EDITORS | MICHAEL CHURCH | PASCALE M. BIRON | ANDRÉ G. ROY

Grave-bed Rivers

Processes, Tools, Environments

WILEY-BLACKWELL

Contents

<u>Cover</u>

<u>Title Page</u>

<u>Copyright</u>

List of Contributing Authors

<u>Preface</u>

Secondary Flows in Rivers

<u>Chapter 1: Secondary Flows in Rivers:</u> <u>Theoretical Framework, Recent</u> <u>Advances, and Current Challenges</u>

1.1 Introduction1.2 Theoretical Framework1.3 Secondary Currents and Turbulence1.4 Secondary Currents and HydraulicResistance1.5 Secondary Currents, Sediments andMorphodynamics1.6 Secondary Currents and MixingProcesses1.7 Conclusions1.8 Acknowledgements

<u>1.9 References</u> 1.10 Discussion

<u>Chapter 2: Secondary Flows in Rivers:</u> <u>The Effect of Complex Geometry</u>

2.1 Introduction 2.2 Background 2.3 Channel non-Uniformity and Secondary Flows 2.4 Discussion 2.5 References

<u>Chapter 3: Aspects of Secondary Flow</u> <u>in Open Channels: A Critical</u> <u>Literature Review</u>

3.1 Introduction 3.2 Secondary Flows and Channel Form 3.3 Secondary Flows and Channel Roughness 3.4 Secondary Flows and River Morphodynamics 3.5 Conclusions 3.6 References

Sediment Transport

<u>Chapter 4: Gravel Transport in</u> <u>Granular Perspective</u> 4.1 Introduction
4.2 Granular Flows
4.3 Full Mobility Transport
4.4 Surface Processes
4.5 Bedload Fluctuations, Sheets, and Patches
4.6 Perspectives and Conclusions
4.7 Acknowledgements
4.8 References
4.9 Discussion
4.10 Discussion References

<u>Chapter 5: On Gravel Exchange in</u> <u>Natural Channels</u>

5.1 Introduction 5.2 Geometric Limits to Exchange Sites 5.3 Gravel Exchange 5.4 Exchange Depths 5.5 Exchange and Size Segregation 5.6 Conclusions 5.7 Acknowledgements 5.8 References 5.9 Discussion 5.10 Discussion References

Modelling Morphodynamics

<u>Chapter 6: Morphodynamics of Bars</u> <u>in Gravel-bed Rivers: Bridging</u>

<u>Analytical Models and Field</u> <u>Observations</u>

6.1 Introduction 6.2 Analytical Models of Bars in Gravel Bed Rivers: Formulation, Terminology, and Solution Approach 6.3 Morphodynamics of Steady Bars in Single-Thread Channels 6.4 Analytical Bar Models and Multiple-Thread Channel Morphodynamics 6.5 Conclusions and Research Perspectives 6.6 Acknowledgements 6.7 References 6.8 Discussion 6.9 Discussion References

<u>Chapter 7: Field Observations of</u> <u>Gravel-bed River Morphodynamics:</u> <u>Perspectives and Critical Issues for</u> <u>Testing of Models</u>

7.1 Introduction 7.2 Field Studies on Bar Dynamics: New Perspectives from Remote-Sensing Techniques? 7.3 Selection of Test Reaches: Equilibrium and Unstable Condition of River Channels 7.4 Active Channel Width in Braided Rivers 7.5 Final Remarks 7.6 Acknowledgements 7.7 References

<u>Chapter 8: Morphodynamics of Bars</u> <u>in Gravel-bed Rivers: Coupling</u> <u>Hydraulic Geometry and Analytical</u> <u>Models</u>

<u>8.1 Introduction</u> <u>8.2 Prediction of Channel Patterns</u> <u>8.3 Summary and Conclusions</u> <u>8.4 References</u>

<u>Chapter 9: Modelling Sediment</u> <u>Transport and Morphodynamics of</u> <u>Gravel-bed Rivers</u>

