Institution: University of Sheffield

Unit of Assessment: 7 – Earth Systems and Environmental Sciences

Title of case study: Understanding and managing the environmental risk to aquatic habitats resulting from road runoff.

1. Summary of the impact

Research by Professor Maltby's group quantified the ecological impacts of contaminants draining off road surfaces into surface waters, revealing the importance of particulate-bound toxicants. We identified the key toxicants involved, the concentration thresholds at which they pose significant risks, and established the extent and the conditions under which they are harmful. These advances provided the scientific underpinning for the Highways Agency's revised (2009) guidance on environmental impact and assessment of road drainage, and it's Water Risk Assessment Tool. Our research has led to significant cost savings, and much improved targetting for monitoring and protecting the environment. The Highways Agency guidance and risk assessment tool has been adopted by the Devolved Administrations in *Scotland, Wales & Northern Ireland* and other EU and non-EU countries, and has been applied to projects worth over £65m in the UK since 2010.

2. Underpinning research

The problem of toxic road run-off: The road network plays a central role in the UK and global economy through the transport of goods and people, but is a major source of pollution. Many of the pollutants produced by road transport are washed off roads and discharged into rivers, streams, ditches and ponds. The environmental costs of water pollution in England and Wales have been estimated at up to £1.3 billion per year (National Audit Office 2010) and roads are a major contributor to this pollution, especially in urban areas. Road runoff is a potentially important source of environmental contaminants including heavy metals and polyaromatic hydrocarbons, but the ecological impacts and toxicity of these constituents in aquatic ecosystems had received little attention and was poorly understood until we conducted research on this in the mid-1990s.

How we addressed this problem: Prof. Maltby's group at the University of Sheffield had established a strong track record of research in aquatic ecotoxicology when commissioned and funded (£187,000) by the oil company Castrol to investigate ecological effects of road-runoff. Our research approach involved an innovative multi-step combination of field and laboratory studies both, to determine the ecological impacts of road runoff, and to resolve the mechanistic basis of these effects [**R1**-**R5**]. We investigated how road runoff affected the structure and functioning of stream ecosystems alongside the M1 motorway [**R2**] and undertook extensive toxicity experiments with key bioassay organisms, sediment manipulation studies and chemical analyses to identify and evaluate key toxicants within the complex mixture of chemicals associated with road runoff [**R1**,**R3**,**R4**]. Field and laboratory experiments were then used to gain a mechanistic understanding of how toxicants associated with contaminated sediments caused the ecological impacts observed in freshwater communities [**R5**].

Through this research, we provided the first extensive and robust demonstration of the ecological impact of road runoff on freshwater organisms [**R1**-**R5**], established sediment-bound contaminants as having major effects [**R1**], and identified the major toxicants, in particular polycyclic aromatic hydrocarbons, as the causal agents [**R3**,**R4**]. These papers, which have a total of over 300 citations, characterised (**i**) the nature and extent of the impact of road runoff, (**ii**) the environmental conditions under which impacts occur, (**iii**) the key toxicants causing the effects, (**iv**) their mode of transportation (aqueous-suspended particulates), and (**v**) pathways of exposure through sediment-bound pollutants acting as long-term reservoirs of contaminants.

Our research conclusively demonstrated that it was the deposition of contaminated particulate material washed off road surfaces that was causing the most serious ecological impacts in adjacent surface waters [**R1**-**R5**]. Efforts to protect and improve the ecology of rivers alongside major roads had previously focussed on controlling soluble contaminants. Our research highlighted the need to monitor and control sediment-bound contaminant transfer from roads into river systems across the thousands of miles of strategic road network in England, and more widely across the millions of miles of highways in the world.

