18

GEOMORPHIC ENGINEERING

Concepts of environmental geomorphology and geomorphic engineering were introduced to headline the ways in which geomorphological research can be directly relevant to environmental management and planning. They provide a focus for applied research embracing environmental auditing, impacts, evaluation and prediction/design with many successful applications now demonstrated and core skills recognized. Further potential for geomorphic engineering could reinforce a holistic approach that positions specific problems in their spatial and temporal contexts.

Figure 18.1 Paradigm lock. An illustration is provided on page 3 of http://www.unesco.org/water/news/pdf/Guadiana_Final_Report.pdf)

The paradigm lock was identified by HELP established in 1999, under UNESCO as a cross-cutting programme component that established a global network of basins to improve the links between hydrology and the needs of society. The ultimate goal of the programme is to help scientists and stakeholders break through the traditional paradigm lock that separates them from integrated solutions.

Table 18.1 Developments related to geomorphic engineering

Year	Examples of Developments in:		
	Publications		National and international trends
	Geomorphology	Related sciences	
1969			National Environmental Policy Act (NEPA) in USA
1970	D.R. Coates (ed.) *Environmental Geomorphology*		
1971	J.A.Steers *Applied Coastal Geomorphology*		
1972		T.R. Detwyler and M.G. Marcus (eds) *Urbanization and Environment* D.R. Coates (ed.) *Environmental Geomorphology and Landscape Conservation. Volume I. Prior to 1900*	D.H. Meadows et al. *The Limits to Growth*
1973		A.G. Isachenko *Principles of Landscape Science and Physic-geographic Regionalization* D.R. Coates (ed.) *Environmental Geomorphology and Landscape Conservation. Volume III. Non-urban regions*	
1974	R.U. Cooke and J.C. Doornkamp *Geomorphology and Environmental Management*	A. Warren and F.B. Goldsmith (eds) *Conservation in Practice*	
1975		R.D. Hey and T.R. Davies (eds) *Science, Technology and Environmental Management*	

Year	Examples of Developments in:		
	Publications		National and international trends
	Geomorphology	Related sciences	
1976	D.R. Coates (ed.) *Geomorphology and Engineering* D.R. Coates (ed.) *Urban Geomorphology*	E.D. Keller *Environmental Geology* New journal initiated *Environmental Management*	
1977	J.R. Hails (ed.) *Applied Geomorphology*		
1978		T. Dunne and L.B. Leopold *Water in Environmental Planning*	
1979		K.J. Gregory and D.E. Walling (eds.) *Man and Environmental Change* K. Smith and G. Tobin. *Human Adjustment to the Flood Hazard*	
1980	D. Brunsden, J.C. Doornkamp and D.K.C. Jones (eds) *Geology, Geomorphology and Pedology of Bahrain*	M.J. Kirkby and R.P.C. Morgan (eds) *Soil Erosion* J.B. Whittow *Disasters: The Anatomy of Environmental Hazards* D.J. Parker and E.D. Penning-Rowsell *Water Planning in Britain.* J.C. Doornkamp, K.J. Gregory and A.S. Burn (eds) *Atlas of Drought in Britain*	World Conservation Strategy published
1981		A.S. Goudie *The Human Impact* D. Dent and A. Young *Soil Survey and Land Evaluation* D.R. Coates *Environmental Geology* T. O'Riordan *Environmentalism* New journal initiated *Applied Geography*	

(Continued)

Table 18.1 (Continued)