9.1 Introduction
9.2 Erosion, Transport, and Deposition of Non-Uniform Sediment
9.3 Analytical Solutions
9.4 Bank Erosion and Bank Accretion
9.5 Vegetation Dynamics and
Ecomorphology
9.6 Validation
9.7 Conclusions
9.8 Acknowledgements
9.9 References
9.10 Discussion

<u>Chapter 10: The Potential of using</u> <u>High-resolution Process Models to</u> <u>Inform Parameterizations of</u> <u>Morphodynamic Models</u>

> 10.1 Introduction 10.2 Process Modelling of Gravel Bed Rivers 10.3 Modelling Flow in a Gravel Bed River using a Computational Fluid Dynamics Approach 10.4 Is discrete particle modelLing an underused method in gravel-bed rivers? 10.5 Sediment transport predictions with high-resolution hydraulics 10.6 How can this information be used to scale up? 10.7 Discussion and Conclusions 10.8 References

<u>Chapter 11: The Importance of Off-</u> <u>channel Sediment Storage in 1-D</u> <u>Morphodynamic Modelling</u>

11.1 Introduction 11.2 Review of 1-D Profile Modelling <u>Approaches</u> 11.3 Inferences Based on Planimetric <u>Centreline Evolution Models</u> 11.4 1-D Profile Modelling with Active <u>Reservoirs for Channel and Lateral Storage</u> 11.5 A Simple 1-D Model with Off-Channel <u>Storage</u> 11.6 Conclusions <u>11.7 Acknowledgements</u> <u>11.8 References</u> <u>11.9 Notation</u>

<u>River Restoration and</u> <u>**Regulation**</u>

<u>Chapter 12: Stream Restoration in</u> <u>Gravel-bed Rivers</u>

12.1 Introduction 12.2 Restoration Practice and the Research Perspective 12.3 Elements of A Successful Stream Restoration Profession 12.4 Challenges 12.5 Conclusions 12.6 References 12.7 Discussion

<u>Chapter 13: River Restoration:</u> <u>Widening Perspectives</u>

<u>13.1 Introduction</u>
<u>13.2 Matters of Definition</u>
<u>13.3 Towards Intelligent Design: Sorting</u>
form from Functionand Alternatives to the
<u>Alluvial Paradigm</u>
<u>13.4 Improving Inventory from the Stock of</u>
<u>Altered River Systems</u>
<u>13.5 The Societal and Social Dimensions</u>

<u>13.6 Conclusions</u> <u>13.7 Acknowledgements</u> <u>13.8 References</u> <u>13.9 Discussion</u>

<u>Chapter 14: Restoring Geomorphic</u> <u>Resilience in Streams</u>

14.1 Introduction 14.2 Reactions to the Wilcock Review 14.3 Restoration of Stream Geomorphic Resilience 14.4 Summary and Conclusions 14.5 Acknowledgements 14.6 References

<u>Chapter 15: The Geomorphic</u> <u>Response of Gravel-bed Rivers to</u> <u>Dams: Perspectives and Prospects</u>

15.1 Introduction 15.2 A Global Paucity of Data 15.3 Characterizing the Geomorphic Response of Rivers to Impoundment 15.4 Some Perspectives and Conclusions 15.5 Acknowledgements 15.6 References 15.7 Discussion

<u>Chapter 16: Mitigating Downstream</u> <u>Effects of Dams</u> 16.1 Introduction16.2 Gravel Augmentation Downstreamfrom Dams16.3 Downstream Propagation andResponse Time16.4 Summary16.5 References

Ecological Aspects of Gravel-Bed Rivers

<u>Chapter 17: River Geomorphology</u> <u>and Salmonid Habitat: Some</u> <u>Examples Illustrating their Complex</u> <u>Association, from Redd to Riverscape</u> <u>Scales</u>

17.1 Introduction 17.2 Salmonid Spawning Habitat 17.3 A "Riverscape" Perspective into Salmonid Habitat Science 17.4 Acknowledgements 17.5 References

<u>Chapter 18: Incorporating Spatial</u> <u>Context into the Analysis of</u> <u>Salmonid-Habitat Relations</u>

