

# GRAVEL-BED RIVERS

---

PROCESSES AND DISASTERS

EDITED BY  
DAIZO TSUTSUMI AND JONATHAN B. LARONNE



WILEY Blackwell



## Gravel-Bed Rivers



# Gravel-Bed Rivers

Processes and Disasters

*Edited by*

*Daizo Tsutsumi*

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

and

*Jonathan B. Laronne*

*Department of Geography and Environmental Development,  
Ben Gurion University of the Negev, Beer Sheva, Israel*

**WILEY** Blackwell

This edition first published 2017  
© 2017 John Wiley & Sons Ltd

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, except as permitted by law. Advice on how to obtain permission to reuse material from this title is available at <http://www.wiley.com/go/permissions>.

The right of Daizo Tsutsumi and Jonathan B. Laronne to be identified as the authors of the editorial material in this work has been asserted in accordance with law.

*Registered Office*

John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

*Editorial Office*

9600 Garsington Road, Oxford, OX4 2DQ, UK

For details of our global editorial offices, customer services, and more information about Wiley products visit us at [www.wiley.com](http://www.wiley.com).

Wiley also publishes its books in a variety of electronic formats and by print-on-demand. Some content that appears in standard print versions of this book may not be available in other formats.

*Limit of Liability/Disclaimer of Warranty*

The publisher and the authors make no representations or warranties with respect to the accuracy or completeness of the contents of this work and specifically disclaim all warranties, including without limitation any implied warranties of fitness for a particular purpose. This work is sold with the understanding that the publisher is not engaged in rendering professional services. The advice and strategies contained herein may not be suitable for every situation. In view of ongoing research, equipment modifications, changes in governmental regulations, and the constant flow of information relating to the use of experimental reagents, equipment, and devices, the reader is urged to review and evaluate the information provided in the package insert or instructions for each chemical, piece of equipment, reagent, or device for, among other things, any changes in the instructions or indication of usage and for added warnings and precautions. The fact that an organization or web site is referred to in this work as a citation and/or potential source of further information does not mean that the author or the publisher endorses the information the organization or web site may provide or recommendations it may make. Further, readers should be aware that web sites listed in this work may have changed or disappeared between when this work was written and when it is read. No warranty may be created or extended by any promotional statements for this work. Neither the publisher nor the author shall be liable for any damages arising herefrom.

*Library of Congress Cataloging-in-Publication Data applied for:*

Hardback : 9781118971406

Cover Design: Wiley

Cover Image: Photograph by Daizo Tsutsumi

Set in 10/12pt Warnock by SPi Global, Pondicherry, India

Printed and bound by CPI Group (UK) Ltd, Croydon, CR0 4YY

10 9 8 7 6 5 4 3 2 1

## Contents

**List of Contributors** *xix*

**Preface** *xxv*

<b>1</b>	<b>Computational Models of Flow, Sediment Transport and Morphodynamics in Rivers</b>	<b>1</b>
	<i>Cristian Escauriaza, Chris Paola, and Vaughan R. Voller</i>	
1.1	Introduction	1
1.2	Numerical Simulations in Rivers	2
1.2.1	Level 0: Reduced Complexity Models	2
1.2.2	Level 1: Diffusion Models	5
1.2.3	Level 2: Models Based on Solving the Shallow-Water Equations	7
1.2.4	Level 3: Unsteady Reynolds-averaged Navier–Stokes	8
1.2.5	Level 4: Large-Eddy Simulations	11
1.2.6	Level 5: Direct Numerical Simulations	12
1.3	Choosing the Right Modeling Approach	13
1.3.1	Models as Research Tools	13
1.3.2	Heuristics: How to Select a Modeling Approach	15
1.4	Next Steps in Modeling	20
1.4.1	High-Fidelity Modeling	20
1.4.2	Model Synthesis	22
1.5	Concluding Questions	23
	Acknowledgments	24
	References	24
	Discussion	29
<b>2</b>	<b>Boulder Effects on Turbulence and Bedload Transport</b>	<b>33</b>
	<i>A.N. (Thanos) Papanicolaou and Achilleas G. Tsakiris</i>	
2.1	Boulders in the Riverine Continuum	33
2.2	Scope and Objectives of the Study	36
2.3	Dataset Selection and Methodology	39
2.3.1	Dataset Selection	39
2.3.2	Experimental Setup and Measurement Techniques	41
2.3.3	Data Post-Processing	45
2.4	Mean Flow Field Around a Single, Wall-Mounted Boulder	47
2.4.1	Mean Streamwise Flow Velocity Field	47
2.4.2	Distribution of $u_*$ Around the Boulder	49
2.5	Mean Vortex Structure Around a Wall-Mounted Boulder	51

2.6	Collective Effects of the Boulder Array	53
2.7	Sediment Transport Within a Boulder Array	56
2.7.1	Qualitative Assessment of Flow and Sediment Deposition Patterns	56
2.7.2	Sediment Deposition Patterns around Boulders	58
2.7.3	Correspondence of Sediment Deposition and Vortex Structure Areas	59
2.8	Morphology of Depositional Patches Around Boulders	60
2.9	Concluding Remarks	61
	Notation and Abbreviations	63
	Acknowledgments	65
	References	65
	Discussion	71
<b>3</b>	<b>Granular Flows Applied to Gravel-Bed Rivers: Particle-Scale Studies of the Mobilization of a Gravel Bed by the Addition of Fines</b>	<b>73</b>
	<i>Kimberly M. Hill and Danielle Tan</i>	
3.1	Introduction	73
3.1.1	Governing Parameters Revealed Through Experimental Flume Studies	73
3.1.2	Potential Physical Mechanisms Governing the Mobilizing Behaviors	75
3.2	Insights from Rheological Models of Dry Dense Granular Flows	76
3.2.1	Rheology of Dense Granular Flows	77
3.2.2	Rheology of Dense Granular Mixtures	78
3.2.3	Rheology of Dense Granular Mixtures Applied to the Mobility Problem of Bedload Mixtures	79
3.3	Discrete Element Model Simulations of Bimodal Mixtures in Bedload Transport	81
3.3.1	Our DEM model	82
3.3.2	Simulation Procedures and Results	85
3.4	Conclusions	88
	Notation and Abbreviations	89
	Acknowledgments	92
	References	92
	Discussion	94
<b>4</b>	<b>Particle Motions and Bedload Theory: The Entrainment Forms of the Flux and the Exner Equation</b>	<b>97</b>
	<i>David Jon Furbish, Siobhan L. Fathel, and Mark W. Schmeeckle</i>	
4.1	Introduction	97
4.2	Sediment Ensembles and Rarefied Conditions	99
4.2.1	Ensembles and Ensemble Distributions	99
4.2.2	Rarefied Versus Continuum Conditions	101
4.3	Entrainment Forms of the Flux and the Exner Equation	101
4.3.1	Nonlocal Behavior	101
4.3.2	Instantaneous Flux	102
4.3.3	The Exner Equation	105
4.4	Distributions of Hop Distances and Travel Times	106
4.4.1	Disentrainment Rates	106
4.4.2	Experimental Measurements	109
4.5	The Meaning of Continuous Functions Applied to Conditions of Rarefied Transport	111
4.6	Conclusions	113



