Institution: University of Leeds

Unit of Assessment: C-17

Title of case study: Case 6 - Improving national surface water quality using an urban non-point pollution model and supporting database.

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

Surface water runoff in urban areas makes a significant contribution to pollution of lakes and rivers, but historically is poorly addressed in catchment models. The School of Geography (SoG) developed a Geographic Information System (GIS) model and supporting database to quantify urban source area loadings of 18 common and priority pollutants. This knowledge improves catchment models and supports impact assessment and mitigation planning by environment managers. The research has been exploited on behalf of the Department for Energy, Food and Rural Affairs (DEFRA), the Welsh Assembly, and the UK water industry (UK Water Industry Research – UKWIR, and United Utilities). The research has had three distinct impacts: 1) its use addressing EU Water Framework Directive obligations; 2) its on-going influence on construction industry guidance; and 3) the commercialisation of its stormwater pollutant coefficient database for Sustainable Urban Drainage Systems (SUDS) planning software.

2. Underpinning research (indicative maximum 500 words)

Stormwater pollution originating from urban areal sources (urban diffuse pollution) is a significant barrier to achieving river water quality objectives. Reducing the problem requires and understanding of the impact of urban diffuse loadings relative to other sources (such as agriculture, or combined sewer overflows), and measures such as installation of SUDS for new development and SUDS retrofit for existing built areas.

The SoG developed a GIS model to assess pollutant loadings in waters draining urban areas (diffuse sources) **[1]**, funded from 1998-2001 by EPSRC ('Urban Development and Nonpoint Source Water Pollution: Developing a Generic Hazard Management Tool'; PI Professor Adrian **McDonald**, Co-Is Dr. Gordon **Mitchell**, J. Packman; £129 K, graded 'outstanding'). **Mitchell** (at Leeds 1994-present, Research Fellow/Senior Research Fellow 1998-2005, Lecturer since 2005), assisted by Mr James Lockyer (Research Assistant) and **Prof. Adrian McDonald** (at Leeds 1972-present, Professor since 1992), developed the model to:

a) map the location of diffuse urban pollution hot spots, under a range of probabilistic conditions;
b) quantify pollutant load to receiving waters and so identify areas which present the greatest pollution hazard; and
c) assess the impact of land-use change on non-point source runoff quality.

The model has fine spatial resolution, yet facilitates pollution appraisal at the river basin scale, to support investigative monitoring and management of emissions at source. It can be used in whole catchment water quality management, and in planning to understand where the implementation of SUDS would have the greatest beneficial effect on pollution of receiving waters. The model can therefore be used to identify sites that could contribute to a failure to meet the environmental objectives set out in the WFD (Directive 2000/60/EC) that comes into force in 2015, and has particular value when combined with estimates of pollutant inputs from other source types across a catchment **[3]**.

The work was detailed in technical reports that describe the GIS model and a pilot application **[1]**, and presents and describes the derivation of concentration coefficients, as mean site event-mean concentrations (EMC), for 18 pollutants **[1]**, before then being published in the peer reviewed press **[2]**. The EMC values were developed for a range of urban land uses (residential, commercial, road etc.), and stratified by UK, northern European and global geographies. The university supports a project website [www.geog.leeds.ac.uk/projects/nps] where the technical reports can be downloaded. In addition to the project website, the reports were provided to key individuals in UK planning and regulatory agencies, including the Environment Agency and the Scottish Environment Protection Agency (SEPA). To further disseminate results, invited presentations were made at UK workshops and conferences, and the work featured in the keynote presentation to the International Water Quality Association (IWQA) specialist conference on diffuse pollution, in Johannesburg **[4]**.

UK Water Industry Research (UKWIR, comprising of 24 water and sewerage undertakers in England and Wales, Scotland and Northern Ireland) commissioned a 2007 pilot study on the contributions and impact of control measures on water quality (UKWIR Report Ref. No. 07/WW/17/9). The study of the Ribble basin, a WFD UK sentinel catchment, was a collaboration between WRc Plc., the Environment Agency, United Utilities (UU) and **Mitchell**, through Emaginating Ltd (a University of Leeds spin-out company specialising in spatial modelling and analysis who applied the model with **Mitchell** acting as consultant). **Mitchell** contributed modelled urban diffuse runoff estimates and pollution loads for the basin to assess the relative contributions and the impact of control measures on river water quality. The pilot study showed current information combined with a catchment modelling approach can be used to: (1) apportion sources of pollution load across a catchment; and (2) identify the water quality co-benefits of point source and diffuse pollution control measures to achieve compliance with WFD river quality standards **[5]**.

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

The research has been published in a range of internationally-recognised, rigorously peer reviewed journals. The technical report [1] was a key input for output 2 in a peer reviewed journal.

Internal Report

[1] *Full account of development and test application of the urban diffuse pollution model* **Mitchell, G.**, **Lockyer, J.** and **McDonald A.T.** (2001). Pollution Hazard from Urban Nonpoint Sources: A GIS-model to Support Strategic Environmental Planning in the UK. Technical Report, Vols 1 and 2, School of Geography, University of Leeds, 240pp.