<u>18.1 Introduction</u> <u>18.2 Uncertainty in Fish-Habitat Relations</u> 18.3 Problems with Density as a Measure of Abundance 18.4 Predicting the Locations of Areas with Locally High Abundance 18.5 Scaling up for Greater Predictive Power 18.6 Acknowledgements 18.7 References

<u>Chapter 19: Animals and the</u> <u>Geomorphology of Gravel-bed Rivers</u>

19.1 Introduction 19.2 It is not only "Habitat" that Matters 19.3 Geomorphological Impacts of Animals in Gravel-Bed Rivers 19.4 Understanding the Mechanisms of Animal Impacts: Laboratory and Field Experiments with Signal Crayfish 19.5 Conclusions 19.6 References 19.7 Discussion

<u>Chapter 20: Geomorphology and</u> <u>Gravel-bed River Ecosystem Services:</u> <u>Workshop Outcomes</u>

20.1 Introduction 20.2 Workshop Structure 20.3 Workshop Outcomes 20.4 Future Research and Challenges 20.5 Acknowledgements 20.6 References 20.7 Appendix A: Program of The Gbr7 Workshop on Gravel-Bed River Ecosystem Services Held 8 September, 2010 In Tadoussac, Québec (Canada) 20.8 Appendix B: Working List of Final Ecosystem Services Associated with Rivers 20.9 Appendix C: Working List of Geomorphological Intermediate Ecosystem Services Associated with Rivers

Tools for Study

<u>Chapter 21: Remote Sensing of the</u> <u>Hydraulic Environment in Gravel-bed</u> <u>Rivers</u>

21.1 Introduction 21.2 The Plan View of the River 21.3 The Vertical Dimension 21.4 Bed Sediment Size 21.5 Other Variables and Platforms 21.6 Future Needs and Directions 21.7 Acknowledgments 21.8 References 21.9 Discussion 21.10 Discussion References

<u>Chapter 22: LiDAR and ADCP Use in</u> <u>Gravel-bed Rivers: Advances Since</u> <u>GBR6</u>

22.1 Introduction 22.2 LIDAR 22.3 Application of ADCP for Combined Depth and Velocity Survey 22.4 Example Studies 22.5 Future Developments Towards GBR8 22.6 References 22.7 Discussion 22.8 Discussion References

<u>Chapter 23: Remotely Sensed</u> <u>Topographic Change in Gravel</u> <u>Riverbeds with Flowing Channels</u>

23.1 Introduction 23.2 The wetted channel problem 23.3 Extracting Meaningful Change in Bed Level and Volume from Remotely Sensed Surveys 23.4 Balancing Spatial Detail Against Vertical Accuracy 23.5 Conclusions 23.6 Acknowledgments 23.7 References

<u>Chapter 24: Modern Digital</u> <u>Instruments and Techniques for</u> <u>Hydrodynamic and Morphologic</u> <u>Characterization of River Channels</u>

24.1 Introduction 24.2 Acoustic River Instrumentation 24.3 Close-Range Remote-Sensing River Instrumentation 24.4 Demonstration of Instrument Capabilities 24.5 Discussion and Conclusions 24.6 Acknowledgements 24.7 References 24.8 Discussion 24.9 Discussion References

<u>Chapter 25: Mapping Water and</u> <u>Sediment Flux Distributions in</u> <u>Gravel-bed Rivers Using ADCPs</u>

25.1 Introduction 25.2 Gravel-Bed Versus Sand-Bed ADCP Measurements 25.3 Gravel-Bed Spatial Distributions 25.4 Discussion and Conclusions 25.5 References

Steep Channels

<u>Chapter 26: Recent Advances in the</u> <u>Dynamics of Steep Channels</u> 26.1 Definition of Steep Channels 26.2 Channel Morphology 26.3 Hydrodynamics and Flow Resistance in Steep Channels 26.4 Sediment Transport 26.5 Conclusions 26.6 Acknowledgements 26.7 References 26.8 Discussion 26.9 Discussion References