Year	Examples of Developments in:		
	Publications		National and international trends
	Geomorphology	Related sciences	
1982	R.C. Craig and J.L. Craft (eds.) *Applied Geomorphology* R.U. Cooke, D. Brunsden, J.C. Doornkamp and D.K.C. Jones *Urban Geomorphology in Drylands*		
1983	H. Verstappen *Applied Geomorphology: Geomorphological Surveys for Environmental Development*	A.P.A. Vink *Landscape Ecology and Land Use* A. Warren and F.B. Goldsmith *Conservation in Perspective* I. Douglas *The Urban Environment* K. Hewitt (ed.) *Interpretation of Calamity* C.C. Park *Environmental Hazards*	
1984	R.U. Cooke *Geomorphological Hazards in Los Angeles* J.E. Costa and P.J. Fleischer (eds.) *Developments and Applications of Geomorphology*	L. Tufnell *Glacier Hazards* G.E. Petts *Impounded Rivers*	
1985		J.C. Doornkamp *The Earth Sciences and Planning in the Third World* W.L. Graf *The Colorado River – Instability and Basin Management*	

Year	Examples of Developments in:		
	Publications		National and international trends
	Geomorphology	Related sciences	
1986	P.G. Fookes and P.R. Vaughan (eds.) *A Handbook of Engineering Geomorphology* M.G. Hart *Geomorphology, Pure and Applied*	E. Penning-Rowsell, D.G. Parker and D.M. Harding *Floods and Drainage*	
1987	T.G. Toy and R.F. Hadley *Geomorphology and Reclamation of Disturbed Lands*		*Our Common Future* (UNWCED) defined Sustainability
1988	J.M. Hooke (ed.) *Geomorphology in Environmental Planning*	A. Brookes *Channelized Rivers* P.Beaumont *Environmental Management in Drylands*	UNEP established *The Intergovernmental Panel on Climate Change* (IPCC)
1989			
1990	R.U. Cooke and J.C. Doornkamp *Geomorphology and Environmental Management: a new introduction*	R. Palm *Natural Hazards* B. Mitchell (ed.) *Integrated Water Management*	IPCC first assessment report published
1991			*Caring for the Earth: A Strategy for Sustainable Living* (IUCN)
1992			UNCED Environment and Development conference, Rio de Janeiro, included *Agenda 21*
1993			
1994		M.E. Morisawa *Geomorphology and Natural Hazards*	
1995		D.M McGregor and D.A. Thompson (eds) *Geomorphology and Land Management in a Changing Environment*	

(Continued)

Table 18.1 (Continued)

Year	Examples of Developments in:		
	Publications		National and international trends
	Geomorphology	Related sciences	
1996		E.C.F. Bird *Beach Management* A. Brookes and F.D. Shields Jnr, (eds) *River Channel Restoration: Guiding Principles for Sustainable Projects* H. Viles and T. Spencer *Coastal Problems: Geomorphology, Ecology and Society at the Coast*	World Water Council established
1997	C.R. Thorne, R.D. Hey and M.D. Newson (eds) *Applied Fluvial Geomorphology for River Engineering and Management*		
1998		J.M. Hooke *Coastal Defence and Earth Science Conservation*	
1999	J.R. Giardino and R.A. Marston *Engineering Geomorphology*	J. Petts (ed.) *Handbook of Environmental Impact Assessment* NRC *New Strategies for America's Watersheds*	
2000		P.J. Boon, B.R. Davies and G.E. Petts (eds) *Global Perspectives on River Conservation: Science, Policy and Practice*	EU established *Water Framework Directive*
2001	M. Oya *Applied Geomorphology for Mitigation of Natural Hazards*	M. Marchetti and V. Rivas *Geomorphology and Environmental Impact Assessment*	

Year	Examples of Developments in:		
	Publications		National and international trends
	Geomorphology	**Related sciences**	
2002	R.J. Allison (ed.) *Applied Geomorphology: Theory and Practice (International Association of Geomorphologists)*	P.L.K. Kneupfer and J.F. Petersen (eds) *Geomorphology in the Public Eye*	
2003			
2004		P.W. Downs and K.J. Gregory *River Channel Management*	
2005	P.G. Fookes, E.M. Lee and G. Milligan (eds) *Geomorphology for Engineers*	G.J. Brierley and K.A. Fryirs *Geomorphology and River Management: Applications of the River Styles Framework*	
2006		D.J. Anthony, M.D. Harvey, J.B. Laronne and M.P. Mosley (eds) *Applying Geomorphology to Environmental Management* L.A. James and W.M. Marcus (eds) *The Human Role in Changing Fluvial Systems*	
2007	C.R. Thorne, R.D. Hey and M.D. Newson (eds) *Applied Fluvial Geomorphology* P.G. Fookes, E.M. Lee and J.S. Griffith *Engineering Geomorphology: Theory and Practice*		

