

Cambridge University Press  
978-1-107-68259-7 - Natural Hazards in Australasia  
Edited by James Goff and C R De Freitas  
Frontmatter  
[More information](#)

# Natural Hazards in Australasia

Many ideas and concepts about natural hazards have been developed in Australasia, but these are often overlooked in books written from a Northern Hemisphere perspective. *Natural Hazards in Australasia* is the first textbook that considers Australasian natural hazards, their triggering mechanisms and the physical and social environments in which they occur.

James Goff and Chris de Freitas lead an expert author team from around Australia and New Zealand to introduce readers to the natural hazards of the Australasian region, including floods, drought, tropical cyclones, volcanic and seismic hazards, tsunamis, landslides and bushfires. This book explores the interactions not only between one hazard and another, but also between humans and natural hazards.

Key pedagogical features for students include learning objectives, regional case studies, summaries, chapter glossaries, end-of-chapter reviews and discussion questions, and further reading and resources. The full colour text is enhanced by a rich array of illustrations, photographs and maps.

**James Goff** is Professor in the School of Biological, Earth and Environmental Sciences at UNSW Australia.

**C R de Freitas** is Associate Professor in the School of Environment at the University of Auckland.

Cambridge University Press  
978-1-107-68259-7 - Natural Hazards in Australasia  
Edited by James Goff and C R De Freitas  
Frontmatter  
[More information](#)

---

Cambridge University Press  
978-1-107-68259-7 - Natural Hazards in Australasia  
Edited by James Goff and C R De Freitas  
Frontmatter  
[More information](#)

# Natural Hazards in **Australasia**



EDITED BY JAMES GOFF AND  
C R DE FREITAS



CAMBRIDGE  
UNIVERSITY PRESS

Cambridge University Press  
978-1-107-68259-7 - Natural Hazards in Australasia  
Edited by James Goff and C R De Freitas  
Frontmatter  
[More information](#)

## CAMBRIDGE UNIVERSITY PRESS

477 Williamstown Road, Port Melbourne, VIC 3207, Australia

Cambridge University Press is part of the University of Cambridge.

It furthers the University's mission by disseminating knowledge in the pursuit of education, learning and research at the highest international levels of excellence.

[www.cambridge.org](http://www.cambridge.org)

Information on this title: [www.cambridge.org/9781107682597](http://www.cambridge.org/9781107682597)

© Cambridge University Press 2016

This publication is copyright. Subject to statutory exception and to the provisions of relevant collective licensing agreements, no reproduction of any part may take place without the written permission of Cambridge University Press.

First published 2016

Cover designed by Eggplant Communications

Typeset by Integra Software Services Pvt Ltd

Printed in Singapore by Markono Print Media Pte Ltd

*A catalogue record for this publication is available from the British Library*

*A Cataloguing-in-Publication entry is available from the catalogue of the National Library of Australia at [www.nla.gov.au](http://www.nla.gov.au)*

ISBN 978-1-107-68259-7 Paperback

### **Reproduction and communication for educational purposes**

The Australian *Copyright Act 1968* (the Act) allows a maximum of one chapter or 10% of the pages of this work, whichever is the greater, to be reproduced and/or communicated by any educational institution for its educational purposes provided that the educational institution (or the body that administers it) has given a remuneration notice to Copyright Agency Limited (CAL) under the Act.

For details of the CAL licence for educational institutions contact:

Copyright Agency Limited

Level 15, 233 Castlereagh Street

Sydney NSW 2000

Telephone: (02) 9394 7600

Facsimile: (02) 9394 7601

E-mail: [info@copyright.com.au](mailto:info@copyright.com.au)

Cambridge University Press has no responsibility for the persistence or accuracy of URLs for external or third-party internet websites referred to in this publication and does not guarantee that any content on such websites is, or will remain, accurate or appropriate.

CONTENTS

<i>List of contributors</i>	x
<i>List of figures and tables</i>	xi
<i>List of case studies</i>	xv
<i>Acknowledgements</i>	xvi
<b>1 Introduction</b>	<b>1</b>
<i>James Goff and C R de Freitas</i>	
Introduction	2
What is Australasia?	2
What is a natural hazard?	3
Conceptual overview	3
Scope and plan of the book	5
References	6
<b>2 Floods</b>	<b>7</b>
<i>C R de Freitas</i>	
Learning objectives	8
Introduction and overview	8
Hazard event characteristics	10
Types of floods and their causes	10
Measuring and monitoring floods	15
Probabilities and frequencies	16
Flood hazard mitigation and management	17
Adjustments and human response	19
Avoidance	19
Protection	20
Regulation	21
Relocation	22
Compensation	22
Education	23
Coastal inundation	23
Hazard risk assessment and management	25
Summary	27
Glossary	28
Review questions	29
Discussion questions	29
Further reading and other resources	29
References	30
<b>3 Drought</b>	<b>32</b>
<i>C R de Freitas</i>	
Learning objectives	33
Introduction and overview	34
Characteristic dimensions of droughts	35