<u>Chapter 27: Examining Individual</u> <u>Step Stability within Step-pool</u> <u>Sequences</u>

27.1 Introduction 27.2 Current Research 27.3 New Analyses 27.4 Summary 27.5 Acknowledgements 27.6 References

<u>Chapter 28: Alluvial Steep Channels:</u> <u>Flow Resistance, Bedload Transport</u> <u>Prediction, and Transition to Debris</u> <u>Flows</u>

<u>28.1 Introduction</u> <u>28.2 Flow Resistance and Bedload</u> <u>Transport</u> 28.3 Transition from Bedload Transport to Debris Floods and Debris Flows 28.4 Conclusions 28.5 Acknowledgements 28.6 References

Semi-Alluvial Channels

<u>Chapter 29: Semi-alluvial Channels</u> and Sediment-Flux-Driven Bedrock <u>Erosion</u>

29.1 Introduction 29.2 Controls on Channel Morphology and Steady State 29.3 Processes of Bedrock Erosion 29.4 Erosion Models 29.5 Bedrock Channels in The Stream Power Model Framework 29.6 The Role of Sediment 29.7 Conclusions and Research Needs 29.8 Acknowledgements 29.9 References 29.10 Discussion 29.11 Discussion References

<u>Chapter 30: Transport Capacity,</u> <u>Bedrock Exposure, and Process</u> <u>Domains</u> <u>30.1 Introduction</u> <u>30.2 Transport Capacity in the Fluvial Zone</u> <u>30.3 Upstream of the Fluvial Zone</u> <u>30.4 References</u>

<u>Chapter 31: Nomenclature,</u> <u>Complexity, Semi-alluvial Channels</u> <u>and Sediment-flux-driven Bedrock</u> <u>Erosion</u>

31.1 Introduction31.2 Definition of Channel Types31.3 Steady-State, Dynamic Equilibrium andthe Role of Sediment31.4 New Concepts31.5 Acknowledgements31.6 References

<u>River Channel Change</u>

<u>Chapter 32: Changes in Channel</u> <u>Morphology Over Human Time Scales</u>

32.1 Introduction32.2 Scales of Channel Change32.3 Spatial and Temporal Variability ofChannel Change32.4 Predicting Channel Change32.5 Channel Stability and Hydroclimate32.6 Conclusion

32.7 Acknowledgements 32.8 References 32.9 Appendix 32.10 References for Appendix 32.11 Discussion 32.12 Discussion References

<u>Chapter 33: Channel Response and</u> <u>Recovery to Changes in Sediment</u> <u>Supply</u>

33.1 Introduction 33.2 Magnitude, Frequency, and Effectiveness of Sediment Transport in Non-Equilibrium Systems 33.3 Case Studies 33.4 Closing Remarks: A Practical Case 33.5 Acknowledgements 33.6 References

<u>Chapter 34: Alluvial Landscape</u> <u>Evolution: What Do We Know About</u> <u>Metamorphosis of Gravel-bed</u> <u>Meandering and Braided Streams?</u>

34.1 Introduction34.2 Data Sources34.3 Defining Meandering and BraidedStreams34.4 Hydraulic Geometry and theRespective Influence of Water and

Sediment Inputs 34.5 The Role of Soil Properties and Vegetation on Bank Stability 34.6 The Record of Channel Metamorphosis 34.7 Discussion and Concluding Remarks 34.8 Acknowledgements 34.9 References 34.10 Discussion 34.11 Discussion References

<u>Chapter 35: Differences in Sediment</u> <u>Supply to Braided and Single-Thread</u> <u>River Channels: What Do the Data Tell</u> <u>Us?</u>

35.1 Introduction 35.2 Key Variables for Estimating Bedload Transport Capacity 35.3 What do the Data and Observations tell us? 35.4 Conclusions 35.5 Acknowledgements 35.6 References