	Notation	114
	Acknowledgments	115
	References	115
	Discussion	118
<b>5</b>	<b>Revisiting the Morphological Approach: Opportunities and Challenges with Repeat High-Resolution Topography</b>	<b>121</b>
	<i>Damià Vericat, Joseph M. Wheaton, and James Brasington</i>	
5.1	Introduction	121
5.2	The Morphological Approach: a Primer	122
5.2.1	Transport Rates from Sediment Budgeting	124
5.2.2	Transport Rates from Path Lengths	124
5.3	Applying a Morphological Approach with HRT	128
5.3.1	Digital Elevation Models and DEMs of Difference	130
5.3.2	Extracting DEMs from Hyperscale Point Clouds	135
5.3.3	What More Might Hyperscale Data Reveal?	137
5.3.4	Case Study: High Frequency Morphodynamics of the Braided Rees River	141
5.4	Discussion	145
5.4.1	New Technologies, Old Problems	145
5.4.2	Channel Morphodynamics: Beyond Quantifying Flux	147
5.4.3	Future Opportunities and Challenges	148
5.5	Conclusions	149
	Acknowledgements	150
	References	150
	Discussion	155
<b>6</b>	<b>Geomorphic Controls on Tracer Particle Dispersion in Gravel-Bed Rivers</b>	<b>159</b>
	<i>Marwan A. Hassan and D. Nathan Bradley</i>	
6.1	Introduction	159
6.2	Bedload Estimates Using Tracers	160
6.3	Scales of Particle Motion	162
6.4	Types of Tracer Experiments and a Review of Results	162
6.5	Practical Relations for Travel Distance	165
6.6	Virtual Velocity	167
6.7	Burial Depth and Vertical Mixing	169
6.8	Depth of the Active Layer	171
6.9	Morphology	172
6.10	Bed Texture	176
6.11	Closing Remarks	177
	Acknowledgments	178
	References	179
	Discussion	184
<b>7</b>	<b>Bedload Transport Measurements with Geophones, Hydrophones, and Underwater Microphones (Passive Acoustic Methods)</b>	<b>185</b>
	<i>Dieter Rickenmann</i>	
7.1	Introduction	185
7.1.1	The Need for Surrogate Measuring Techniques	185

7.1.2	Passive Acoustic Methods	186
7.2	Particle Impact Systems	187
7.2.1	Swiss Plate Geophone	187
7.2.2	Japanese Pipe Microphone (Hydrophone)	190
7.2.3	Other Impact Plate Systems	192
7.3	Underwater Microphones	195
7.4	Important Findings Related to System Calibration	196
7.4.1	Calibration for Total Mass Flux	196
7.4.2	Identification of Grain Size (Classes)	197
7.5	Some Operational Aspects to be Considered For Different Systems	200
7.6	Conclusions	200
	Acknowledgement	201
	References	201
	Discussions	205
<b>8</b>	<b>Calibration of Acoustic Doppler Current Profiler Apparent Bedload Velocity to Bedload Transport Rate</b>	<b>209</b>
	<i>Colin D. Rennie, Damià Vericat, Richard D. Williams, James Brasington, and Murray Hicks</i>	
8.1	Introduction	209
8.2	aDcp Apparent Bedload Velocity	210
8.2.1	Estimation	210
8.2.2	Sampling Volume	211
8.2.3	Errors	214
8.3	Previous Calibration Efforts	215
8.3.1	Fraser River	215
8.3.2	Missouri River	217
8.3.3	Trinity River	218
8.3.4	Assiniboine River	218
8.3.5	Saint Anthony Falls Laboratory	219
8.4	Rees River Survey: New Fractional Calibration Data	220
8.4.1	Study Site	220
8.4.2	Calibration Measurements	220
8.4.3	Analysis	220
8.5	Discussion	223
8.6	Conclusions	226
	Notation	226
	Acknowledgements	227
	References	228
	Discussion	231
<b>9</b>	<b>Modeling Surface–Subsurface Exchange of Heat and Nutrients</b>	<b>235</b>
	<i>Daniele Tonina, Alessandra Marzadri, and Alberto Bellin</i>	
9.1	Introduction	235
9.2	Hyporheic Hydraulics	238
9.3	Hyporheic Residence Time	241
9.3.1	Pool–Riffle Morphology	241
9.3.2	Dune-Like Morphology	241