What is drought?	36
Meteorological drought	36
Agricultural drought	37
Hydrological drought	37
Socioeconomic drought	38
Causes of drought	38
Drought indices	40
Impacts of drought	43
Human response to the drought hazard	44
Water supply management	45
Water demand management	45
Mitigation of drought impact	45
Summary	48
Glossary	48
Review questions	48
Discussion questions	49
Further reading and other resources	49
References	49
<b>4 Tropical cyclones</b>	<b>51</b>
<i>C R de Freitas</i>	
Learning objectives	52
Introduction	52
Characteristics of tropical cyclones	53
Tropical cyclone formation and decay	54
Tropical cyclone intensity	55
Monitoring and warnings	58
Trends and links with large-scale atmospheric circulation	61
Impacts of tropical cyclones	63
Impact mitigation	67
Risk analysis and future trends	68
Summary	69
Glossary	69
Review questions	70
Discussion questions	70
Further reading and other resources	70
References	71
<b>5 Volcanic hazards</b>	<b>73</b>
<i>Jan Lindsay, Mary Anne Thompson and Philip Shane</i>	
Learning objectives	74
Introduction	74
Overview of volcanoes in Australasia	77
Australia	80
New Zealand	81
Melanesia	83
South-West Pacific	85
Physical dimensions of volcanic hazard	87
Likelihood of eruption	87
Style of eruption	88

Hazardous volcanic phenomena	89
Hazards of the AVF	91
Human and social dimensions of volcanic hazard	93
Terminology of risk	93
Volcanic impacts	94
Impact assessment in the AVF	94
Hazard mitigation and risk reduction for volcanic hazard	94
Summary	97
Glossary	98
Review questions	100
Discussion questions	101
Further reading and other resources	101
References	101
<b>6 Seismic hazards</b>	<b>104</b>
<i>M C Quigley and B Duffy</i>	
Learning objectives	105
Introduction	105
The origin of earthquakes	108
Plate tectonics, stress and rock fracturing	108
Earthquakes, faults, and plate tectonic settings	108
Earthquake behaviour and triggering	113
Models for describing earthquake behaviour	113
Earthquake triggering	115
Measurement and characterisation of earthquake shaking and faulting	117
Earthquake shaking intensity	117
Measuring fault ruptures	120
Earthquake frequency–magnitude relationships	122
Earthquake hazards	125
Faulting-induced hazards	125
Shaking-induced hazards	126
Assessing, avoiding and mitigating earthquake hazards	127
Summary	135
Glossary	136
Review questions	140
Discussion questions	140
Further reading and other resources	140
References	143
<b>7 Tsunamis</b>	<b>147</b>
<i>James Goff and Catherine Chagué-Goff</i>	
Learning objectives	148
What is a tsunami?	148
Introduction and overview	148
Overview of tsunamis in Australasia	151
Australia	151
New Zealand	153
Pacific Island countries and territories within Australasia	157
Distant threats for Australasia	160

Physical dimensions of tsunamis	162
Causes	162
What is a tsunami?	163
Measuring and observing tsunamis	163
Human and social dimensions of tsunamis	166
Hazard mitigation and risk reduction for tsunamis	168
Summary	172
Glossary	172
Review questions	174
Discussion questions	174
Further reading and other resources	174
Websites	174
Papers	175
References	175
<b>8 Landslides</b>	<b>178</b>
<i>Samantha Clarke and Thomas Hubble</i>	
Learning objectives	179
Introduction	179
What is a landslide and why do they happen?	179
Case studies	180
An overview of landsliding	186
Landslide terminology	186
Overview of landslide occurrence in Australasia	188
Australia	191
New Zealand	192
Papua New Guinea	198
Understanding and modelling landslides	198
Anatomy of a landslide	200
Slope stability analysis and the infinite slope equation	200
Infinite slope equation: static analysis	202
Reconsideration of the case studies	209
Management and mitigation strategies	210
Risk avoidance and hazard mapping	210
Engineered solutions and barriers	213
Summary	216
Glossary	216
Review questions	218
Discussion questions	219
Further reading and other resources	219
References	219
<b>9 Bushfires</b>	<b>225</b>
<i>Joshua Whittaker and Katharine Haynes</i>	
Learning objectives	226
Introduction	226
Overview of bushfire in Australia	226
Significant bushfire events	227