<u>Chapter 36: Can We Link Cause and</u> <u>Effect in Landscape Evolution?</u>

<u>36.1 Introduction</u> <u>36.2 Non-Linearity in Numerical Modelling</u> <u>36.3 Model Investigations</u> <u>36.4 Discussion</u> <u>36.5 Conclusion</u> <u>36.6 References</u> <u>36.7 Discussion</u>

Ice In Gravel-Bed Rivers

<u>Chapter 37: River-Ice Effects on</u> <u>Gravel-Bed Channels</u>

37.1 Introduction 37.2 Thermal Processes 37.3 Aufeis 37.4 Length, Time, and Dynamic Scales 37.5 Bed Material Transport 37.6 Channel Responses to Ice 37.7 Channel Banks 37.8 Defining Effects of Ice 37.9 Concluding Comments 37.10 References

<u>Chapter 38: Is There a Northern</u> <u>Signature on Fluvial Form?</u>

38.1 Introduction 38.2 Driving and Resisting Forces for Sediment Entrainment in Ice-Affected Rivers 38.3 River Ice and Geomorphologic Work 38.4 Universality of Fluvial Form in Ice-Affected Rivers 38.5 Concluding Remarks 38.6 References

<u>Chapter 39: Long-term and Large-</u> <u>scale River-ice Processes in Cold-</u> <u>region Watersheds</u>

<u>39.1 Introduction</u> <u>39.2 The Necopastic River Data Set</u> <u>39.3 Some Perspectives on Long-Term and</u> <u>Large-Scale River-Ice Jam Dynamics</u> <u>39.4 Conclusions</u> <u>39.5 References</u>

<u>Index</u>

Colour Plates

GRAVEL-BED RIVERS: PROCESSES, TOOLS, ENVIRONMENTS

Edited by

Michael Church

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

Pascale M. Biron

Department of Geography, Planning and Environment, Concordia University Montreal, Quebec, Canada

André G. Roy

Département de géographie Université de Montréal Montréal, Québec, Canada

with Associate Editors

Peter Ashmore

Department of Geography University of Western Ontario London, Ontario, Canada

Normand Bergeron

Institut National de la Recherche Scientifique, Centre Eau-Terre-Environnement, St.Foy, Québec, Canada

Thomas Buffin-Bélanger

Département de biologie, chimie et géographie, Université de Québec à Rimouski, Rimouski, Québec, Canada

Colin Rennie

Department of Civil Engineering University of Ottawa Ottawa, Ontario, Canada



A John Wiley & Sons, Ltd., Publication

This edition first published 2012 $\ensuremath{\mathbb{C}}$ 2012 by John Wiley & Sons, Ltd

Wiley-Blackwell is an imprint of John Wiley & Sons, formed by the merger of Wiley's global Scientific, Technical and Medical business with Blackwell Publishing.

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

Editorial offices: 9600 Garsington Road, Oxford, OX4 2DQ, UK

The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, UK

111 River Street, Hoboken, NJ 07030-5774, USA

For details of our global editorial offices, for customer services and for information about how to apply for permission to reuse the copyright material in this book please see our website at <u>www.wiley.com/wiley-blackwell</u>.

The right of the authors to be identified as authors of this work has been asserted in accordance with the UK Copyright, Designs and Patents Act 1988.

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 the UK Copyright, Designs and Patents Act 1988, without the prior permission of the publisher.

Designations used by companies to distinguish their products are often claimed as trademarks. All brand names and product names used in this book are trade names, service marks, trademarks or registered trademarks of their respective owners. The publisher is not associated with any product or vendor mentioned in this book. This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold on the understanding that the publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional should be sought.

Library of Congress Cataloging-in-Publication Data

Gravel bed rivers: processes, tools, environments / edited by Michael Church, Pascale Biron, André G. Roy; with associate editors Peter Ashmore . . . [et al.].

p. cm.

ISBN 978-0-470-68890-8 (cloth)

1. River channels. I. Church, Michael Anthony, 1942- II. Biron, Pascale. III. Roy, André G. IV. Ashmore, Peter.

TC175.G765 2012

551.48′3-

dc23

2011025981

A catalogue record for this book is available from the British Library.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic books.

