Institution: Loughborough University

Unit of Assessment: C17 Geography, Environmental Studies and Archaeology

Title of case study: Shaping practices in the management of river sediments

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

Fluvial geomorphology research at Loughborough University has impacted on the approaches and procedures of practitioners responsible for characterising and managing river-bed sediments. Dr Graham's research has underpinned the development to commercialisation of an automated method for measuring river-bed sediment size. The associated cost-saving benefits have had an international reach into field practice, demonstrated by non-academic software sales across Europe, North America and Australasia. Professor Rice's research has underpinned strategies focused on managing river sedimentation problems, as well as the design of new tools and adoption of new approaches, especially in the USA, aimed at better managing fish populations.

2. Underpinning research (indicative maximum 500 words)

Two closely related examples of research at Loughborough University that has underpinned impacts in river sediment management are: (1) Dr Graham's Sedimetrics® Digital Gravelometer™ software for automated grain-sizing; and (2) Professor Rice's research on sediment connectivity in river ecosystems.

Automated grain-sizing Work on automated techniques for sizing river-bed gravels was initially funded by a Leverhulme Trust award **[G3.1]** to Professor Stephen Rice (1995-present) and Professor Ian Reid (1994-present) which employed Dr David Graham (2001-present) as a research assistant at Loughborough University (2001-2002). The research was commercialized during Dr Graham's employment as a Gatsby Foundation Innovation Fellow (2004-2005) **[G3.2]**, after which he was employed by Loughborough University as a full-time lecturer. Surface grain-size in rivers is a commonly-measured parameter because of its importance for river hydraulics, sediment transport fluxes and fisheries habitat. Automated grain sizing is beneficial because conventional, manual procedures are labour intensive and time consuming. This makes sediment sampling costly and impacts data quality by limiting the size of individual samples and/or the numbers that are collected across space and time. Dr Graham developed innovative algorithms and processing procedures to automatically extract grain-size information from digital photographs. These procedures were experimentally tested to ensure transferability between a variety of sedimentary environments. The resulting Automated Grain Sizing (AGS) technique can be applied under diverse field conditions without recourse to local parameterization to optimize performance **[3.1, 3.2]**. Subsequent research has developed practical guidance on sampling procedures so that practitioners can optimize the quality of the derived grain-size data whilst minimizing field time and cost **[3.3]**.

Sedimentary links in fluvial landscape ecology Underpinning knowledge relevant to this impact emerged from research on coarse sediment connectivity that Professor Rice undertook during his PhD in Canada. Research published between 1996 and 1998 after his appointment at Loughborough University as a lecturer in 1995, showed the importance of tributary sediment loads for modifying river-bed sediment character. That research included the definition of sedimentary links, which are analogous and sometimes equivalent to hydrological links, but structure river sediment routing. Refinement of these concepts benefitted from the strength of freshwater science in Geography at Loughborough University and focused on the potential importance of sedimentary links for riverine ecosystems. Subsequently, competitive funding from the Royal Geographical Society **[G3.3]** facilitated new Loughborough-based research into the ecological implications of

sedimentary links. That work demonstrated how sediment recruitment points along rivers affect substantial shifts in physical habitat **[3.4]** and led to an important conceptual breakthrough: sedimentary and hydrological networks configure an abiotic framework within which confluence nodes and the intervening channel links are important spatial elements of biotic organisation **[3.5]**. Further research funded by the Natural Environment Research Council **[G3.4]** modelled some of these processes **[3.6]** and led to a fuller understanding of the role of tributary junctions in producing biodiversity hotspots within riverine ecosystems. By recognizing the ecological role of tributary junctions, sedimentary links and fluvial network structures this work has contributed to the development of an emerging paradigm, *fluvial landscape ecology*, which has broad implications for the conservation and management of aquatic ecosystems.

3. References to the research (indicative maximum of six references)
Research outputs in peer-reviewed international journals, with evidence of quality summarised [in brackets].