Cambridge University Press  
978-1-107-68259-7 - Natural Hazards in Australasia  
Edited by James Goff and C R De Freitas  
Frontmatter  
[More information](#)

Physical dimensions of bushfire	232
Climate and fire weather	232
Vegetation and fuel	233
Fire behaviour	235
Human and social dimensions of bushfire	237
Human locations and land uses	237
Planning, preparation and response	239
Gender and bushfire	240
Life and property losses	240
Hazard mitigation and risk reduction	242
Fuel management	243
Land-use planning	244
Building regulations and codes	245
Reducing bushfire ignitions	245
Fire and emergency response	246
Prepared, responsive communities	247
Future challenges	248
Conclusion	248
Summary	248
Glossary	250
Review questions	251
Discussion questions	251
Further reading and other resources	252
References	252
<i>Index</i>	258

## CONTRIBUTORS

**Catherine Chagué-Goff** is Senior Lecturer in the School of Biological, Earth and Environmental Science at UNSW Australia.

**Samantha Clarke** is Assistant Lecturer in Geology and Engineering Geology in the Geocoastal Research Group at the University of Sydney.

**C R de Freitas** is Associate Professor in the School of Environment at the University of Auckland.

**Brendan Duffy** is Lecturer in Applied Geoscience in the School of Earth Sciences at the University of Melbourne.

**James Goff** is Professor in the School of Biological, Earth and Environmental Sciences at UNSW Australia.

**Katharine Haynes** is a Senior Research Fellow at Risk Frontiers, Macquarie University.

**Thomas Hubble** is Associate Professor in Geology and Engineering Geology at the University of Sydney.

**Jan Lindsay** is Associate Professor in the School of Environment at the University of Auckland.

**Mark Quigley** is Associate Professor of Active Tectonics and Geomorphology in the School of Earth Sciences at the University of Melbourne.

**Philip Shane** is Associate Professor in the School of Environment at the University of Auckland.

**Mary Anne Thompson** is Research Fellow in the School of Environment at the University of Auckland.

**Joshua Whittaker** is a Research Fellow at the Centre for Risk & Community Safety at the Royal Melbourne Institute of Technology.

FIGURES AND TABLES

Figures

2.1	Hazard and resource thresholds in relation to rainfall	9
2.2	Aerial view of Milton during Brisbane River flood, January 2011	12
2.3	Brisbane flood 2011	13
2.4	Hydrograph curve produced by continuously measuring run-off from a catchment	16
2.5	Multi-strategy flood management	20
2.6	Flooded house – elevated	26
3.1	Land surface effects intensify drought during summer by positive land–atmosphere feedback	39
3.2	North and South island of New Zealand Soil Moisture Deficit Index anomalies relative to the normal, 1992–2013	46
3.3	Drought conditions during 2013 in the Wairarapa, New Zealand	47
4.1	Tropical cyclones and tornadoes compared	52
4.2	Schematic illustration of the structure of a tropical cyclone in the Southern Hemisphere	53
4.3	Tracks of TC Steve in 2000	56
4.4	Tracks of TC Ingrid in 2005	56
4.5	Coverage areas of Tropical Cyclone Warning Centres in the Australasian region	59
4.6	Tracks of all tropical cyclones for the period 1981–2005	60
4.7	A comparison of tropical cyclone tracks in the South-West Pacific region during La Niña and during El Niño conditions	62
4.8	Impacts of tropical cyclones resulting from rain, wind and storm surge	64
4.9	Illustration of a storm surge during the coastal impact of a tropical cyclone	64
4.10	The track of TC Tracy 21–25 December 1974	66
4.11	Wreckage left by TC Tracy	67
5.1	Map showing Auckland urban areas and past eruption vents and volcanic deposits of the Auckland Volcanic Field	75
5.2	Map showing the location of Australasia in relation to major plate tectonic boundaries and the Pacific Ring of Fire	76
5.3	Map of Australasian volcanic areas and subduction zone trenches	78
5.4	Different shapes and sizes of volcanic landforms	79
5.5	Map of intraplate Newer Volcanics Province in south-eastern Australia	80
5.6	Map showing active volcanic regions of New Zealand’s North Island	81
5.7	Images of different volcano types and eruption styles	84

