Institution: Queen Mary University of London		
Unit of Assessment: 14 Geography and Environmental Studies		
Title of case study: Hydrogeomorphological Monitoring and Assessment Tools for Rivers		
Period when the underpinning research was undertaken: 2010–2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed:**
Angela Gurnell	Professor of Physical Geography	2009–present
Geraldene Wharton	Professor of Physical Geography	1990–present
Period when the impact occurred: 2014 to July 2020		
Is this case study continued from a case study submitted in 2014? N		

1. Summary of the impact

Research at Queen Mary University of London has created a set of multi-scale tools for assessing river form, function and condition that have enabled stakeholders in river catchments to know their rivers better and manage them more sustainably. These tools connect rivers' diverse ecological habitats with their dynamic geomorphological characteristics and permit river scientists and managers to integrate data to improve spatio-temporal understanding of river systems. This supports a more robust and sustainable river environment management decision.
The tools have been integrated into river monitoring and assessment regimes in the UK and EU, and have been extensively taken-up by citizen scientists and river managers in the UK and Republic of Ireland. Together the tools deliver geomorphologically-framed information for habitat-based river monitoring and assessment, enabling statutory agencies, NGOs, consultants and volunteers, in England and across Europe, to achieve sustainable environmental goals.

2. Underpinning research

Natural processes and human actions drive the form and function of rivers from small patches of the river bed to entire catchments across timescales from hours to centuries, and yet the majority of assessments of river condition are only based on limited habitat inventories, often recorded on a single occasion. Our overarching aim is to use our fundamental research on the complex interactions between rivers, vegetation and landscape to underpin applied research. This applied research builds and tests multi-scale, geomorphologically-informed, monitoring and assessment tools for river management and conservation by stakeholders from volunteers to professionals. With over thirty years of experience interlinking fundamental and applied research, Gurnell and Wharton have produced a body of work on river management and conservation, as exemplified by the six peer-reviewed outputs listed.

Fundamental research

Our research has demonstrated that vegetation growing both from the bed and along the banks and margins of rivers plays a crucial role in driving river form and function by retaining and stabilising sediments that are transported by the river [3.1, 3.2, 3.3, 3.4]. These vegetation-river interactions can be observed even in wide, high-energy rivers such as the >600 m wide, braided River Tagliamento, Italy [3.3] and operate at all scales from small patches on the river bed and banks [3.4] to entire river corridors and networks [3.1, 3.2]. For example, across all unmanaged, humid temperate rivers, uprooted riparian trees (willows, poplars) can sprout when deposited on the river bed, bars or along channel edges. These tree species grow rapidly, trapping and stabilising fine river sediments to form new, expanding landforms and habitats that are quickly colonised by other plants to form islands and extensions to the river's banks. Such natural vegetation-river interactions fundamentally influence the morphology and lateral migration of rivers and can be used judiciously by river managers to support sustainable, low cost, river self-restoration and maintenance. At *catchment to river corridor scales* our research over two decades has produced highly innovative conceptual models of the nature and extent of river hydroecological and biomorphodynamic influences and responses. This research has recently

included a new process-based zonation of river corridors applicable across biogeographical regions and river types [3.2]. At *reach to sub-reach scales*, we have spearheaded scientific understanding of the fundamental dependence of river morphodynamics on interactions between vegetation and fluvial processes [3.1] in different environments [3.3, 3.4].

Since 1 January 2014, we have published over 50 fundamental science peer-reviewed papers and book chapters that are relevant to framing and designing the assessment tools outlined here. This research has been supported by funding from EU FP7, NERC, Leverhulme Trust, Marie Curie, Erasmus Mundus, and the Irish Environmental Protection Agency [EQR.3.1-3.6] and numerous PhD theses (NERC-funded: Cockel, 2010; NERC-ESRC funded: Shuker, 2012; SMART-funded: Cashman, 2014; Garcia Lugo, 2014; Holloway, 2015; Mardhiah, 2014; Mohajeri, 2014; Pilotto, 2014; Sekarsari, 2014; Serlet, 2018)].

