, 2001) and were published by CIRIA (2000) as the basis for the technology in the UK (updated in 2007). After the establishment of a

D'Arcy BJ, Gillard J, Clayton J, Hamilton E and McLean N (2011). Scottish SUDS retrofits to address pollution from industrial estates. In *Diffuse Pollution and Eutrophication*, Proceedings of 15<sup>th</sup> International conference on Diffuse Pollution, Rotorua, New Zealand.

clearer regulatory framework, detailed guidance for SEPA was developed for staff to aid consistency in dealing with developers (SEPA 2006a and b).

### A new national SUDS retrofit programme

In order to address existing problems, a programme to retrofit SUDS was required, but a pre-requisite was to establish a remit for a public body to spend money in that way, and to maintain retrofit systems on completion. The public water utility for Scotland (Scottish Water) was agreed by a stakeholder partnership as best placed to be given that remit. The Water Environment and Water Services Act (Scotland) 2003, (referred to as the WEWS Act) implemented the EU Water Framework Directive (WFD) in Scotland. As well as bringing in a new regulatory regime to be applied by SEPA, including measures to control diffuse pollution, the legislation gave responsibility for SUDS features to Scottish Water. Consequently, it became possible to put together a national capital programme to retrofit SUDS to address the anthropogenic background levels of contamination implicated in pollution of urban waterbodies (table 2). For the Scottish Water programme an initial budget of £25M was estimated (2005 value) to address chronic urban diffuse pollution (in D'Arcy *et al* 2007). Candidate sites for retrofit SUDS schemes were identified in consultations between SEPA and Scottish Water. The SEPA process comprised examination of ecological data for any adverse impacts, along with any available chemical data and expert local knowledge by SEPA staff.

**Table 2. Examples from first retrofit SUDS by Scottish Water & a predecessor organisation\* and sites where additional/alternative actions have been required**

Industrial estate	Retrofit action	Comments
*Houston Industrial Estate, Livingston (Caw Burn)	Off-line pond & wetland, resulting in class change improvement in Caw Burn (Heal et al 2005)	*Established by Scottish Water predecessor, ESWA.
Eastfield & Southfield Industrial estates, Glenrothes (Lochty Burn)	Conversion of flood attenuation field to dual purpose detention basin at each estate (treatment function added)	Both completed, 2010, but problem initially with reed establishment.
Cumbernauld industrial estates (Red Burn)	Retention or detention ponds planned at major trunk surface water sewer outfalls below largest industrial estates	First SUDS pond under construction, 2011
Deans Industrial estate, Livingston	Retention pond	Delayed: topography issues
South Gyle, Edinburgh (within Bird-circle: Edinburgh Airport)	Proprietary filters and separators? (Source & site controls)	Measures to be agreed with owners/operators of each component site on estate
Nether Stenton, Glenrothes	SUDS pond	Due for completion spring 2012
Commerce Road, Stranraer, Dumfries & Galloway	Three 2-stage retention ponds	Pond designs developed; due for completion in 2012
Greenykes,	SUDS Pond to be created on land below industrial estate	Planning permission for housing granted on land identified for a retrofit pond for the estate

### Treatment train

In SEPA policy, a treatment train has been sought for industrial estates in order to provide successive pollutant removal steps from source control, to site or conveyance system, to final retention pond and discharge to the water environment. It has also been sought to provide buffering in event of incidents on the industrial estate, so an intervention can easily be made to trap or collect spilled material, or to easily observe malpractices on the estate, as close to source as possible. That has been achieved for two industrial estates that were green field developments (papers in prep.). The challenge for retrofits is more difficult. Class change improvement resulted from establishment of

D'Arcy BJ, Gillard J, Clayton J, Hamilton E and McLean N (2011). Scottish SUDS retrofits to address pollution from industrial estates. In *Diffuse Pollution and Eutrophication*, Proceedings of 15<sup>th</sup> International conference on Diffuse Pollution, Rotorua, New Zealand.