5.8	Images illustrating the volcanic impacts of eruptions	86
5.9	A transdisciplinary, holistic approach to mitigating volcanic activity	96
6.1	(a) The plate tectonic setting of Australasia; (b) Cross-sectional cartoon through the Australian plate; (c) Cross-sectional cartoon through the Australian–Pacific Plate boundary in New Zealand’s North Island; (d) Cross-sectional cartoon through the Australian–Pacific continent–continental collisional plate boundary in New Zealand’s South Island	109
6.2	Types of faults	110
6.3	(a) The subsurface anatomy of an earthquake rupture; (b) Cross-sectional depth profile of a fault zone and related changes in seismic shear wave velocities	111
6.4	Scaling relationships between earthquake moment magnitude and frequency in Australasia	112
6.5	(a) The seismic cycle and elastic rebound; (b) Plot of fault stress versus time through the seismic cycle; (c) Elastic strain versus time through the seismic cycle; (d) Fault total displacement versus time through the seismic cycle; (e) Stress evolution	114
6.6	The many ways in which earthquakes may be triggered	116
6.7	Methods for measuring earthquake ruptures and studying active faults	121
6.8	(a) Gutenberg–Richter plot for frequency–magnitude relationships in the Canterbury region; (b) Temporal distribution of earthquakes during the Canterbury earthquake	123
6.9	(a) Epicentral locations of $M_w \geq 5$ earthquakes in Australasia since 1905; (b) Gutenberg–Richter plot summarising $M_w \geq 5$ seismicity for the regions delineated in (a) for the period 1905–2014	124
6.10	Earthquake faulting and shaking hazards in a geologically heterogeneous landscape	125
6.11	The geological and seismologic context for the 2010–11 Canterbury earthquake sequence	129
6.12	Recording of the Darfield earthquake surface rupture	130
7.1	Tsunami propagation map showing approximate extent of the 2009 South Pacific tsunami	149
7.2	The 2009 South Pacific tsunami in Samoa	150
7.3	Australasia and its tectonic setting	152
7.4	A series of maps summarising the Australian tsunami record	154
7.5	New Zealand showing main local, regional and distant tsunami sources	155
7.6	Detail of South-West Pacific region highlighting similarly aged Australasian events	156
7.7	Plan geomorphology of Pacific atolls	158
7.8	Summary of wave height data for the 1868 and 1960 distant source Chilean tsunamis	161
7.9	Key terms associated with the life cycle of a tsunami from generation to inundation limit	164
7.10	Simplified risk management process	166

7.11	Example of tsunami inundation and evacuation route map from Waihou Bay, Bay of Plenty, North Island, New Zealand	169
7.12	Generic New Zealand tsunami evacuation sign	169
7.13	Hawaii Island's Z-Card	171
8.1	(a) Geological map of the Abbotsford landslide; (b) Geological cross-section of the Abbotsford landslide; (c) Oblique aerial view of the Abbotsford landslide	181
8.2	(a) An example of the problems faced along Lawrence Hargrave Drive; (b) The Sea Cliff Bridge	183
8.3	(a) Location map of Tumbi Quarry landslide; (b) Site geology of the Tumbi Quarry; (c) Aftermath of the landslide at Tumbi Quarry	185
8.4	Types of landslides	187
8.5	(a) Landslides occurring along the cliff escarpments of Whakatane coast, New Zealand; (b) Rotational landslide on the coast of the North Island of New Zealand	190
8.6	Fatal landslides in the Australasian region 2004–10	190
8.7	(a) Australasian mean rainfall map; (b) Australasian earthquake distribution and Australian landslide distribution map; (c) Australasian digital elevation map	191
8.8	Map of Australia showing (a) mean rainfall; (b) earthquake distribution; (c) landslide distribution; and (d) digital elevation model showing distribution of steep hillslopes	192
8.9	Map of New Zealand showing (a) mean rainfall; (b) earthquake distribution; (c) distribution of large, multiple-occurrence, rainfall-triggered, regional landslide events 1974–2004; (d) digital elevation model showing the distribution of steep hillslopes	193
8.10	Glade's map dividing New Zealand into regions of landslide susceptibility	194
8.11	EIL opportunity in New Zealand	196
8.12	Map of PNG showing (a) digital elevation model showing distribution of steep hillslopes; (b) earthquake distribution; (c) landslide distribution; (d) mean rainfall	199
8.13	The 1985 Bialla debris avalanche in Papua New Guinea	200
8.14	Anatomy of a soil slump/landslide with major features labelled	201
8.15	Force stress vectors within a slope	201
8.16	Forces involved in infinite slope model	203
8.17	Simple hillslope stability investigations using the infinite slope equation	206
8.18	(a) The process of cutting the toe of a slope; (b) Example of a hillslope with toe cut away	208
8.19	Schematic approach to landslide hazard and risk evaluation	211
8.20	(a) Hazard due to precipitation-induced landslides in Indonesia; (b) exposure to earthquake-induced landslides in Indonesia	212