9.4	Damköhler Numbers	244
9.4.1	The Biogeochemical Damköhler Number	244
9.4.2	Thermal Damköhler Number	246
9.5	Role of Stream Morphology on Nitrous Oxide Emissions	247
9.6	Conclusions and Research Needs	249
	Notation	250
	Acknowledgments	251
	Appendix	252
	References	253
	Discussion	259
<b>10</b>	<b>Ecological Effects of Flow Intermittence in Gravel-Bed Rivers</b>	<b>261</b>
	<i>Thibault Datry</i>	
10.1	Introduction	261
10.2	Flow Intermittence in GBRs from a Hydrological Perspective	261
10.2.1	What is Flow Intermittence?	261
10.2.2	Intermittent Rivers: Importance and Distribution	263
10.2.3	Origins, Causes of Flow Intermittence, and Trends	265
10.3	Flow Intermittence in GBRs: an Ecohydrological Perspective	270
10.3.1	Flow Intermittence and Habitat Dynamics in GBRs at the Local Scale	270
10.3.2	Flow Intermittence and Habitat Dynamic in GBRs at the Reach Scale	273
10.3.3	Flow Intermittence and Habitat Dynamics in GBRs at the Catchment Scale	280
10.4	Intermittent GBRs as Coupled Aquatic–Terrestrial Disturbed Ecosystems	284
10.4.1	Disturbance Ecology and Intermittent GBRs	284
10.4.2	Aquatic and Terrestrial Communities, and their Interactions, in Intermittent GBRs	285
10.5	Flow Intermittence in GBRs: Research Needs and Open Questions	286
10.5.1	How Many, Where, How, and Why?	286
10.5.2	The Vertical Dimension: Surface- and Groundwater Interactions in Intermittent GBRs	287
10.5.3	Diversity Patterns and Community Dynamics at the Catchment Scale in Intermittent Rivers	287
10.5.4	Evolutionary Perspectives in Intermittent Rivers	287
10.5.5	Aquatic–Terrestrial Interactions in Intermittent GBRs	288
10.5.6	What are the Costs of Not Managing and Protecting Intermittent GBRs?	288
	Acknowledgements	288
	References	288
<b>11</b>	<b>Catastrophic Deposition of Gravel from Outbreak Floods</b>	<b>299</b>
	<i>Paul A. Carling</i>	
11.1	Introduction	299
11.2	Depositional Context	300
11.3	A Framework for Description of Megaflood Sedimentary Successions	301
11.4	Typical Sequences Within a Succession	302
11.4.1	Coarse Parallel-Bedded Units	303

11.4.2	Large-Scale Clinoforms	306
11.4.3	Horizontally Bedded Laminations	309
11.4.4	Ripple and Dune Cross-Lamination	310
11.4.5	Silt Beds	311
11.4.6	Debris Flow	314
11.5	Discussion	315
11.6	Conclusions	318
	Acknowledgements	318
	References	319
	Discussion	325
<b>12</b>	<b>Linkage Between Sediment Transport and Supply in Mountain Rivers</b>	<b>329</b>
	<i>Mikaël Attal</i>	
12.1	Introduction	329
12.2	Sediment Supply to Mountain Rivers and its Influence on the Characteristics of the Sediment Available for Fluvial Transport	330
12.2.1	Spatial Variations	330
12.2.2	Temporal Variations	333
12.3	Influence of Varying Sediment Availability on Sediment Transport and Export During Floods	336
12.3.1	Geomorphic Work as a Result of the Interplay Between Flood Magnitude and Sediment Supply	336
12.3.2	Grain Size and Sediment Mobility: the Boulder Issue	338
12.3.3	Sediment Transport During Extreme Flood Events	339
12.4	Concluding Remarks	345
	Acknowledgement	345
	References	345
	Discussion	351
<b>13</b>	<b>Geomorphic Responses to Dam Removal in the United States – a Two-Decade Perspective</b>	<b>355</b>
	<i>Jon J. Major, Amy E. East, Jim E. O'Connor, Gordon E. Grant, Andrew C. Wilcox, Christopher S. Magirl, Mathias J. Collins, and Desiree D. Tullos</i>	
13.1	Introduction	355
13.2	Reservoir and Downstream Channel Responses to Dam Removal	357
13.2.1	Reservoir Erosion	357
13.2.2	Downstream Deposition	361
13.3	Factors Influencing Responses to Dam Removals	366
13.3.1	Dam Height and Removal Strategy	366
13.3.2	Relations Among Reservoir Sediment Volume, Rate of Sediment Release, and Background Sediment Flux	367
13.3.3	Reservoir-Sediment Grain Size	369
13.3.4	Breach and Post-Breach Hydrology	370
13.3.5	Downstream Valley Morphology	372
13.3.6	Watershed Geologic Setting and Geographic Context	372

13.4	Time Scales of Channel Responses to Dam Removals	373
13.5	Common Findings from Analyses of Responses to Dam Removals	375
	Acknowledgments	377
	References	377
	Discussion	381
<b>14</b>	<b>Reservoir Sediment Flushing and Replenishment Below Dams: Insights from Japanese Case Studies</b>	<b>385</b>
	<i>Tetsuya Sumi, Sameh Kantoush, Taymaz Esmaeili, and Giyoung Ock</i>	
14.1	Introduction	385
14.2	Present State of Reservoir Sedimentation in Japan	386
14.2.1	Reservoir Storage Loss	386
14.2.2	Comprehensive Sediment Management in the Sediment Routing System	387
14.3	Selecting Suitable Sediment Management Options	388
14.3.1	Classification of Sediment Management Measures	388
14.3.2	Promotion Strategy of Reservoir Sedimentation Management	388
14.4	Sediment Flushing	390
14.4.1	Classification of Sediment Flushing	390
14.4.2	Case Study in the Kurobe River, Japan	393
14.4.3	Improvement of Sediment Flushing	398
14.4.4	Environmental Impacts	404
14.5	Sediment Replenishment	405
14.5.1	Definition and Objectives	405
14.5.2	Implementation of Sediment Replenishment	405
14.5.3	Environmental Effects and Monitoring	407
14.5.4	Case Studies in Japan	408
14.6	Conclusions	410
	Acknowledgment	410
	References	411
<b>15</b>	<b>Bedload Transport in Laboratory Rivers: The Erosion–Deposition Model</b>	<b>415</b>
	<i>Eric Lajeunesse, Olivier Devauchelle, Florent Lachaussée, and Philippe Claudin</i>	
15.1	Introduction	415
15.2	The Erosion–Deposition Model	417
15.2.1	Laboratory Observations	417
15.2.2	Average Particle Velocity	420
15.2.3	Surface Concentration of Moving Particles	423
15.2.4	Bedload Transport Rate	424
15.3	Deposition Length and Bedforms	425
15.4	Spreading of a Plume of Tracers	427
15.5	Conclusions	430
	Notation	430
	Acknowledgements	431
	References	431
	Discussion	435