List of Contributing Authors

Note: Bold names indicate the corresponding authors *Dominique Arseneault*

Département de biologie, chimie et géographie, Université du Québec à Rimouski, Rimouski, Québec, Canada.

dominique_arseneault@uqar.qc.ca

Laurie Barrier

Institut du Physique du Globe de Paris, Jussieu, Paris, France. <u>barrier@ipgp.fr</u>

Colden V. Baxter

Idaho State University, Pocatello, Idaho, USA. <u>baxtcold@isu.edu</u>

Yves Bégin

Institut National de la Recherche Scientifique, Centre Eau-Terre-Environnement, St.Foy, Québec, Canada. <u>yves.begin@ete.inrs.ca</u>

Normand Bergeron

Institut national de la recherche scientifique, Centre Eau-Terre-Environnement, Québec, Canada <u>normand.bergeron@ete.inrs.ca</u>

Walter Bertoldi

School of Geography, Queen Mary University of London, London, UK and Dipartimento di Ingegneria Civile e Ambientale, University of Trento, Trento Italy. <u>walter.bertoldi@ing.unitn.it</u>

Pascale M. Biron

Department of Geography, Planning and Environment, Concordia University, Montreal, Quebec, Canada

Etienne Boucher

CEREGE, Europole Mediterranéen de l'Arbois, Aix-en-Provence, France.

boucher.etienne@uqam.ca

Thomas Buffin-Bélanger

Département de biologie, chimie et géographie, Université du Québec à Rimouski, Rimouski, Québec, Canada. <u>thomas_buffin-</u> <u>belanger@uqar.qc.ca</u>

John M. Buffington

USDA Forest Service, Rocky Mountain Research Station, Boise, Idaho, USA. jbuffington@fs.fed.us

Paul A. Carling

Geography and Environment, University of Southampton, Southampton, UK. p.a.carling@soton.ac.uk

Michael Church

Department of Geography, The University of British Columbia, Vancouver, British Columbia, Canada. <u>mchurch@geog.ubc.ca</u>

Nicholas J. Clifford

Department of Geography, King's College, London, UK. <u>nicholas.clifford@kcl.ac.uk</u>

Francesco Comiti

Faculty of Science and Technology, Free University of Bozen-Bolzano, Bolzano, Italy. <u>francesco.comiti@unibz.it</u>

Thomas J. Coulthard

Department of Geography, University of Hull, Hull, UK. <u>T.Coulthard@hull.ac.uk</u>

Joanna Crowe Curran

Department of Civil and Environmental Engineering, University of Virginia, Charlottesville, Virginia, USA. <u>curran@virginia.edu</u>

Joseph L. Ebersole

US Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division, Corvallis, Oregon, USA. <u>ebersole.joe@epa.gov</u>

Robert Ettema

Civil and Architectural Engineering Department, University of Wyoming, Laramie, Wyoming USA. <u>rettema@uwyo.edu</u>

Joanna Eyquem

Parish Geomorphic Ltd., Mississauga, Ontario, Canada. jeyquem@parishgeomorphic.com

Philippe Frey

CEMAGREF, Unité de recherche Erosion Torrentielle, Neige et Avalanches, Saint-Martind'Hères, France. <u>phillipe.frey@cemagref.fr</u>

David Gaeuman

Trinity River Restoration Program, Weaverville California, USA. <u>dgaeuman@usbr.gov</u>

Gordon E. Grant

USDA Forest Service, Pacific Northwest Research Station, Corvalllis, Oregon, USA. <u>gordon.grant@oregonstate.edu</u>

Robert E. Gresswell

US Geological Survey, Northern Rocky Mountain Science Center, Bozeman, Montana, USA. bgresswell@usgs.gov

Richard J. Hardy

Department of Geography, Durham University, Durham, UK. <u>r.j.hardy@durham.ac.uk</u>

Judith K. Haschenburger

Department of Geological Sciences, University of Texas at San Antonio, San Antonio, Texas, USA. judy.haschenburger@utsa.edu