8.21	(a) Abseilers installing rock-bolts and wire mesh to prevent rock blocks falling; (b) Meshed rock wall and safety fence; (c) and (d) Abseilers installing soil nails and wire mesh to control slope failure	214
8.22	The Australian Geomechanics Society's dos and don'ts of hillslope construction	215
9.1	Areas of Victoria affected by bushfires during January and February 2009	229
9.2	A house destroyed in the 2009 'Black Saturday' bushfires	230
9.3	Australian bushfire seasons	233
9.4	Parts of a bushfire	236
9.5	Fire danger ratings	237
9.6	Population growth and residential development are increasing the exposure of people and assets in bushfire risk areas	238
9.7	Prescribed burning is undertaken to reduce fuel load	243

Tables

2.1	Structural and non-structural methods for flood damage reduction	18
3.1	Rainfall decile classification	40
3.2	Drought indices and their data needs	41
3.3	The Drought Monitor classification ranking percentile scheme	42
4.1	Tropical cyclone categories and corresponding values of approximate average maximum wind speeds and central pressures, modified for the Australian region from the Saffir–Simpson scale	57
4.2	The Saffir–Simpson tropical cyclone wind scale with types of damage due to wind as used by the US National Hurricane Center Service (NOAA)	57
4.3	Tropical Cyclone Warning Centres (TCWCs) with regional responsibility throughout Australasia	58
5.1	Typical characteristics of basalt, andesite, dacite and rhyolite magmas	79
6.1	Notable earthquakes in Australia and New Zealand, by date	106
6.2	Modified Mercalli Intensity (MMI) scale and comparison with peak ground acceleration	118
8.1	Summary of Varnes's 1978 classification of landslide types	188
8.2	Landslide velocity scale	188
8.3	Natural slopes and rock types affected by earthquake-induced landslides	195
8.4	Typical slope threshold levels from the main types of earthquake-induced landslides	195
8.5	A range of ground classes of varying landslide vulnerability	197
8.6	Typical values of unit weight, cohesion and friction angle for a range of slope materials	207
9.1	A selection of significant Australian bushfire events	227
9.2	Australian fire danger ratings	237

CASE STUDIES

2.1	The 2011 Brisbane flood	12
2.2	Coastal flooding and sea-level rise	23
2.3	The making of a tragic flash flood	27
3.1	The Millennium Drought	33
3.2	Dust bowled: the 2012–13 New Zealand drought	46
4.1	Tropical cyclone Tracy (1974)	65
5.1	The Auckland Volcanic Field	75
6.1	The 2010–11 Canterbury earthquake sequence in New Zealand's South Island	128
7.1	Samoa 2009	148
8.1	Abbotsford, New Zealand (1979)	180
8.2	Rockfalls and earth flows at Lawrence Hargrave Drive, Australia	182
8.3	Complex, multi-factor deep-seated landslide at Tumbi, Papua New Guinea	184
9.1	The 2009 'Black Saturday' bushfires	228

## ACKNOWLEDGEMENTS

The authors and Cambridge University Press would like to thank the following for permission to reproduce material in this book.

### Text extracts

Extract from *Concise Australian National Dictionary*: Reproduced by permission of Oxford University Press Australia from *Concise Australian National Dictionary*, Joan Hughes, 1992 © Oxford University Press, [www.oup.com.au](http://www.oup.com.au); Extract from *The New Zealand Oxford Dictionary*: Reproduced by permission of Oxford University Press Australia from *The New Zealand Oxford Dictionary*, Tony Deverson 2004 © Oxford University Press, [www.oup.com.au](http://www.oup.com.au).