<b>16</b>	<b>Bedforms, Structures, Patches, and Sediment Supply in Gravel-Bed Rivers</b>	<b>439</b>
	<i>Jeremy G. Venditti, Peter A. Nelson, Ryan W. Bradley, Dan Haught, and Alessandro B. Gitto</i>	
16.1	Introduction	439
16.2	Bedload Transport, Sediment Supply, and Bed Mobility	439
16.2.1	Sediment Supply	440
16.2.2	Mobility of the Grain-Size Distribution	444
16.3	Bed Features in Gravel-Bed Rivers	446
16.3.1	Equal Mobility Regime	447
16.3.2	Selective Mobility Regime	448
16.3.3	Partial Mobility Regime	450
16.4	A Phase Diagram for Bed Features in a Gravel-Bedded River	456
16.5	Perspective and Conclusions	458
	Acknowledgments	460
	References	460
	Discussion	464
<b>17</b>	<b>Linking Debris Flows and Landslides to Large Floods in Gravel-Bed Rivers</b>	<b>467</b>
	<i>Lorenzo Marchi</i>	
17.1	Introduction	467
17.2	Interactions Between Mass Wasting and Floods in Gravel-Bed Rivers	468
17.2.1	Changes in Flow Process Type	469
17.2.2	Increase in Sediment Transport	470
17.2.3	Channel Damming and Failures of Landslide Dams	470
17.2.4	Erosion and Delivery of Large Wood Debris	475
17.3	Approaches to Prediction	477
17.3.1	Temporal Scale	478
17.3.2	Spatial Scale	478
17.4	Discussion	485
17.5	Conclusions	487
	Acknowledgements	487
	References	487
	Discussion	493
<b>18</b>	<b>Gravel Riverbed Processes Resulting from Large-Scale Landslides</b>	<b>497</b>
	<i>Chjeng-Lun Shieh and Yu-Shiu Chen</i>	
18.1	Introduction	497
18.2	Case Study: Shoufeng River	498
18.2.1	Shoufeng River	498
18.2.2	Disaster History	498
18.2.3	Transformation of the Catchment	500
18.3	Case Study: Taimali River	508
18.3.1	Background	508
18.3.2	Disaster History	509
18.3.3	Transformation of the Taimali River Catchment	509
18.4	Conclusion	512
	Acknowledgements	513
	References	513
	Discussion	513

<b>19</b>	<b>Gravel-Bed River Management Focusing on Finer Sediment Behaviour</b>	<b>517</b>
	<i>Koichi Fujita</i>	
19.1	Introduction	517
19.2	Background Information	518
19.2.1	Grain-size Distribution of Sediment Supplied to Alluvial Rivers	519
19.2.2	Material $m$ , $s$ , and $t$ for Classification of Riverbed Material	519
19.2.3	Classification of River Channels Based on Longitudinal Segment Types	519
19.2.4	Exchange Type and the Pass-Through Type for Grain-Size Group Movement	520
19.2.5	Class-A and Class-B River Systems	521
19.3	Vital Points to Advance Channel Management Strategy	522
19.3.1	Sensitivity of Flooding Probability to Riverbed Variation	522
19.3.2	Transition in Total Channel Capacity of Major Reaches of Japanese Rivers	523
19.3.3	Potential Impacts of Sediment Supply on Channel Capacity	525
19.3.4	Strategies for Channel Capacity Management	525
19.4	Role of Finer Sediment in the Expansion of Dense Vegetation Areas in Segment-1G Reaches	526
19.4.1	Deposition of a Top Fine-Sediment Layer as an Essential Process	526
19.4.2	Simulation of the Expansion and Extinction of Stable Vegetation Areas	529
19.4.3	Use of the Simulation Model for Channel Management Strategy	531
19.5	Floodplain Accretion by Finer Sediment Deposition and Resulting Channel Narrowing in Segment-2G Reaches	532
19.5.1	Channel Narrowing in the Sendai and the Powder Rivers	532
19.5.2	Mechanism of the Channel Narrowing by Fine Sediment Deposition	534
19.5.3	Development into Planar Two-Dimensional Calculation of Floodplain Accretion	538
19.6	Engineering Framework for Gravel-Bed River Management	540
	Notation	541
	Acknowledgements	542
	References	543
	Discussion	544
<b>20</b>	<b>Lahar Flow Disaster, Human Activities, and Risk Mitigation on Volcanic Rivers: Case Study of Rivers on Mount Merapi Slopes, Indonesia</b>	<b>549</b>
	<i>Djoko Legono and Adam Pamudji Rahardjo</i>	
20.1	Introduction	549
20.2	Riverbed Characteristics	552
20.3	Human Activities	554
20.3.1	Sand Mining in the Upper Pabelan River	557
20.3.2	Sand Mining in the Gendol River	557
20.3.3	Sand Mining in the Woro River	557
20.4	Sediment Management and Risk Mitigation	559
20.4.1	Damage Due to the 2010 Mount Merapi Eruption	559
20.4.2	The Human Dimension	560
20.4.3	Integrated Sediment Management	560
20.4.4	Minimizing Risk by Establishing Lahar-Flow Warning Criteria	561
20.5	Conclusions	564
	Acknowledgements	564
	References	565

<b>21</b>	<b>A Method for Estimating the Porosity of Sediment Mixtures and Application to a Bed-Porosity Variation Model</b>	<b>567</b>
	<i>Masaharu Fujita, Muhammad Sulaiman, and Daizo Tsutsumi</i>	
21.1	Introduction	567
21.2	Identification of Grain-Size Distribution	569
21.2.1	Classification	569
21.2.2	Identification	570
21.3	Relationship Between the Geometric Parameters of Grain-Size Distributions and Porosity	576
21.3.1	Particle-Packing Simulation	577
21.3.2	Measurement Method	577
21.3.3	Simulation and Measurement Results	579
21.4	An Algorithm for Estimating the Porosity	581
21.4.1	Input of Grain-Size Distribution Data	581
21.4.2	Identification and Classification	582
21.4.3	Obtaining the Geometric Parameters of Grain-Size Distribution	582
21.4.4	Estimating the Porosity	583
21.5	Application to Bed-Porosity Variation Model	583
21.5.1	Basic Equations	583
21.5.2	Conditions of Simulation	583
21.5.3	Results	584
21.6	Conclusions	586
	Acknowledgements	586
	References	586
	Discussion	588
<b>22</b>	<b>Gravel Sorting and Variation of Riverbeds Containing Gravel, Sand, Silt and Clay</b>	<b>591</b>
	<i>Masato Sekine and Yuki Hiramatsu</i>	
22.1	Introduction	591
22.2	Summary of Experiments	592
22.2.1	Experiment on a Bed with an Extremely Wide Range of Sediment Grain Size (Experimental Set 1)	592
22.2.2	Experiments on a Clay Bed (Experimental Set 2)	596
22.3	Vertical Sorting and Variation of the Riverbed with Extremely Wide Range of Sediment Sizes	597
22.4	Variation of a Clay Bed Caused by Sand or Gravel Transport Over It	601
22.5	Conclusions	606
	Notation	607
	Acknowledgement	608
	References	608
<b>23</b>	<b>Modeling Stratigraphy-Based Gravel-Bed River Morphodynamics</b>	<b>609</b>
	<i>Enrica Viparelli, Astrid Blom, and Ricardo R. Hernandez Moreira</i>	
23.1	Introduction	609
23.2	Model Formulation	612
23.2.1	Governing Equations for the Flow	613
23.2.2	Governing Equations for the Bed Material	613