Application of our research findings to policy and practice. The importance of our research findings and their implications for managing risks of water pollution from the motorway and trunk road

network was recognised by the Highways Agency and Environment Agency, especially in relation to the increasing stringency of environmental protection required by the EU Water Framework Directive (2000). It was clear that our research provided essential new insights required for assessments of the potential impact of road runoff on river ecosystems and for identifying rivers most at risk from road runoff. It also could be used to inform the selection of interventions to mitigate the impact of road runoff (e.g. design and management of sediment traps, swales, sustainable urban drainage systems) and the targeting of risk reduction measures in order to improve environmental quality.

As a result, the Highways Agency, supported by the Environment Agency, commissioned and funded (£822,000) Maltby's group from 2002–08 to extend the original study to a large number of sites to evaluate the generality of the conclusions drawn from the studies on the M1 motorway, conduct intensive site-specific studies to characterise the discharge pattern of runoff-derived contaminated particles, and to investigate how river hydrology and sedimentation processes influence the magnitude and nature of their ecological impact. This enhanced understanding was combined with the toxicity testing results of the initial research [**R3-R5**] to develop risk assessment procedures and tools that would underpin revised Highways Agency policy and practice, that has subsequently been adopted in other countries. The programme was managed through ECUS (Environmental Consultancy University of Sheffield) and led jointly by Prof. Maltby (Sheffield 1984 -) and Dr Ian Guymer (Sheffield 1990-2005, now Professor at The University of Warwick). The PDRA was Dr Paul Gaskell.

3. References to the research [* = References that best indicate the quality of the research]

R1 Boxall, A.B.A. & Maltby, L. (1995). The characterisation and toxicity of sediment contaminated with road runoff. *Water Research,* **29**, 2043-2050 doi: 10.1016/0043-1354(95)00029-K **38 Citations** (Scopus)

R2* Maltby, L, Forrow, D.M., Boxall, A.B.A., Calow, P. & Betton, C.I. (1995a). The effects of motorway runoff on freshwater ecosystems: I. Field study. *Environmental Toxicology & Chemistry*, **14,** 1079-1092 doi: 10.1002/etc.5620140620 **99 Citations** (Scopus)

R3* Maltby, L, Forrow, D.M., Boxall, A.B.A., Calow, P. & Betton, C.I. (1995b). The effects of motorway runoff on freshwater ecosystems: II. Identifying major toxicants. *Environmental Toxicology & Chemistry*, **14**, 1093-1101. doi: 10.1002/etc.5620140621 **81 Citations** (Scopus)

R4 Boxall, A. & Maltby, L. (1997). The effects of motorway runoff on freshwater ecosystems III. Toxicant confirmation. *Archives of Environmental Contamination and Toxicology* **33**, 9–16

53 Citations (Scopus)

R5* Forrow, D. M. & Maltby, L. (2000). Towards a mechanistic understanding of contaminant-induced changes in detritus processing in streams: Direct and indirect effects on detritivore feeding. *Environmental Toxicology & Chemistry,* **19**, 2100-2106 doi: 10.1002/etc.5620190820 **45 citations** (Scopus)

4. Details of the impact

Our research on road run-off has had ***impacts on practitioners*** through improved monitoring and risk assessment methods for managing pollutants, and changes in guidelines for road and bridge construction, resulting in a more efficient use of resources and ***economic benefits***; it has had ***impacts on public policy*** by informing the development of legislation and standards; ***impacts on the environment*** by developing new approaches for assessing the risks of road runoff to aquatic habitats, resulting in a more robust assessment and an enhanced level of protection.

The principal direct beneficiary: The Highways Agency (HA) is responsible for England's strategic road network, which comprises 4300 miles of motorways and truck roads, carries about 4 million vehicles/day and is valued at £108bn. Our research in collaboration with the HA and Environment Agency (EA) on the effects of routine road runoff on receiving waters and their ecology, was used to develop a new Environmental Impact Assessment tool designed to prevent adverse ecological effects in the receiving water. The Highways Agency Water Risk Assessment Tool (HAWRAT) uses toxicity thresholds established by our research that are consistent with the requirements of the EU Water Framework Directive and are agreed with the EA. The HAWRAT forms part of the HA guidance published in the Design Manual for Roads and Bridges (DMRB, HD45 Road Drainage and the Water Environment) [**S1**]. The DMRB contains all current standards, advice notes and other published

documents relating to the design, assessment and operation of the strategic road network in the UK. It is used by all highway practitioners, including those working on the non-strategic road network. Maltby's team's contribution to HD45 and the risk assessment tool HAWRAT is evidenced by text in the manual:

"Collaborative research has been undertaken by the HA and EA to investigate the chronic effects of sediment-bound pollutants on the ecology of receiving waters (Gaskell et al., 2008) [**S2**]*. This research identifies the scenarios under which contaminated sediment in runoff would be likely to have a negative impact on receiving water ecology. The results have been used to develop Threshold Effects Levels (TELs) and Probable Effects Levels (PELs) for metal and PAH concentrations in sediment. .....This research is discussed in further detail in Chapter 3 and forms the basis of the risk assessment procedure discussed in Chapter 5*." [**S1**]. Chapter 5 in the manual introduces and explains the use of the HAWRAT tool, and again draws on our research [**S2**].

Impacts on practitioners: Commenting on the impact of our research, the HA has stated:

"*The outputs of this research have had a major impact on the policies and practices of the HA, resulting in a more efficient and sustainable use of resources and enhancing environmental protection. It has also informed policy formulation by UK government departments and the resulting guidance has been adopted by several other countries*.

"The HA guidance is issued through the Design Manual For Roads and Bridges (DMRB) which is signed up to and used by the Devolved Administrations (Scotland, Wales & Northern Ireland). DMRB has also been adopted elsewhere most notably in Ireland, Australia and most parts of the Middle East. The Japanese have developed a hybrid version and the Chinese have had it translated for their use. The Portuguese, via the National Laboratory for Civil Engineering, used the outputs from this research to develop "Guidelines for the Integrated Management of Road Runoff in Portugal." [**S3**]. Our research has also informed the Norwegian Public Roads Administration's research and development programme [**S4**].

In the UK, "*Since 2010, HD45 has been applied to approximately 5–10 major projects (> £10m) and 30 –50 smaller improvement schemes (£0.5–5.0m). In the future it can be expected that there will on average be 2–3 major projects and 10–20 improvement/maintenance schemes that the advice will routinely be applied to on an annual basis"* [**S3**]. The DMRB guidance and HAWRAT resulting from our research has been used in a large number of environmental impact assessments of road projects across the UK (e.g. in England [**S5**], Scotland [**S6**] and Northern Ireland [**S7**]).

Economic impacts: "*The revised guidance has led to rationalisation of design with significant cost savings on some projects and more sustainable use of resources on others. It is not easy to separate the savings from one element of a highway design as a scheme progresses, however, as an example the updated approach to guidance was in part attributable to a saving of c. £1m on a widening scheme on the M1*" [**S3**]. Savings accrue from more targeted use of interventions. Our research contributed to an important change in the Environment Agency's policy for dealing with road runoff, providing a measured, risk-based approach to replace the blanket requirement for silt traps and oil separators on all discharges from motorways and major trunk roads. We enabled this risk-based approach to be extended from only considering soluble contaminants (DMRB, 2006) to now including sediment-bound contaminants (which we showed can have a much greater impact on the ecology of receiving waters) in the most recent guidance (DMRB, 2009) [**S1**].

Impacts on public policy: Our research strengthened cooperation between the HA and EA, with the *HD45/09: Road Drainage and the Water Environment* forming part of the key commitments between the two agencies specified in their 2009 memorandum of understanding [**S8**]. "*The research has contributed towards a shared understanding between the HA and EA of the environmental impacts and risks associated with routine non-urban highway runoff and an agreed position on how to address risks*" [**S3**]. Through this, our research input to *HD45/09* has influenced secondary legislation in relation to Sustainable Urban Drainage Systems (SuDS) and "*has been used to inform central government departments on policy formulation, in particular development of the National SuDS Standards*" [**S3**].