Peer Reviewed Articles

[2] *Key contribution to urban diffuse pollution appraisal in a highly ranked journal*
Mitchell, G. (2005) Mapping Hazard from Urban Non-Point Source Pollution: A Screening Model to Support Sustainable Urban Drainage Planning. *Journal of Environmental Management*, 74, 1-9. DOI: 10.1016/j.jenvman.2004.08.002

[3] *Paper reporting on threat to WFD targets from identified diffuse pollution sources and estimated loadings, and role of urban diffuse source modelling in compliance planning*
Ellis, J.B. and **Mitchell, G.** (2006) Urban Diffuse Pollution: Key Management Issues For the Water Framework Directive. *Water and Environment Journal*, 20, 19-26. DOI:10.1111/j.1747-6593.2006.00025.x

[4] *Paper from keynote address to international practitioner conference (9th IWQA 2005) drawing on stormwater quality database and identifying urban diffuse pollution mitigation challenges*
D'Arcy, B., Rosenqvist, T., **Mitchell, G.,** Kellagher, R. and Billett, S. (2007). Restoration Challenges for Urban Rivers. *Water Science and Technology*, 55, 3, 1-7. DOI: 10.2166/wst.2007.065

[5] *Paper reporting on use of urban diffuse pollution model and database in the national source apportionment pilot study, funded by and conducted with practitioner agencies*
Crabtree, B., Kelly, S., Green, H., Squibbs, G., and **Mitchell, G.** (2009). Water Framework Directive catchment planning: a case study apportioning loads and assessing environmental benefits of programme of measures, *Water Science and Technology*, 59, 3, 407-416. DOI: 10.2166/wst.2009.875.

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

The impacts of this research in the assessment period have been in three distinct areas.

Use in Addressing EU Water Framework Directive Obligations

Pre-2008 Context of Impact: Mitchell was invited by DEFRA to work with their non-agricultural diffuse pollution policy group, including invited presentations to DEFRA policy makers and analysts in June and October 2006. The context for this work was the water quality objectives defined by the EC Water Framework Directive (WFD), and the need to understand strategies and costs to attain compliance nationally. Members of the working group were then charged by DEFRA with

developing a 'source apportionment' methodology, to identify compliance with in-river water quality standards given a range of source inputs (rural diffuse, urban diffuse, point etc.) and mitigation scenarios. The work was based on a UK WFD sentinel catchment - the Ribble in NW England (includes Blackburn, Preston, Blackpool) - with financial support from UK water industry research (UKWIR). Mitchell produced model estimates of urban diffuse loadings to river reaches in the basin. Other source inputs were modelled by the Environment Agency and the Water Industry, whilst WRc **[A]** integrated inputs in SIMCAT, a river mass balance model that determines in river pollutant concentrations, and compiled the final report **[B]**. Mitchell's database and the Ribble study are cited in works on preliminary cost effectiveness assessment of measures by DEFRA **[C]** and Water Industry Working Group **[D]**.

Assessment Period Impacts: The Ribble study demonstrated the value of having reliable estimates of pollutant inputs, integrated across a catchment, and the potential benefits of different control measures in terms of compliance with WFD directive standards. It was the first study able to include a detailed appraisal of urban diffuse inputs. The methodology developed in the study has been enhanced through development of SAGIS - a commercially available source apportionment GIS model funded by UKWIR and led by Atkins working with WRc (i.e. Ribble partners) and AMEC (formerly Entec) **[A]**. SAGIS has been adopted by the Environment Agency in WFD Article 5 risk assessments for 'River Basin Planning 2', which runs from 2012 runs to 2015; Article 5 of the WFD mandates assessment of the pressures and impacts on water bodies **[E]**.

The SoG work has also been used by other parties to provide catchment data and advice to UK governments in support of catchment planning and policy appraisal. ADAS UK Ltd **[F]** in conjunction with the Centre for Ecology and Hydrology used the methodology and export coefficients in quantifying urban diffuse exports of sediment and nutrient species, as an input to whole catchment pollutant budgets. Their work for DEFRA (e.g. projects WQ0106 and WQ0128) assessed the likelihood of catchments failing to meet Water Framework Directive 'good ecological status' targets for 2015 and provided evidence for ecological impacts of fine sediment, whilst that for the Welsh Government (Agri-Environment Monitoring and Services Contract Lot 3 No.183/2007/08) contributed to an on-going evaluation of agri-environment schemes (whereby farmers receive grant aid to farm in an environmentally sensitive manner). United Utilities (UU) **[G]** also commissioned Mitchell, via Emaginating Ltd, to model urban diffuse loads for their entire company region, most of NW England. UU's integrated river water quality model accounts for river hydrology, background water quality, continuous and intermittent discharges (flow and quality) from wastewater treatment works, combined sewers, storm tanks and urban surface water discharges, the latter addressed by data modelled by Mitchell. UU's integrated models are used to identify the location of intermittent discharge problems, and in design of Capital Projects to alleviate the effects of unsatisfactory discharges **[G]**. Finally, work for SEPA **[H]** allowed an evaluation of urban diffuse loading tools in Scotland, and via scenario modelling at Leeds, provision of advice on diffuse loading implications of urbanisation.