Marwan A. Hassan

Department of Geography, The University of British Columbia, Vancouver, British Columbia, Canada. <u>mhassan@geog.ubc.ca</u>

George L. Heritage

JBA Consulting, The Bank Quay House, Sankey St., Warrington, UK.

george.heritage@jbaconsulting.co.uk

D. Murray Hicks

NIWA, Christchurch, New Zealand. <u>m.hicks@niwa.co.nz</u>

Matthew F. Johnson

Department of Geography, Loughborough University, Loughborough, Leicestershire, UK. <u>m.f.johnson@lboro.ac.uk</u>

Edward W. Kempema

Civil and Architectural Engineering Department, University of Wyoming, Laramie, Wyoming USA. <u>kempema@uwyo.edu</u>

Dongsu Kim

Department of Civil and Environmental Engineering, Dankook University, Kyunggido, Korea. <u>dongsu-kim@dankook.ac.kr</u>

Michel Lapointe

Department of Geography, McGill University, Montreal, Québec, Canada. <u>lapointe@geog.mcgill.ca</u>

J. Wesley Lauer

Department of Civil and Environmental Engineering, Seattle University, Seattle, Washington, USA. <u>lauerj@seattleu.edu</u>

Thomas E. Lisle

USDA Forest Service, Redwood Sciences Laboratory, Arcata, California, USA. <u>tel7001@humboldt.edu</u>

Bruce MacVicar

Department of Civil and Environmental Engineering, University of Waterloo, Waterloo, Ontario, Canada. <u>bmacvicar@uwaterloo.ca</u>

Luca Mao

Faculty of Science and Technology, Free University of Bozen-Bolzano, Bolzano, Italy. luca.mao@unibz.it

W. Andrew Marcus

Department of Geography, University of Oregon, Eugene, Oregon, USA. <u>marcus@uoregon.edu</u>

James P. McNamara

Department of Geosciences, Boise State University, Boise, Idaho, USA. <u>jmcnamar@boisestate.edu</u>

Venkatesh Merwade

School of Civil Engineering, Purdue University, West Lafayette, Indiana, USA. <u>vmerwade@purdue.edu</u>

Lyubov V. Meshkova

Geography and Environment, University of Southampton, Southampton, UK. <u>I.v.meshkova@soton.ac.uk</u>

François Métivier

Institut du Physique du Globe de Paris, Jussieu, Paris, France. <u>metivier@ipgp.fr</u>

David J. Milan

Department of Natural and Social Sciences, University of Gloucestershire, Cheltenham, Gloucestershire, UK. <u>dmilan@glos.ac.uk</u>

Robert G. Millar

Department of Civil Engineering, The University of British Columbia, Vancouver, British Columbia, Canada. <u>millar@civil.ubc.ca</u>

Erik Mosselman

Inland Water Systems Unit, Deltares and Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands. <u>erik.mosselman@deltares.nl</u>

Erich R. Mueller

Geography Department, University of Colorado, Boulder, Colorado, USA. <u>erich.mueller@colorado.edu</u>

Marian Muste

IIHR-Hydroscience & Engineering and Civil & Environmental Engineering Department, The University of Iowa, Iowa City, Iowa, USA. <u>marian-muste@uiowa.edu</u>

Vladimir Nikora

School of Engineering, Kings College, Aberdeen, UK. v.nikora@abdn.ac.uk

Taha B.M.J. Ouarda

Institut National de la Recherche Scientifique, Centre Eau-Terre-Environnement, Québec, Canada. <u>taha_ouarda@ete.inrs.ca</u>

Athanasios (Thanos) N. Papanicolaou

IIHR-Hydroscience & Engineering and Civil & Environmental Engineering Department, The University of Iowa, Iowa City, Iowa, USA. apapanic@engineering.uiowa.edu

John Pitlick

Geography Department, University of Colorado, Boulder, Colorado, USA. <u>pitlick@colorado.edu</u>

Ian Reid

Department of Geography, Loughborough University, Loughborough, Leicestershire, UK. <u>ian.reid@lboro.ac.uk</u>

Colin D. Rennie