Applied research

Within the work package led by Gurnell, the REFORM project [EQR.3.3, 5.7] produced the multi-scale, Catchment Framework for Hydrogeomorphology subsequently adopted by the European Committee for Standardization (CEN). This Framework defines the appropriate river landscape processes and properties to be analysed at different space-time scales and then synthesised to determine river-floodplain system functioning, and the degree of modification by human activities. The Framework has been peer reviewed [3.5], is already heavily cited, and has led to collaboration with the Environment Agency to disseminate and explain the Framework's potential application in the UK through publication in the professional *Water Environment Journal***.**

Applied research has also delivered scientifically robust *reach and sub-reach scale* tools to capture river morphodynamics with sufficient precision to support inferences about processes from forms (for example, noting the presence of geomorphic or vegetation features that are formed by particular sets of processes such as bank erosion and sediment deposition) and to determine morphodynamic responses to measured processes (such as linking observed changes in geomorphic or vegetation features to changes in measured river flows or sediment transport). These tools include PlaceMarker, funded by the Environment Agency (ca. GBP 60,000), which incorporates the Urban River Survey [5.8]. The tools also include MoRPh CSci, a hydrogeomorphology-habitat assessment tool designed for use by citizen scientists that has been subject to peer review and publication in *Earth Surface Processes and Landforms*, financially supported by the EA and others (ca. GBP 30,000), and communicated to users via the *Water Environment Journal* publication**.** MoRPh CSci has been refined for professional use (MoRPh Pro) and combined with River Type**,** a tool for determining the geomorphic type of river under analysis, to produce an innovative, peer-reviewed method for River Condition Assessment (RCA, [3.6]). RCA delivers the river condition component of BM2 [5.6]**,** which is Natural England's / DEFRA's method for measuring and accounting for biodiversity losses and gains resulting from development or land management change across England.

Since 1 January 2014, we have published 15 applied science peer-reviewed papers and book chapters relating to the above tools or to broader aspects of river conservation and management.

3. References to the research

[3.1] Gurnell, A.M. (2014). Plants as river system engineers. *Earth Surface Processes and Landforms, 39*(1), 4-25. doi.org/10.1002/esp.3397

[3.2] Gurnell AM, Corenblit D, García de Jalón D, González del Tánago M, Grabowski RC, O'Hare MT, Szewczyk M. (2016). A conceptual model of vegetation-hydrogeomorphology interactions within river corridors. *River Research and Applications*, 39(2), 142-163. doi.org/10.1002/rra.2928

[3.3] Gurnell, A.M., Bertoldi, W. (2020). Extending the conceptual model of river island development to incorporate different tree species and environmental conditions. *River Research and Applications*, *36*(8), 1730-1747. doi.org/10.1002/rra.3691

[3.4] Cornacchia L, Wharton G, Davies G, Grabowski RC, Temmerman S, van der Wal D, Bouma TJ, van de Koppel J. (2020). Self-organization of river vegetation leads to emergent buffering of river flows and water levels. *Proceedings of the Royal Society B, 287*(1931), 20201147.

doi.org/10.1098/rspb.2020.1147 [3.5] Gurnell AM and 33 others. (2016). A multi-scale hierarchical framework for developing understanding of river behaviour to support river management. *Aquatic Sciences*, *78*(1), 1-16. doi.org/10.1007/s00027-015-0424-5.
[3.6] Gurnell, A.M., Scott, S.J., England, J., Gurnell, D.J., Jeffries, R., Shuker, L., Wharton, G. Assessing river condition: A multiscale approach designed for operational application in the context of biodiversity net gain. *River Research and Applications*, *36*(8), 1559-1578. doi.org/10.1002/rra.3673.

Evidence of the quality of research

[EQR.3.1] Gurnell, A. [PI]. (2009-2012). Biogeomorphology of Riparian Systems: Space, Time and New Information Sources [F/07 040/AP]. *Leverhulme*. GBP146,748.
[EQR.3.2] Gurnell, A. [PI]. (2009-2011). Physical Ecosystem Engineering by Riparian and Aquatic Plants [NE/FO14597/1]. *NERC*. GBP224,846.
[EQR.3.3] Gurnell, A. [Co-I and Work Package 2 lead] (2011-2015) Restoring rivers FOR effective catchment Management (REFORM) [282656]. *European Commission*. FP7 Project. EUR6,997,602.50.
[EQR.3.4] Wharton G. [Co-I]. (2013-18). HYTECH [N.316546]. *Marie Curie*. FP7-PEOPLE-2012-ITN. EUR3,900,000.
[EQR.3.5] Wharton, G. [Co-I]. (2011-2019). Sustainable Management of Rivers and their Tidal systems (SMART). Erasmus Mundus PhD programme FPA [2011-2024]. EUR1,141,932.
[EQR.3.6] Gurnell, A. [Co-I]. (2018-2022). Managing the small stream network for improved water quality, and biodiversity and ecosystem services protection (SSNet) [2017-W-LS-14]. *Irish Environmental Protection Agency*. EUR499,995.35.