23.2.3	Grain Size Specific Equations of Conservation of Bed Material in the Active Layer Model	614
23.2.4	Grain Size Specific Equations of Conservation of Bed Material in the Continuous Model	615
23.2.5	The Calculation Procedure	621
23.3	Application to a Case Inspired by the Trinity River, California, United States	621
23.3.1	The Active Layer Model Run	623
23.3.2	The Continuous Model Runs	625
23.4	Conclusions	630
	Notation	631
	Acknowledgments	633
	References	633
	Discussion	636
<b>24</b>	<b>Sediment Processes in Bedrock–Alluvial Rivers: Research Since 2010 and Modelling the Impact of Fluctuating Sediment Supply on Sediment Cover</b>	<b>639</b>
	<i>Rebecca A. Hodge</i>	
24.1	Introduction	639
24.2	Differences Between Sediment Processes in Alluvial and Bedrock–Alluvial Channels	639
24.3	Review of Sediment Processes in Bedrock–alluvial Rivers Since 2010	640
24.3.1	Grain-Scale Dynamics	641
24.3.2	Sediment Cover	643
24.3.3	Morphology and Sediment Supply/Transport/Cover: Event Timescales	643
24.3.4	Morphology and Sediment Supply/Transport/Cover: Geological Timescales	644
24.3.5	Flow	645
24.4	Literature Review Findings and Cross-Cutting Themes	646
24.4.1	Saltation-Abrasion Model	646
24.4.2	Channel Evolution	646
24.4.3	Sediment Supply	647
24.5	Outstanding Research Questions	647
24.5.1	Flow Research Questions	647
24.5.2	Sediment Supply Research Questions	648
24.5.3	Sediment Cover Research Questions	649
24.5.4	Upscaling Research Questions	650
24.6	Implications for Modelling Sediment Processes in Bedrock–Alluvial Rivers	650
24.6.1	Appropriate Level of Process Representation	651
24.6.2	Stochastic Versus Deterministic Approaches	651
24.6.3	Constraining Boundary Conditions and Input Parameters	651
24.6.4	Developing Physical Models	651
24.7	An Application of a Numerical Model of Sediment Processes	651
24.7.1	Methods	652
24.7.2	Results	656
24.7.3	Discussion	661
24.8	Conclusions	663
	Acknowledgements	664
	References	664
	Discussion	668

<b>25</b>	<b>Modelling Braided Channels Under Unsteady Flow and the Effect of Spatiotemporal Change of Vegetation on Bed and Channel Geometry</b>	<b>671</b>
	<i>Hiroshi Takebayashi</i>	
25.1	Introduction	671
25.2	Numerical Analysis Method	674
25.2.1	Framework of the Numerical Model	674
25.2.2	Hydraulic Conditions	680
25.3	Flume Experiments: Method and Hydraulic Conditions	685
25.4	Results and Discussion	685
25.4.1	Effects of Unsteady Characteristics of Water Supply on Bed and Channel Configuration	685
25.4.2	Effects of Vegetation Growth on Bed and Channel Configuration	689
25.4.3	Effects of Spatiotemporal Change of Vegetation on the Yoshino River	692
25.5	Conclusions	694
	Notation	696
	Acknowledgements	698
	References	699
	Discussion	701
<b>26</b>	<b>Modelling of Mixed-Sediment Morphodynamics in Gravel-Bed Rivers Using the Active-Layer Approach: Insights from Mathematical and Numerical Analysis</b>	<b>703</b>
	<i>Annunziato Siviglia, Guglielmo Stecca, and Astrid Blom</i>	
26.1	Introduction	703
26.2	The Saint-Venant–Hirano Model	705
26.2.1	Governing Equations	705
26.2.2	Closure Relations for Sediment Transport	707
26.3	Mathematical Analysis	708
26.3.1	The System in Matrix–Vector Form for a Two-Fraction Mixture	708
26.3.2	Analysis of Characteristics	709
26.3.3	Loss of Hyperbolic Character	712
26.3.4	Linearized Wave Dynamics	714
26.4	Assessment of Numerical Solutions	717
26.4.1	Numerical Modelling of Small-Amplitude Wave Dynamics	717
26.4.2	Streamwise and Vertical Sorting in a Flume Experiment	718
26.4.3	Failure of Numerical Solutions Under Elliptic Conditions	722
26.5	Conclusions and Research Perspectives	722
26.5.1	Restoration of Hyperbolicity	724
26.5.2	Improved Description of Vertical Sorting	724
26.5.3	Optimal Discretization of the Granulometric Curve	725
26.5.4	Two-Dimensional Morphodynamics: Bar Instability	725
	Acknowledgements	725
	References	726
	Discussion	728
<b>27</b>	<b>Physical and Numerical Modelling of Large Wood and Vegetation in Rivers</b>	<b>729</b>
	<i>Walter Bertoldi and Virginia Ruiz-Villanueva</i>	
27.1	Introduction	729
27.2	Physical Modelling of Vegetation	730

27.2.1	Flow–Vegetation Interaction	730
27.2.2	Characterization of Plant Growth and Uprooting	731
27.2.3	Reach-Scale Models of River Evolution: a Two-Way Interaction	733
27.3	Numerical Modelling of Riparian Vegetation	735
27.3.1	The Effect of Flow and Climate Change on Vegetation Dynamics	735
27.3.2	Effect on Bank Processes	736
27.3.3	Two-Dimensional Shallow-Water Models	737
27.4	Physical Modelling of Large Wood	739
27.4.1	Impact of Large Wood on Flooding	739
27.4.2	Impact of Large Wood on Habitat	739
27.4.3	Dynamics of Large Wood and River Morphology	741
27.5	Numerical Modelling of Instream Large Wood Transport	742
27.5.1	Modelling Large Wood Transport in Rivers Using a Computational Fluid-Dynamics Approach	742
27.5.2	Exploring Factors Controlling Large Wood Transport and Deposition	744
27.5.3	Potential Hazards Related to Instream Large Wood	744
27.6	Future Challenges	747
	Acknowledgements	748
	References	748
<b>28</b>	<b>Fluvial Gravels on Mars: Analysis and Implications</b>	<b>755</b>
	<i>William E. Dietrich, Marisa C. Palucis, Rebecca M. E. Williams, Kevin W. Lewis, Frances Rivera-Hernandez, and Dawn Y. Sumner</i>	
28.1	Introduction	755
28.2	First Observations of Fluvial Conglomerates on Mars	756
28.3	Some Fluvial Conglomerates on the Way to Mount Sharp	758
28.4	Estimates of Stream Velocity, Channel Discharge, and Gravel Mobility on Mars	759
28.4.1	Threshold Channel Concept	761
28.4.2	Hydraulic Geometry Applications	766
28.4.3	Analysis of Martian Gravel Conglomerates	770
28.5	Runoff Volume and Implications for Climate	773
28.6	Conclusions	775
	Acknowledgments	776
	References	776
	Discussion	779
Index		785