3.1. Graham DJ, Rice SP and Reid I. (2005) "A transferable method for the automated grain sizing of river gravels", *Water Resources Research,* **41**(7), W07020, DOI: 10.1029/2004WR003868. [WoS cites = 31; Journal impact factor 3.149. Ranked 3/80 [Q1] in Water Resources]

3.2. Graham DJ, Reid I and Rice SP. (2005) "Automated sizing of coarse-grained sediments: Image-processing procedures", *Mathematical Geology,* **37**(1), 1-28, DOI: 10.1007/s11004-005-8745-x. [WoS cites = 33; Journal impact factor 1.440, ranked 26/92 [Q2] in Interdisciplinary Applications of Mathematics]

3.3. Graham DJ, Rollet A-J, Piegay H, Rice SP. (2010) "Maximising the accuracy of image-based surface sediment sampling techniques", *Water Resources Research,* **46**(2), W02508, DOI: 10.1029/2008WR006940. [WoS cites = 5; Journal impact factor 3.149. Ranked 3/80 [Q1] in Water Resources]

3.4. Rice SP, Greenwood MT, Joyce CB. (2001) "Macroinvertebrate community changes at coarse sediment recruitment points along two gravel-bed rivers", *Water Resources Research,* **37**(11), 2793-2803, DOI: 10.1029/2000WR000079. [WoS cites = 20; Journal impact factor 3.149. Ranked 3/80 [Q1] in Water Resources]

3.5. Rice SP, Greenwood MT, Joyce CB. (2001) "Tributaries, sediment sources, and the longitudinal organisation of macroinvertebrate fauna along river systems", *Canadian Journal of Fisheries & Aquatic Sciences,* **58**(4), 824-840, DOI: 10.1139/f01-022. [WoS cites = 107, Journal impact factor 2.323. Ranked 23/100 [Q1] in Marine and Freshwater Biology]

3.6. Rice SP, Ferguson RI and Hoey TB. (2006) "Tributary control of physical heterogeneity and biological diversity at river confluences", *Canadian Journal of Fisheries and Aquatic Sciences,* **63**(11), 2553-2566, DOI: 10.1139/f06-145. [WoS cites = 25, Journal impact factor 2.323. Ranked 23/100 [Q1] in Marine and Freshwater Biology]

Grants (£'s given are the allocation to Loughborough University)

Code	*Dates*	*Title*	*Funder*	*Amount*
G3.1	*2000-2002*	*Innovative sediment characterisation for river research and management: a pilot (Rice, PI)*	Leverhulme	£14,137
G3.2	2004-2005	*Innovative measurement technology for granular materials (Rice Co-I)*	Gatsby Foundation	£24,079
G3.3	1997-1998	*The role of tributary and other sediment inputs in punctuating benthic gradients in lotic ecosystems (Rice PI)*	Royal Geographical Society	£2,970
G3.4	*2001-2004*	*Modelling the impacts of sediment inputs along gravel-bed rivers (Rice PI)*	NERC	£105,822

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

Automated grain-sizing Automated Grain Sizing (AGS) procedures are fast and efficient, driving down field time and costs whilst maximising data quality. These significant advantages make AGS methods very attractive to practitioners charged with measuring surface grain size in rivers. The AGS procedures described above were developed into a commercial software package, marketed under the *Sedimetrics*® brand (full details at http://sedimetrics.com).

The international reach and extent of this impact is evidenced by sales of the Digital Gravelometer™ software made to North America (USA, Canada), Australasia (New Zealand), the Middle East (Israel) and across Europe (UK, Greece, Czech Republic, Italy, Germany, France, Slovakia). A total of 36 licences have been sold since 2008 **[5.1]**.

The software has been used by the commercial sector in high-profile consultancy projects, including assessing the environmental impacts of a new 1100 MW hydroelectric power dam for the British Columbia Hydro and Power Authority **[5.2]**. Other commercial clients include the National Institute of Water and Atmospheric Research in New Zealand, the US science and innovation company Batelle, and international engineering consultancy Knight Piésold **[5.3]**.