4. Details of the impact

Impact on river management in Europe

The multi-scale Hydrogeomorphological Framework has underpinned the rewriting of European Union guidance for river management under the Water Framework Directive (WFD) by demonstrating the following:

i) the interaction of ecological and physical processes to create the river's landform-habitat mosaic both over time and across spatial scales within and far beyond the boundaries of individual river reaches; and
ii) the key role of vegetation in driving river morphodynamics within these interactions.

In March 2015, Gurnell presented the Framework to ECOSTAT, the working group on the Common Implementation Strategy of the WFD and the body charged with ensuring a collective and co-operative approach to the challenges of integrated river basin management across EU member states. The chair notes the Framework's role in enabling the necessary harmonization of assessment methods, and concludes that:

> 'Key to the success of this approach was the active engagement of Prof. Gurnell [with] groups working on the science-policy interface such as ECOSTAT' [5.1]**.**

The ensuing impact of the method at EU scale is demonstrated by its incorporation into a new European standard. As the chair of the Working Group (CEN/ TC 230/ WG 25) in the European Committee for Standardization (CEN) that produced this Standard, confirms Gurnell 'played a key role in redesigning and rewriting' [5.2] the *Guidance Standard for Assessing the HydromorphologicalFeatures of Rivers* (EN 14614:2020), which was published in 2020. The new guidance standard is heavily based on the REFORM framework. It delivers a common mode of Hydromorphological assessment to river professionals and to the National Standards Bodies in 34 European countries including the UK (British Standards Institution).

Transforming river monitoring and assessment

Underpinned by cutting-edge river science, Framework-compatible *reach* and *sub-reach* tools (MoRPh CSci, MoRPh Pro, River Type, PlaceMarker) have been designed to operate through information systems with easy-to-use data entry, mapping and download features [5.9]. These methods assemble and interpret data on the sedimentary, geomorphological, hydraulic and vegetation characteristics of rivers, and the degree of human interventions and pressures along

them and their margins. In the case of Placemarker, assessments go beyond the river edges to evaluate the biodiversity, landscape, heritage and amenity characteristics of the surrounding river corridor / floodplain. All tools are supported with training packages (taught courses, manuals, field guides, field survey forms, worked examples), enabling stakeholders from volunteers to professionals to produce scientifically rigorous data on specific rivers. These easily accessible supporting materials have greatly enhanced uptake of the tools and their impact on river monitoring and management.

PlaceMarker underpins the work of the EA's National Environmental Assessment and Sustainability (NEAS) team for pre- and post-appraisal of river projects, where it is used to assess innovative approaches to environmental design. As of 15 December 2020, 91 EA staff have been trained and the survey is being used on over 80 river stretches in England. This adds to the widespread use of the Urban River Survey, for which 198 surveyors have been trained and 669 surveys have been conducted since 2000, mainly in England, Wales and the Republic of Ireland, but also in Belgium, Germany and Singapore. In November 2018, an evidence-gathering exercise was conducted on PlaceMarker's impact within NEAS to ensure its continued relevance. The Head of NEAS, said that the tool had made 'a significant difference' to their ways of working and that its ability 'to make specific improvement into the future as needs require [was] an important aspect of the usability of the tool as flood risk management moves toward creating resilient communities to respond to the climate emergency' [5.3].

The MoRPh CSci tool (available since mid-2016) has been rapidly adopted and has significantly improved river monitoring and project appraisal by 'citizen science' volunteers interested in the 'health' of their rivers. The EA's Principal Research Scientist (Hydromorphology), said:

> 'Until this approach was developed, we did not have a consistent approach that we could use to assess river habitats and processes at a relevant scale to match our biological sampling […] Your expertise and openness to collaboration and including us within the development and trial of the approach has been key to its success' [5.4].