### Images

**Figure 2.2, 2.3:** © Shutterstock.com/Brisbane; **2.6:** © Shutterstock.com/nevenm; **3.2:** © Reserve Bank of New Zealand; **3.3:** Photo courtesy of NIWA – National Institute of Water and Atmospheric Research (Taihoro Nukurangi); **4.6:** Created using User:jdorje/Tracks by Nilfanion on 2006-08-05. Background image from File: Whole\_world\_-\_land\_and\_oceans.jpg (NASA). Tracking data for storms within the Atlantic and Eastern Pacific basins is taken from the National Hurricane Center and the Central Pacific Hurricane Center's Northeast and North Central Pacific hurricane database. The tracking data for storms within the Indian Ocean, the Northwest Pacific and the Southern Pacific is from the Joint Typhoon Warning Center. Tracking data for Cyclone Catarina in the South Atlantic was published in Gary Padgett's April 2004 Monthly Tropical Cyclone Summary and was originally produced by Roger Edson of the University of Guam; **4.9:** © The State of Queensland 2015; **4.11:** Billibeee/Wikimedia Commons; **5.7a, b, e:** © Lloyd Homer GNS Science; **5.7c:** © Steven Sherburn GNS Science; **5.7d:** Photo: Sonja Storm; **5.8a:** © Brad Scott GNS Science; **5.8b:** Photo: Carol Stewart; **5.8c-f:** Photos by Jan Lindsay; **6.8:** GeoNet content is copyright GNS Science and is licensed under a Creative Commons Attribution 3.0 New Zealand License; **7.2:** Photo: Catherine Chagué-Goff; **7.7a:** Satellite image courtesy of NASA (Visible Earth: <http://visibleearth.nasa.gov/>); **7.7b:** Satellite image courtesy of NASA-Johnson Space Center, Image Science and Analysis Laboratory (<http://eol.jsc.nasa.gov/>); **7.11:** Reproduced with permission of Bay of Plenty Emergency Management Group (BOP CDEM) - (<http://bopcivildefence.govt.nz/media/CDBOP/MemberLibrary/Waihou%20Bay%20Tsunami%20Evacuation%20Route%20Map.gif>, 2014); **7.13:** Courtesy Hawaii Tourism Authority; **8.2a:** Photo: Hendrickx et al. 2011. Reproduced with permission from Australian Geomechanics Society; **8.2b:** Wikimedia Commons/Illawarrashowcase; **8.4, 8.14:** U.S. Geological Survey Department of the Interior/USGS; **8.5a:** Image courtesy of tumekeFM 2013; **8.5b:** Image courtesy of Mike Marden of New Zealand Landcare Research, Manaaki Whenua; **8.7a:** Asia-Pacific: Annual Precipitation (Jul 2015). UN Cartographic Section, WORLDCLIM (Indicator BIO12 of the BIO Coverage), United Nations Office for the Coordination of Humanitarian Affairs (OCHA) Regional Office for Asia Pacific (ROAP). Reprinted with the permission of the United Nations; **8.8a:**



Bureau of Meteorology (2015). 'Average rainfall – annual'. Retrieved 22 May 2015, from [http://www.bom.gov.au/jsp/ncc/climate\\_averages/rainfall/index.jsp](http://www.bom.gov.au/jsp/ncc/climate_averages/rainfall/index.jsp); **8.9a, b**: National Institute of Water and Atmospheric Research 2015; **8.13**: King, J. et al. (1989). 'The 1985 Bairaman landslide dam and resulting debris flow, Papua New Guinea'. *Quarterly Journal of Engineering Geology and Hydrogeology* 22(4): 257–270. <http://qjehg.geoscienceworld.org/feedback>; **8.18b**: Image courtesy of Thomas Hubble, 2011; **8.19, 8.20**: From 'Risk Assessment and Mitigation Measures for Natural and Conflict Related Hazards in Asia-Pacific', by Cepeda et al, © 2010 United Nations. Reprinted with the permission of the United Nations; **8.22a, b**: Images courtesy DJ Matheson of Abseil Access Engineering New Zealand; **8.22c, d**: Images courtesy of Abseil Access Engineering New Zealand; **9.2, 9.5, 9.6, 9.7**: Image courtesy of Bushfire & Natural Hazards Cooperative Research Centre

**Page 1**: © Shutterstock.com/VanderWolf Images; **32**: © Shutterstock.com/Alberto Loyo; **51**: © Shutterstock.com/Harvepino; **73**: © Shutterstock.com/Fredy Thuerig; **104**: © Shutterstock.com/NigelSpiers; **147**: FEMA/Casey Deshong; **178**: AusAID/Department of Foreign Affairs and Trade; **225**: © Shutterstock.com/kwest.

*Every effort has been made to trace and acknowledge copyright. The publisher apologises for any accidental infringement and welcomes information that would redress this situation.*