(Continued)

Table 18.1 (Continued)

Year	Examples of Developments in:		
	Publications		National and international trends
	Geomorphology	Related sciences	
2008			
2009			
2010	D.A. Sear, M.D.Newson and C.R. Thorne *Guidebook of Applied Fluvial Geomorphology*		
2011		S. Anbazhagan, S.K. Subramanian and X.J. Yang *Geoinformatics in Applied Geomorphology*	
2012			

Table 18.3 Core skills and techniques required by the early 21st century applied geomorphologist (from Downs and Booth, 2011)

Service	Skills	Example methods
Project orientation	1. Background information assembly	• Assimilation of geology, soils, vegetation, precipitation, population history, land management history, prior geomorphology reports
	2. Terrain modelling using GIS	• Empirical modelling for expected conditions • Development of process domains/ landscape units
	3. Development of conceptual models	• Expert interpretation using known site details and accepted process-form linkages in academic literature
Determination of current conditions	4. Mapping and inventorying	• Survey, aerial photographic interpretation • Field reconnaissance using rapid assessment protocols
	5. Baseline data collection	• Collation of existing data records • Collection of additional data to supplement existing records (e.g., transects and cross-sections, grain size determination)
	6. Field interpretation of current morphology and process	• Field reconnaissance using rapid assessment protocols • Expert judgement
	7. Classification and characterization of landscape units	• Application of *a priori* classification hierarchy • Characterization via statistical analysis of attributes
	8. Monitoring of site dynamics	• Repeat measurements (tracer studies, repeat transects/cross-sections) over a designated interval or following large forcing events such as high intensity rainfall, floods, storm surges)
	9. Determine regional sediment flux (also for past conditions)	• Estimate of sediment yield, budget for watershed or coastal zone

(Continued)

Table 18.3 (Continued)

Service	Skills	Example methods
Investigation of past conditions	10. Reconstruction of historical data series	• Air photo/map/survey overlay • Reconstruction of sediment flux from historical records • Use of narrative accounts, ground photographs • Vegetation composition and age
	11. Palaeo-environmental reconstruction for pre-historical conditions	• Stratigraphic analysis and interpretation of sedimentary deposits • Geochronology dating methods, e.g. radio carbon, lead 210, 237 • Erosion estimates using short-lived radio nuclides
Prediction of future conditions	11. Sensitivity analysis of potential for change	• According to measured potential for changes related to threshold: e.g., stream power • Interpretation of departure from 'expected' conditions: e.g., using hydraulic geometry comparisons, discriminant bi-variate plots • Positioning of units in expected sequence of change: e.g., channel evolution model • Statistical deterministic or probabilistic analysis • Using hydrological and sediment transport models (see below)
	12. Computer and physical model simulations	• Computer modelling of hillslope stability • Computer modelling of river bank stability • Computer modelling of sediment transport in rivers, and near shore • Modelling of planform change • Physical modelling using scale models or generic experiment in flume
Problem solution/design	13. Expert interpretation and integration	• Based on the geomorphologist's experience and mental models, project perception • Ability to determine and contextualize the historical legacy on contemporary geomorphological processes
	14. Contribution to project objectives for sustainable/ minimum maintenance/ impact	• Contribution via problem-solving forum of technical specialists, government agency representatives, other stakeholders