## List of Contributors

### ***Mikaël Attal***

School of GeoSciences  
University of Edinburgh, Edinburgh, UK

### ***Alberto Bellin***

Department of Civil  
Environmental and Mechanical Engineering  
University of Trento, Trento, Italy

### ***Walter Bertoldi***

Department of Civil  
Environmental and Mechanical Engineering  
University of Trento, Trento, Italy

### ***Astrid Blom***

Faculty of Civil Engineering and Geosciences  
Delft University of Technology  
Delft, Netherlands

### ***D. Nathan Bradley***

US Bureau of Reclamation  
Sedimentation and River Hydraulics Group  
Denver, Colorado, USA

### ***Ryan W. Bradley***

Department of Geography  
Simon Fraser University, Burnaby  
British Columbia, Canada

### ***James Brasington***

The School of Geography  
Queen Mary, University of London  
London, UK

### ***Paul A. Carling***

Geography and Environment  
University of Southampton  
Southampton, UK

### ***Yu-Shiu Chen***

Disaster Prevention Research Center  
National Cheng Kung University  
Tainan City, Taiwan, ROC

### ***Philippe Claudin***

Physique et Mécanique des Milieux Hétérogènes  
(PMMH), ESPCI Paris - PSL Research University,  
Univ. P. M. Curie - Sorbonne Universités, Univ.  
D. Diderot - Sorbonne Paris Cité, Paris, France.

### ***Mathias J. Collins***

NOAA, National Marine Fisheries Service  
Restoration Center  
Gloucester, MA, USA

### ***Thibault Datry***

IRSTEA, UR MALY  
Centre de Lyon-Villeurbanne  
Villeurbanne, France

### ***Olivier Devauchelle***

Institut de Physique du Globe de Paris, Sorbonne  
Paris Cité, Univ. Paris-Diderot, Paris, France

### ***William E. Dietrich***

Department of Earth and Planetary Science  
University of California at Berkeley  
Berkeley, CA, USA

**Amy E. East**

US Geological Survey, Pacific Coastal and  
Marine Science Center  
Santa Cruz, CA, USA

**Cristian Escauriaza**

Departamento de Ingeniería  
Hidráulica y Ambiental  
Pontificia Universidad Católica de Chile  
Santiago, Chile

**Taymaz Esmaeili**

Civil Engineering Department  
Islamic Azad University of Gorgan  
Aq Qala, Iran

**Siobhan L. Fathel**

Department of Earth and  
Environmental Sciences, and  
Department of Civil and Environmental  
Engineering, Vanderbilt University  
Nashville, TN, USA

**Koichi Fujita**

The National Institute for Land and  
Infrastructure Management (NILIM)  
The Japanese Ministry of Land,  
Infrastructure, Transport and  
Tourism (MLIT)  
Tsukuba, Ibaraki, Japan

**Masaharu Fujita**

Disaster Prevention Research Institute  
Kyoto University, Kyoto, Kyoto, Japan

**David Jon Furbish**

Department of Earth and Environmental  
Sciences and Department of Civil and  
Environmental Engineering  
Vanderbilt University, Nashville, TN, USA

**Alessandro B. Gitto**

Department of Geography  
Simon Fraser University  
Burnaby, British Columbia, Canada

**Gordon E. Grant**

USDA Forest Service  
Pacific Northwest Research Station  
Corvallis, OR, USA

**Marwan A. Hassan**

Department of Geography  
The University of British Columbia  
Vancouver, British Columbia, Canada

**Dan Haught**

Department of Geography  
Simon Fraser University, Burnaby  
British Columbia, Canada

**Ricardo R. Hernandez Moreira**

Department of Civil and  
Environmental Engineering  
University of South Carolina at Columbia  
South Carolina, USA

**Murray Hicks**

National Institute of Water and  
Atmospheric Research  
Christchurch, New Zealand

**Kimberly M. Hill**

St. Anthony Falls Laboratory and the  
Department of Civil, Environmental and  
Geo-Engineering, University of Minnesota  
Minneapolis, Minnesota, USA

**Yuki Hiramatsu**

Department of Civil and  
Environmental Engineering  
Waseda University, Tokyo, Japan

**Rebecca A. Hodge**

Department of Geography  
Durham University, Durham, UK

**Sameh Kantoush**

Disaster Prevention Research Institute  
Kyoto University  
Uji, Kyoto, Japan

**Florent Lachaussée**

Laboratoire FAST  
Univ. Paris-Sud, CNRS  
Université Paris-Saclay  
Orsay, France

**Eric Lajeunesse**

Institut de Physique du Globe de Paris  
Sorbonne Paris Cité  
Univ. Paris-Diderot  
Paris, France

**Djoko Legono**

Department of Civil and  
Environmental Engineering  
Universitas Gadjah Mada  
Yogyakarta, Indonesia

**Kevin W. Lewis**

Department of Earth  
and Planetary Sciences  
Johns Hopkins University  
Baltimore, MD, USA

**Christopher S. Magirl**

US Geological Survey  
Arizona Water Science Center  
Tucson, AZ, USA

**Jon J. Major**

US Geological Survey  
Volcano Science Center  
Cascades Volcano Observatory  
Vancouver, WA, USA

**Lorenzo Marchi**

Research Institute for  
Geo-hydrological Protection  
National Research Council of Italy (CNR IRPI)  
Padova, Italy