"*The research was used to inform the development of secondary legislation for Floods and Water Management Act 2010, which granted an exemption to the HA from the SuDS Approval Board for its drainage designs (The Sustainable Drainage (Approval and Adoption) (England) Order 2012 (Clause 3(1)(b)(i))* [**S3**]. Prior to this exemption, most of the HA's construction work would require approval

under this Act, a process that can have considerable time and cost implications. However, because the HA uses the HAWRAT tool to guide assessment and design of highway drainage systems, they are exempted from the need to seek approval. The HA must comply with the requirements of the Act, but have become their own approval board, saving time and money.

Impacts on the environment: "*The outputs of this research are being used to assess the risk of pollution arising from existing highway outfalls on the HA network that are a legacy of design practices which, whilst appropriate at the time of construction, would not meet today's stricter environmental requirements.*" "*The new guidance is a more robust approach to environmental impact assessment ensuring identified risks are mitigated effectively through the design process, and that resources are directed and used in the most effective way*" [**S3**].

Our research outputs are *"being used to develop a code of practice and set of tools that can be adopted by Local Highway Authorities to assist them with meeting their obligations under the EU Water Framework Directive (WFD).*" "*This research has had considerable impact beyond the HA. It has informed the EA's Source Apportionment Tool used in WFD planning, contributes towards DEFRA's programme of work to tackle non-agricultural sources of diffuse pollution and will inform the second round of River Basin Management Planning and associated Programme of Measures*" [**S3**].

In addition, our project partner at the EA has stated that "*Given the recently announced £28bn spending on roads, having the tools to identify where mitigation measures are needed and where they provide no benefit will have immense value. In the past, the Environment Agency has demanded the provision of facilities such as oil separators at virtually every site, which may not always provide good value for money. In the future programme the Highways Agency guidance will enable both the regulators and the highways operators to invest in protection of the environment where it is needed and effective and not elsewhere*" [**S9**].

In conclusion, our research has played a crucial role in the development and implementation of ecological risk assessment tools for road runoff contaminants that have been widely used in the UK and internationally to the benefit of the environment and greater cost-effectiveness.

5. Sources to corroborate the impact

S1 Highways Agency (2009) *Design Manual for Roads and Bridges. Volume 11 Environmental Assessment*, *Section 3 Part 10 HD45 Road Drainage and the Water Environment* (http://tinyurl.com/o39kcr5) See especially Table 3.3 – which specifies the TELs and PELs for metal and PAH concentrations in sediment from the values we provided in our commissioned technical report [**S2**].

S2 Gaskell P, Maltby L, & Guymer I, (2008). *Accumulation and Dispersal of Suspended Solids in Watercourses, ECUS, University of Sheffield, University of Warwick, Report No. HA3/368, UK.* Technical report that integrates our Castrol and HA-funded research work.

S3 Head of Drainage and Water, The Highways Agency. Detailed explanation of the impact of our research for the Highways Agency, and the Environment Agency, and its international reach and significance. [Letter on file]

S4 NPRA (2013). Rensing av vann fra veg og anlegg. Rapportnumner 195 (in Norwegian) [Title translation: Treatment of runoff from building and operating of roads] (http://tinyurl.com/q7hkkaw)

S5 Highways Agency (2012) M1 Junction 19 Improvement. Supplementary Note 9. (http://tinyurl.com/ov8cf55)

S6 Transport Scotland (2013) The A737/A738 Trunk Road (Dalry Bypass) (http://tinyurl.com/q3ht28f)

S7 Department for Regional Development Northern Ireland (2013) A8 Belfast to Larne (e.g. p 239) (http://tinyurl.com/oplj79r)

S8 Memorandum of Understanding between the Highways Agency and Environment Agency. (http://tinyurl.com/ppv63aw)

S9 Philip Chatfield (2013). Environment Agency liaison for our research with HA, now in the Energy, Water and Flood Division in the Welsh Government. [Email to Prof. Maltby on file].