Influence on Construction Industry Guidance

Pre-2008 Context of Impact: The stormwater pollutant coefficient database addresses 18 important urban diffuse pollutants, which environment managers seek to control. Analysis of these data led to the recommendation of probabilistic (including central tendency) values of pollutant concentrations in stormwater, subdivided by geographical region (UK, N. Europe, Global) and urban land use (residential, commercial, road etc.). The UK construction industry, which is responsible for the installation of sustainable urban drainage systems (SUDS) that are used to control stormwater pollution, recognises these data as the most comprehensive analysis of urban stormwater pollutant concentrations. The data are published in guidance to developers (CIRIA 609) on SUDS planning and implementation produced by the Construction Industry Research and Information Association, the UK construction industry advisory body [**I**: 45-49].

Assessment Period Impact: CIRIA 609 was superseded in 2007 by "The SUDS manual" and its abridged guide "Site Handbook for the Construction of SUDS", but for technical design guidance relating to water quality (as opposed to flow), developers continue to be referred to CIRIA 609 [see page xxxii), and hence this has been the relevant guidance throughout the assessment period.

DEFRA estimate 40% of all new build and redevelopments in the UK are now being developed with SUDS measures (for reference, planning authorities in England permitted 342,000 domestic and commercial developments in 2012, and 108,000 new homes were constructed).

Commercialisation for SUDS Planning

The 2010 Flood and Water Act mandated national standards for SUDS and statutory SUDS approval bodies (SABs) to regulate and permit SUDS designs. Quantitative techniques support evaluation of SUDS designs, and SAB decision making, hence in 2012 Jeremy Bentham Associates (JBA, www.jbaconsulting.co.uk), a UK based international environmental engineering consulting firm licenced the stormwater pollutant (EMC) coefficient database from the SoG. The database underpins UK applications of the proprietary SUDS planning model MUSIC (model of urban stormwater improvement conceptualisation) developed by the Australian Cooperative Research Centres and sold by eWater Innovation Pty Ltd (www.ewater.com.au; company ABN 80 133 551 283), who appointed JBA as their sole European agent (for context, MUSIC received £4 million of investment funding from the Commonwealth Scientific and Industrial Research Organisation, and has sold 2000 copies in Australia over the last decade). MUSIC requires geographically suitable stormwater loading coefficients for use in UK/Eire applications of the model, and JBA have purchased non-exclusive rights to Mitchell's EMC database, for 5.5% of net revenue **[J] [K]**.

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

[A] Letter from former Head of Environmental Management Division, WRc Plc. To verify role of model in UKWIR source apportionment, and legacy of Ribble project; dated 23 August 2013. [Available on request]

[B] Crabtree, B. and Kelly, S. (2007) Ribble SIMCAT Pilot Study: Assessment of Relative Contributions and the Impact of Control Measures on Water Quality, UKWIR Report Ref. No. 07/WW/17/9, 2007. [Available on request]

[C] DEFRA (2007) Cost-effectiveness of measures: Analysis of measures to reduce non-agricultural diffuse pollution. Final Report version 1 9S4904.A0; 9S4870.02.34A. [Available on request].

[D] WFD preliminary cost effectiveness analysis (pCEA) - Water Industry working group, Supporting Document (version 0.3, dated 20 June 2007). [Available on request]

[E] Environment Agency update to DEFRA Water Stakeholder Forum - Update on Progress, dated June 2012, page 8. [Available on request]

[F] ADAS UK Ltd – Assessment for the development of a screening tool to identify and characterise diffuse urban pollution pressures. Pages 19, 30, 33-40, 42, 43, 47, 50, 53, 160, 164, dated May 2003. [Available on request]

[G] Email from Network Modelling Technical Specialist, United Utilities Plc; dated 20 June 2013. To verify consultancy work for United Utilities. [Available on request]

[H] Letter from Former Director of Diffuse Pollution, SEPA 1996-2010 (and commissioner of review work for SEPA), commenting on the value of the GIS urban modelling work, dated 12 October 2013. [Available on request].

[I] *Sustainable Drainage Systems: Hydraulic, structural and water quality advice*. CIRIA 609, ISBN 0-86017609-6, 2004. Pages 45-49. [Available on request]

[J] Letter from former eWater International Business Development and Technical Manager, eWater Innovation Pty Ltd.; dated 4 September 2013 [Available on request]

[K] Commercialisation Agreement between University of Leeds (Gordon Mitchell) and eWater Innovation pty Ltd; dated 30 November 2011. [Available on request].