Service	Skills	Example methods
	15. Project siting	• Interpretation or risk analyses to determine minimum conflict point or maximum benefit between natural process and project requirements
	16. Project design	• Use of empirical and numerical models to propose process-based dimensions suitable to contemporary forcing mechanisms • Experience with implementation methods and techniques • Design of adaptive monitoring and evaluation programmes, experience in hypotheses-setting
	17. Project implementation oversight	• In assistance to project engineer
Post-project monitoring and evaluation	18. Determination of measurable success criteria	• Expert knowledge of geomorphological system relationships (analytical references)
	19. Development of monitoring and evaluation plan	• Identification of primary variables, methods, locations, and frequency of monitoring • Suggestions for suitable analyses
	20. Adaptive management response to outcomes of post-project appraisal	• Ability to interpret evaluation in context of implemented project to determine success and next steps
Expert advisory	21. Data provision	• Analytical expertise to provide data for open use or to bolster case
	22. Cross-examination capability	• Expert knowledge of specific geomorphological system and related systems to answer questions in deposition and in court

RELEVANT ARTICLES IN *PROGRESS IN PHYSICAL GEOGRAPHY:*

Brookes, A. (1985) Traditional engineering methods, physical consequences and alternative practices, *Progress in Physical Geography*, 9: 44–73.

Church, M. (2010) The trajectory of geomorphology, *Progress in Physical Geography*, 34: 265–86.

Fish, R.D. (2011) Environmental decision making and an ecosystems approach: some challenges from the perspective of social science, *Progress in Physical Geography*, 35: 671–80.

Gregory, K.J. (1979) Hydrogeomorphology: how applied should we become?, *Progress in Physical Geography*, 3: 84–101.

Newson, M. (1992) Twenty years of systematic physical geography: issues for a 'New Environmental Age', *Progress in Physical Geography*, 16: 209–21.

Poesen, J.W.A. and Hooke, J.M.(1997) Erosion, flooding and channel management in Mediterranean environments of southern Europe, *Progress in Physical Geography*, 21: 157–99.

UPDATES

Acting as an expert witness is a clear demonstration of applying geomorphology (Chapter 18, p. 199) and the general requirements are outlined together with an illustration from a California case involving the Ventura River, where building of a flood control levee restricted flow to a narrower channel, increasing unit stream power as well as potential for bank erosion and landsliding by:

Keller, E.A. (2015) Being an expert witness in geomorphology, *Geomorphology*, 231: 383–89.

Analysis of the geomorphic status of 74 river sites downstream of dams distributed across four large basins in the Iberian Peninsula, developing a Geomorphic Status (GS) index that allows assessment of the physical structure of a channel reach and its change through time, with results describing the degree of geomorphological alteration experienced by representative Iberian rivers mostly because of regulation, challenging the successful long-term implementation of river basin management programmes: Lobera, G., Besné, P., Vericat, D., Elosegi, A. and Batalla, R.J. (2015) Geomorphic status of regulated rivers in the Iberian Peninsula, *Science of the Total Environment*, 508: 101–14.

Related to the paradigm lock (p. 201 and Figure 18.1) is the Climate Change Impacts Report Card (CCIRC) which is an emerging medium for communicating climate science that attempts to bridge the gap between scientists and decision-makers and used in relation to climate change in: Fung, F., Orr, H.G. and Charlton, M.B. (2015) Research resource review, *Progress in Physical Geography*, 39: 130–34.

A suggestion that in many cases biogeomorphic ecosystem engineering in karst is *contingent*, in that the engineer organisms may have no, or different, biogeomorphic impacts in non-karst environments, and contingent ecosystem engineers have substantial geomorphic impacts whereas most work on biogeomorphology and ecosystem engineering has focused on obligate engineers – organisms whose engineering effects are at least inevitable, if not necessary to their survival is provided in: Phillips, J.D. (2016) Biogeomorphology and contingent ecosystem engineering in karst landscapes, *Progress in Physical Geography*, 40: 503–26.