The software has also been used by public sector agencies responsible for environmental protection and regulation, including the Pacific Northwest National Laboratory (US Department of Energy), the US Geological Survey and the Regional Agency for Environmental Protection in the Emilia-Romagna region, Italy **[5.1]**. Officers of the Canada Department of Fisheries and Oceans use the software in assessments of fish habitat and potential fishery productivity, and urge consultants to use it in routine assessments of environmental impacts of gravel removal from rivers **[5.2]**. The Scottish Environmental Protection Agency (SEPA) is using it to perform their regulatory and statutory functions more effectively; for example, to assess sediment characteristics prior to channel engineering activities and evaluate the quality of restoration activities **[5.3]**. SEPA are also using it in a large-scale project to validate the national sediment budget model for Scotland, enabling them to meet their obligations under the EU Water Framework Directive, the Water Environment and Water Services (Scotland) Act 2007, and the Flood Risk Management (Scotland) Act 2009 **[5.3]**. As part of this work, Dr Graham has provided consultancy services to the SEPA Hydromorphology Team to ensure maximum benefit is obtained from the software and to assist in developing appropriate national protocols for its use.

Sedimentary links in fluvial landscape ecology Professor Rice's research on sediment transfer networks and their ecological importance has underpinned several impacts. First, Natural England commissioned him to establish the extent of sedimentation problems in the Upper Dove catchment of the Peak District, drawing on his research in sediment connectivity to identify likely sources of sediment pollution and management solutions. Two projects in 2010 produced a fluvial audit of sediment sources, problems and mitigation strategies within DEFRA's English Catchment Sensitive Farming Delivery Initiative and completion of six statutory Condition Assessments. Three reports were delivered to Natural England in 2011 (currently in press) and Natural England's view is that "*at least partly as a result of this work, water quality in the Dove catchment has improved.*" In addition to this benefit, the reports led Natural England to identify a number of river restoration projects for future funding and the Condition Assessments have been used by Natural England as a template for similar assessments on other rivers **[5.4]**.

In North America, government agencies (such as the United States Geological Survey and National Oceanic and Atmospheric Administration) have applied Rice's work on sedimentary links, demonstrating its reach and significance. For example, a Research Landscape Ecologist at the United States Geological Survey **[5.5]**, writes that the *"concept of sedimentary links and the role of*

tributaries in structuring physical habitat and biological response in rivers has changed the way we think about managing watersheds and monitoring trends in fish populations. We have applied this concept in … the Oregon Coast Range and along the Yakima and Elwha rivers in Washington State (non-academic partners include tribal governments, the Washington Department of Fish and Wildlife, and the National Park Service), and we have developed an entire study around the concept in collaboration with Weyerhaeuser Company … to minimize the effects of road building and timber harvest on fish populations." Rice's conceptual ideas about sedimentary links have reached the private sector where the Earth Systems Institute (Seattle, Washington) refer to his publications as a "*guiding light*" **[5.6]** in developing GIS-based tools for assessment of riverine habitat. Most recently this includes NetMap **[5.7]**, a community-based watershed GIS system that uses Rice's work on the importance of tributary junctions as biodiversity hotspots.

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

The following sources of corroboration can be made available at request:

5.1. Sales data.

5.2. University of British Columbia – corroborating letter.

5.3. Scottish Environmental Protection Agency (SEPA), Senior Hydromorphologist, Hydromorphology Team – corroborating email.

5.4. Natural England, Land Use Operations Manager, Midlands Team – corroborating letter.

5.5. United States Geological Survey, Research Landscape Ecologist – corroborating letter.

5.6. President, Earth System Institute, earthsystems.net – corroborating e-mail

5.7. Web page of community-based watershed science GIS system, http://netmaptools.org