**Alessandra Marzadri**

Center for Ecohydraulics Research  
University of Idaho  
Boise, Idaho, USA

**Peter A. Nelson**

Department of Civil and  
Environmental Engineering  
Colorado State University  
Fort Collins, Colorado, USA

**Giyoung Ock**

Division of Basic Research  
National Institute of Ecology  
Seocheon, South Korea

**Jim E. O'Connor**

US Geological Survey  
Geology, Minerals, Energy  
and Geophysics Science Center  
Portland, OR, USA

**Marisa C. Palucis**

Division of Geological and  
Planetary Sciences  
California Institute of Technology  
Pasadena, CA, USA

**Chris Paola**

Department of Earth Sciences  
St. Anthony Falls Laboratory  
University of Minnesota  
Minneapolis, Minnesota, USA

**A.N. (Thanos) Papanicolaou**

Department of Civil and  
Environmental Engineering  
Hydraulics and Sedimentation Laboratory  
The University of Tennessee, Knoxville  
Tennessee, USA

**Adam Pamudji Rahardjo**

Department of Civil and  
Environmental Engineering  
Universitas Gadjah Mada  
Yogyakarta, Indonesia

**Colin D. Rennie**

Department of Civil Engineering  
University of Ottawa, Ottawa, Canada

**Dieter Rickenmann**

Mountain Hydrology and Mass Movements  
Swiss Federal Institute for Forest  
Snow and Landscape Research WSL  
Birmensdorf, Switzerland

**Frances Rivera-Hernandez**

Geology Department  
University of California at Davis  
Davis, CA, USA

**Virginia Ruiz-Villanueva**

Dendrolab.ch, Institute of Geological Sciences  
University of Bern, Bern, Switzerland  
and Institute for Environmental Sciences  
University of Geneva, Geneva  
Switzerland

**Mark W. Schmeeckle**

School of Geographical Sciences and  
Urban Planning, Arizona State University  
Tempe, Arizona, USA

**Masato Sekine**

Department of Civil and  
Environmental Engineering  
Waseda University  
Tokyo, Japan

**Chjeng-Lun Shieh**

Disaster Prevention Research Center  
National Cheng Kung University  
Tainan City, Taiwan, ROC

**Annunziato Siviglia**

Laboratory of Hydraulics  
Hydrology and Glaciology VAW  
ETH Zurich, Zurich, Switzerland

**Guglielmo Stecca**

National Institute of Water and  
Atmospheric Research  
Christchurch, New Zealand  
and Department of Civil and  
Environmental Engineering  
University of Trento  
Trento, Italy

**Muhammad Sulaiman**

Department of Civil and Environment  
Engineering, Gadjah Mada University  
Yogyakarta, Indonesia

**Tetsuya Sumi**

Disaster Prevention Research Institute  
Kyoto University  
Uji, Kyoto, Japan

**Dawn Y. Sumner**

Geology Department  
University of California at Davis  
Davis, CA, USA

**Hiroshi Takebayashi**

Disaster Prevention Research Institute  
Kyoto University, Kyoto  
Kyoto, Japan

**Danielle Tan**

Department of Mechanical Engineering  
National University of Singapore  
Singapore

**Daniele Tonina**

Center for Ecohydraulics Research  
University of Idaho  
Boise, Idaho, USA

**Achilleas G. Tsakiris**

Department of Civil and  
Environmental Engineering  
Hydraulics and Sedimentation Laboratory  
The University of Tennessee  
Knoxville, Tennessee, USA

**Daizo Tsutsumi**

Disaster Prevention Research Institute  
Kyoto University  
Kyoto, Japan

**Desiree D. Tullos**

Department of Biological and  
Ecological Engineering  
Oregon State University  
Corvallis, OR, USA



***Jeremy G. Venditti***

Department of Geography  
Simon Fraser University  
Burnaby, British Columbia, Canada

***Damià Vericat***

Fluvial Dynamics Research Group  
Department of Environment and  
Soil Sciences  
University of Lleida, Lleida  
Catalonia, Spain  
and Forest Sciences Centre of Catalonia, Solsona  
Catalonia, Spain

***Enrica Viparelli***

Department of Civil and Environmental  
Engineering, University of South Carolina at  
Columbia, South Carolina, USA

***Vaughan R. Voller***

Department of Civil, Environmental and  
Geo-Engineering, St. Anthony Falls Laboratory  
University of Minnesota, Minneapolis  
Minnesota, USA

***Joseph M. Wheaton***

Department of Watershed Sciences  
Utah State University  
Logan, Utah, USA

***Andrew C. Wilcox***

Department of Geosciences  
University of Montana  
Missoula, MT, USA

***Richard D. Williams***

School of Geographical and Earth Sciences  
University of Glasgow  
UK

***Rebecca M. E. Williams***

Planetary Science Institute  
Tucson, AZ, USA



## Preface

The *8th International Gravel-Bed Rivers (GBR) Workshop* was held in Kyoto (first day) and Takayama, Japan between 14 and 18 September 2015. Kyoto was the capital of Japan during the period AD 794–1869 and is the center of Japanese culture, with its many traditional Buddhist temples, Shinto shrines together with their unique gardens, and Zen gardens that are adorned with gravel that is as lovely as the plants. Kyoto University is among the oldest in Japan. Takayama is a small city surrounded by mountains. Due to its location and cultural uniqueness, tradition and cuisine are preserved in this city, which is traversed by gravel-bed rivers. The workshop was attended by 116 (of which, 17 were PhD students) gravel-bed river enthusiasts from Austria, Canada, Chile, China, France, Germany, Indonesia, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Switzerland, Taiwan, United Kingdom, and United States.

In further keeping with the GBR tradition, the workshop was designed to present an authoritative review of recent progress in understanding the morphology of and processes operating in gravel-bed rivers. Accordingly, the workshop was constructed around a series of invited keynote presentations that tackled the principal themes selected for the meeting. Each theme included two presentations – the chapters comprising this book. Sessions for each theme incorporated considerable time for discussions. These discussions appear at the end of each chapter. The workshop included 61 posters (of which 15 were first-authored by PhD students). Ample time was given for questioning the poster presenters and exchanging information. Several among the poster presenters are preparing manuscripts for a special issue of the journal *Earth Surface Processes and Landforms*.