Scotland's first retrofit SUDS on the Caw Burn (Heal et al 2005), but lack of maintenance or treatment train measures upstream in the industrial estate has led to loss of treatment capacity with consequent reduced ability to cope with shock impacts of intermittent pollution incidents (see current quality in table 1). Some limited storm event monitoring at the Caw Burn has shown two different phenomena. Firstly, the highest concentrations of cadmium, copper, lead and zinc were measured after the largest storm event captured (albeit only light rain; 5.4mm of rain in the 8 hours preceding the sample) – anthropogenic background contamination. But another set of samples showed a peak concentration of 4100ug/l aluminium and the highest suspended solids result (100 mg/l). No significant rainfall was recorded at the site on that date (1.8mm over preceding 24 hours) suggesting it was probably a site specific pollution incident that should be taken out by source control features at the site where it originated.

The importance of a treatment train of measures was demonstrated by a project to restore the Knebilstorp Stream in Halmstad, Sweden, where industrial estate drainage was also a priority issue (D'Arcy et al 2007). SUDS retrofit options for end of pipe situations have proved difficult, but to find space for conventional basins and swales, for example, upstream on an existing drainage network has so far not been achieved in Scottish projects. If consideration is given to proprietary treatment systems for installation as source controls, that initial treatment need could perhaps be effectively met. Caution in selecting options is required; the poor quality of the Dedridge Burn below Brucefield industrial estate (table 1) is despite a novel end of pipe proprietary treatment unit being installed (not by Scottish Water), in lieu of a more conventional treatment wetland or perhaps alternative units using established vortex separator or filtration technology. There has been an intensive clean-up programme of work on the Brucefield estate (SEPA and Scottish Water in partnership), but there is no upstream SUDS or equivalent treatment features on the drainage infrastructure; once again demonstrating the need for treatment train of infrastructural measures.

## **Discussion**

Constraints faced by the retrofit programme at many sites have included a lack of available land or insufficient land, or topographical issues (slopes, volume of earth to be moved leaving artificial cliff edged ponds) that make provision of large retention ponds for example impractical or excessively expensive. SEPA policies for green field developments have been difficult to translate into retrofit practicalities. How can treatment train networks be established for the most severe impacts? Should the capital programme try and establish end of pipe measures as first phase actions, or spend more resources delivering a series of facilities for fewer polluted watercourses? Discussions between the stakeholder organisations are continuing, to develop answers. One option is to improve liaison with Local Planning Authorities to catch new and redevelopments on industrial estates, to deliver unit plot SUDS, to minimise costs for the public purse. A unit plot SUDS concept means that each specific business has its own SUDS features, to be maintained by that business, not from the public purse. That will gradually allow improvements and the spread of source control techniques as first stages of a treatment train, if new developments and redevelopments are addressed as they come up for planning approval on existing estates.

The capital programme therefore will not be the only approach to address pollution from industrial estates, and a partnership approach is also being developed to scrutinise priority estates with high pollution risks, for opportunities to require new SUDS features as needs and opportunities become apparent. The inevitable limits on the budget for a retrofit programme will set the rate of improvement in the quality of watercourses, but the in parallel focus on planning controls for redevelopments, and the emerging establishment of a market for source control proprietary SUDS, or surface water treatment techniques, will provide another delivery mechanism.

D'Arcy BJ, Gillard J, Clayton J, Hamilton E and McLean N (2011). Scottish SUDS retrofits to address pollution from industrial estates. In *Diffuse Pollution and Eutrophication*, Proceedings of 15<sup>th</sup> International conference on Diffuse Pollution, Rotorua, New Zealand.

An effective regulatory regime to use the statutory powers available has yet to be finalised. The Water Framework Directive, with its emphasis on ecological quality for the water environment, is a new driver for improvements using a similar evidence base to the ecological data described above (as well as additional ecological data). But its focus has been limited to larger watercourses than many of the tributaries targeted for improvements under earlier abatement plans. The Floods Directive redresses the balance in favour of smaller watercourses however, since that is where most people are at risk from pluvial flooding (anticipated to become a larger risk with climate change), alongside the priorities for flood risks associated with the larger rivers. A combined approach to stormwater management that addresses pluvial flood risk and water quality is being developed by the Scottish Government.

The roll out of the national retrofit programme needs to be supported by monitoring and research to assess effectiveness and investigate possible cost saving approaches that have not been adequately tested to date.