As of 15 December 2020, there are 488 MoRPh CSci surveyors who have jointly undertaken and uploaded 4487 MoRPh surveys. In addition to 49 EA staff, many of whom are involved in running catchment partnerships, other river professionals (e.g. Affinity Water, Broads Authority, EA, Forestry England, National Trust, Wessex Water) and numerous NGOs (e.g. Rivers Trusts: Essex, Ouse and Arun, Severn, South-East, Thames21; Wildlife Trusts: Dorset, Essex, Kennet, Norfolk, Suffolk, Trent, Wiltshire) are using MoRPh CSci to evaluate river restoration and natural flood management projects.

The success of MoRPh CSci led to the development of a professional version, MoRPh Pro, which combines with a new desk-based tool, River Type, to produce a geomorphologically-driven River Condition Assessment (RCA) [see 3.6 for a full description of the RCA]. The RCA feeds into Natural England's / DEFRA's Biodiversity Metric 2.0 (BM2) [5.6]. BM2:

> 'provides developers, planners, land managers, and others with a tool to help limit damage to nature […] and to help it thrive' [5.6].

It uses habitat features as a proxy measure for capturing the value and importance of nature, taking into account their size, ecological condition, location and proximity to nearby 'connecting' features. BM2 enables assessments to be made of the present and potential future biodiversity value of a site. BM2 is approaching the end of the beta testing stage with the final version currently scheduled for release in 2021. The River Condition Assessment (RCA) component of BM2 (i.e. linked MoRPh Pro and River Type tools) was released in September 2019. Training has been significantly impacted by Covid-19, although development of an online training course has maintained the training programme through 2020. As of 15 December 2020, there are 40 EA staff with access to MoRPh Pro; 67 surveyors from 23 environmental consultancies (including Aecom, Arup, Ascerta, Atkins, Black & Veatch, cbec, FPCR, Jacobs, Mott MacDonald); and 25 surveyors from 17 Rivers Trusts who are trained in the RCA and have jointly collected 2121 MoRPh Pro surveys. The EA's lead on BM2 [5.6], said:

> 'The survey you have developed […] is a major component in evaluating Biodiversity Net Gain for Rivers and Streams. Without your input we do not feel that the evaluation for rivers and streams would have been as robust, or methodical' [5.5].

Applied research continues to expand the MoRPh family of high-impact assessment tools [5.9]. These will soon include MoRPh Estuaries and MoRPh Canals physical assessment tools and Sediment budget and Floodplain characterisation tools, founded on collaborations with the EA, Thames21 and the Canal and River Trust.

5. Sources to corroborate the impact

[5.1] [Testimonial] Chair ECOSTAT. *European Commission Joint Research Centre* (31 October 2019). [Corroborator 1]

[5.2] [Testimonial] Chair, Writing Committee CEN/ TC 230/ WG 25/ N159. *Freshwater Biological Association* (23 July 2019). [Corroborator 2]

[5.3] [Testimonial] Operations Manager, National Environmental Assessment and Sustainability, *Environment Agency* (25 October 2019). [Corroborator 3]

[5.4] [Testimonial] Principal Research Scientist (Hydromorphology), National Evidence Team. *Environment Agency*. [Corroborator 4]

[5.5] [Testimonial] Environment Agency lead for Biodiversity Metric 2.0 [5.6], Biodiversity Technical Specialist, Biodiversity and Geomorphology (now: Senior Advisor, Natural Capital, Environment & Business). *Environment Agency* (30 October 2019). [Corroborator 5]

[5.6] [Toolkit] Natural England. (29 July 2019). *The Biodiversity Metric 2.0 (JP029)*. http://nepubprod.appspot.com/publication/5850908674228224

[5.7] [Report] Restoring rivers FOR effective catchment Management (REFORM). *Homepage*. www.reformrivers.eu – for Work Package 2 deliverables D2.1 and D2.2 that relate to the 'process-based European framework for hydromorphology.'

[5.8] [Data] Urban River Survey. *Homepage*. www.urbanriversurvey.org - providing display of data and access to documents (Technical Manual; Field Guide; survey forms); a login issued after training provides facilities to enter, view, map and retrieve all existing data).

[5.9] [Data] Modular River Survey. *Homepage*. www.modularriversurvey.org - the MoRPh family of surveys providing display of data and access to documents (Technical Manual; Field Guide; survey forms); a login issued after training provides facilities to enter, view, map, and retrieve all existing data.