The workshop's main theme was Gravel-Bed Rivers and Disasters. In keeping with previous workshops, session topics covered a wide area, only some directly relevant to the workshop main theme of disasters. Because most measurements and data for gravel-bed rivers are available almost exclusively for small to intermediate (bankfull) flows, it is timely to pay more attention to large, often disastrous floods, more so in this age of climate change and urbanization. For instance, in Japan such floods accounted for 54% of the dead and missing in natural disasters during the period 2010–2014: altogether 5512 sediment disasters (landslides, slope failures, or debris flows) took place and 254 people were killed or missing in Japan (MLIT; [http://www.mlit.go.jp/river/sabo/jirei/h26dosha/150331\\_H26saigai.pdf](http://www.mlit.go.jp/river/sabo/jirei/h26dosha/150331_H26saigai.pdf), 2015). We had chosen this theme because Japanese gravel-bed rivers cause many and frequent disasters (as in other tectonically and/or mountainous countries), but also because the Disaster Prevention Research Institute, Kyoto University played host to the workshop. The topics of this theme included gravel transport and deposition by large floods, sediment supply and availability, and integrated channel management.

Workshop themes included those that have become classics for the quinquennial meetings. So, gravel transport processes dealt with flow and transport near the river bed, theoretical considerations of bedload transport and bedload transport quantification by both direct and surrogate methods.

Represented were the two different approaches of physical and morphodynamic modeling. In demonstrating the continued awareness of the relevance of ecology to gravel-bed rivers, one session was devoted to in-stream habitat issues and the significance of vegetation. Dam removal and sediment flushing were included because these topics have gained interest and momentum by researchers and practitioners. As geomorphic, hydraulic and fluvial sedimentologic studies are often insufficiently interdisciplinary, the workshop included two other relevant issues: sediment porosity and modeling of deposit stratigraphy and bed cover. Also, for first time in the history of these meetings, the workshop hosted a topic on gravels away from Earth and explored evidence of past activity on Mars.

Field trips have continued to be central to successive workshops and that reported here was no exception. The pre-workshop trips took us to the urban Kamo River in Kyoto, guided by Yasuhiro Takemon, and to the Ujigawa Hydraulics Laboratory, Disaster Prevention Research Institute (DPRI), Kyoto University, where researchers from outside the university and the country are invited to take advantage of the flumes. The Gamada River (demonstrated by Michinobu Nonaka) and the Kamikoch area (guided by Hiroshi Suwa) were visited mid-workshop, demonstrating various devices used to monitor bedload and debris flows in DPRI's long-running Hodaka Observatory, only 4 km from the crater of the active Mount Yakedake volcano. The observatory invites researchers to collaborate or merely stay for short or extended periods at no cost. The post-workshop field trip was devoted to the Kurobe River, with its source in Mount Washiba (2924 m a.s.l.), part of the Hida Mountain Range of the Japanese Alps, carving the deep Kurobe gorge. It emerges from the mountains at Unazuki and forms an alluvial fan that debouches directly to the Sea of Japan. The guide (Tetsuya Sumi) demonstrated evidence of the ultra-high sediment yields from the Japanese Alps and the means by which dams are used to retain and flush the sediments.

Novelties of this workshop were the two-day special short-courses offered free to PhD students and postdoctoral fellows. Moreover, live web-streaming was accessible and presentations as well as discussions were recorded and uploaded to a freely available website (<https://www.youtube.com/channel/UC8oW0AbmlhcJYwvtTBrAAsA>).

There are many people to thank for the success of the workshop. First, our sponsors: the Japan World Exposition 1970 Commemorative Fund; Hida-Takayama Tourism and Convention Bureau; Sabo and Landslide Technical Center; Sabo Frontier Foundation; Association for Disaster Prevention Research; Nippon Koei; Civil Engineering and Eco-Technology Consultants Co. Ltd; the Kyoto University Foundation; and the DPRI, Kyoto University. We thank our supporters: Takayama City, the Jinzu and Matsumoto Sabo (meaning 'sand') offices, and Kurobe River office of the Japan Ministry of Land, Infrastructure, Transportation and Tourism.

Peer reviews of the invited papers were completed prior to the workshop. The papers were accepted between 17.03.2015 and 16.09.2015; the last reply to discussions was submitted on 1.03.2016. Special thanks go to more than 60 reviewers who helped to ensure the quality of the manuscripts. We thank the discussants of the papers and the presenters of the posters. Thanks go to Shusuke Miyata for organizing the workshop web site, the live videoconference and its recording, to Tatsuko Fujita for the workshop logo, to Harumi Miura for management of registration issues, preparation of the workshop, and tours for companions, to Cecilia Laronne Corrado for her help in the registration and support for attendees, to the staff of the Japan Travel Bureau for their assistance and management of the workshop, to the staff of the Hotel Associa Takayama Resort for their help in preparing the meeting place and accommodations, and to K. Lab Ltd for the booklet of the program and abstracts. Hiroshi Takebayashi and Joe Wheaton voluntarily offered short courses respectively on 'Modeling river flow, sediment transport and morphodynamics' and 'Introduction to geomorphic change,' to Ian Reid for English edits, to the PhD students and postdoctoral fellows, for which students Jun Nishiura and Satoru Masuda ensured a welcome. Appreciation goes to the excellent suggestions made by members

of the Scientific Advisory Board: Jochen Aberle, Peter Ashmore, James Brasington, Shinji Egashira, Chris Paola, Klement Tockner and Guido Zolezzi. Many thanks to Rachael Ballard, Shummy Metilda, Vinodhini Mathiyalagan, Delia Sandford, Audrie Tan, Teresa Netzler, Bella Talbot and Andrew Harrison, Lyn Nesbitt-Smith, staff at John Wiley & Sons, for their invaluable help during the entire editing process and to Mike Church for his suggestions and introduction to Wiley.

Professor Richard Hey (who could not participate), Professor James Bathurst and Professor Colin Thorne were guests invited and honored for their foresight in initiating the Gravel-Bed River series of workshops, beginning with the first in Newtown, Wales, in 1980. Thanks go to James and Colin, who, as banquet speakers, entertained everyone with the history of GBR workshops and their importance. Professor Takahisa Mizuyama was praised during the dinner for his central role in developing Japanese research on gravel bed rivers during the past two decades.

We trust that this book, like its predecessors, will become part of an authoritative record of advances in knowledge and understanding of gravel-bed rivers. And we wish the hosts of the next meeting, GBR9, to be held in Chile, as much success as we have enjoyed.

*Daizo Tsutsumi*

Kyoto, Japan  
and

*Jonathan B. Laronne*  
Beer Sheeva, Israel