### Conclusions

- After due consultation, Scottish Government established a remit for the water utility in Scotland (Scottish Water) to have existing and new public SUDS features vested in Scottish Water (subject to compliance with standards).
- Scottish Government has agreed with Scottish Water a capital programme, to allow retrofitting of SUDS technology to address chronic urban diffuse pollution problems, and SEPA has identified a list of priority watercourses accordingly.
- Significant progress has been made by Scottish Water, with several schemes under way and completed or close to completion.
- Practical difficulties have required flexibility in policy and action to keep the programme on track to deliver effective retrofit schemes, for example where space or topography preclude extensive treatment (retention) ponds. Smaller or modular units, supported or even replaced by (where no space at all for ponds or basins) proprietary filter or separator units need to be considered.
- Treatment train principles are as important for retrofit programmes as for new build, green field developments, and technology that is compatible with existing infrastructure will need to be considered.
- Individual businesses on estates need to be made aware of the scope for retrofits on their premises, and regulatory bodies and planning authorities need to work together in partnership with industry sectors and individual estates, to promote best practice.
- A partnership approach to encouraging good housekeeping by businesses on industrial estates will continue to be as important in the future as it has been for the past decades. But now and in the future this partnership approach will have to be delivered in parallel with the gradual implementation of more appropriate drainage infrastructure.

### Acknowledgements

The authors are grateful to Calum McPhail, Tim Foster, Duncan Clarke and Andy Hemingway in SEPA for information and comment. Any opinions expressed in the paper are those of the authors, and not necessarily of the organisations they represent.

### References

- Campbell N, D'Arcy B, Frost A, Novotny V and Sansom A (2004) *Diffuse Pollution: an introduction to the problems and solutions*. IWA Publishing, London. ISBN 1 900222 53 1
- CIRIA (2000) Sustainable urban drainage systems – design manual for Scotland and Northern Ireland, C521, London.

D'Arcy BJ, Gillard J, Clayton J, Hamilton E and McLean N (2011). Scottish SUDS retrofits to address pollution from industrial estates. In *Diffuse Pollution and Eutrophication*, Proceedings of 15<sup>th</sup> International conference on Diffuse Pollution, Rotorua, New Zealand.

CIRIA 697 (2007) SUDS Manual and SUDS Construction Handbook, London.

D'Arcy BJ, Rosenqvist T, Mitchell G, Kellagher R and Billett S (2007) Restoration Challenges for urban rivers. *Water Science & Technology* **55**, no. 3, pp 1-7.

Fisher TS, Hayward DG, Stephens RD and Stenstrom MK (1999) Dioxins and Furans Urban Runoff. *Journal of Environmental Engineering, ASCE*, February 1999, 185-191.

Hawkes HA (1997) Origin and development of the Biological monitoring Working Party score system, *Water Resources* **32** 964-8.

Heal, K.V., Scholz, M., Wilby, N. and Homer, B. (2005). The Caw Burn SUDS: performance of a settlement pond/wetland SUDS retrofit. In: Proc. 3rd National Conf. On Sustainable Drainage, Newman, A.P., Pratt, C.J., Davies, J.W. and Blakeman, J.M. (eds.), Coventry University, Coventry, UK, pp. 19–29.

Roesner LA, Campbell NS and D'Arcy BJ (2001) Master Planning Stormwater Management Facilities for the Dunfermline, Scotland Expansion Project. NOVATECH 2001, Lyons.

SEPA (1999) Improving Scotland's Water Environment. SEPA State of the Environment Report. Scottish Environment Protection Agency, Stirling.

SEPA (2006a) The Water Environment (Control Activities) (Scotland) Regulations 2005; A practical Guide.

SEPA (2010) Regulatory Method (WAT-RM-08): Sustainable Urban Drainage Systems (SUDS).

Stenstrom MK, Silverman GS and Bursztynsky TA (1984). Oil and grease in urban stormwaters. *J. Envir. Engrg.*, ASCE, 110(1), 58-72.

The River Almond Catchment Partnership Group (1997). The River Almond Catchment – a plan for integrated Management. Scottish Wildlife Trust and West Lothian Council, Livingstone.

Walker WJ, McNutt RP and Maslanka CAK (1999) The potential contribution of urban runoff to surface sediments of the Passaic River: sources and chemical characteristics. *Chemosphere*, vol. 38, No. 2, pp. 363-377.