Copyright Statement

The digital copy of this thesis is protected by the Copyright Act 1994 (New Zealand).

This thesis may be consulted by you, provided you comply with the provisions of the Act and the following conditions of use:

- Any use you make of these documents or images must be for research or private study purposes only, and you may not make them available to any other person.
- Authors control the copyright of their thesis. You will recognize the author's right to be identified as the author of this thesis, and due acknowledgement will be made to the author where appropriate.
- You will obtain the author's permission before publishing any material from their thesis.

General copyright and disclaimer

In addition to the above conditions, authors give their consent for the digital copy of their work to be used subject to the conditions specified on the Library Thesis Consent Form and Deposit Licence.
SEARCHING FOR THE IDEAL RIVER?

NEW DIRECTIONS IN
GEOGRAPHICAL GEOMORPHOLOGY

BRENDON BLUE

A thesis submitted in fulfilment of the requirements
for the degree of Doctor of Philosophy in Geography

The University of Auckland

2018
Primary supervisor: Professor Gary Brierley
Secondary supervisor: Dr Karen Fisher

*Searching for the ideal river? New directions in geographical geomorphology*
Brendon Blue © 2018
To absent friends

Hiroki
Julian
Ferg
Dorothy
Gramps
June
John
Nanna
Grandpa
ABSTRACT

Geomorphology’s development as a scientific subject has produced increasingly sophisticated insight into the physical processes shaping the earth’s surface. It is increasingly apparent, however, that understanding contemporary environments requires equal attention to the processes through which people’s aspirations for landscape are constructed and enacted. Building on and extending traditions of geographical geomorphology as the study of relations between people and landscape, this thesis draws attention to the politics of knowledge production in fluvial geomorphology and river management. Drawing on case studies from western China and Aotearoa New Zealand, the thesis demonstrates how the contemporary practice of geomorphology and river management are entangled with normative understandings of an ideal river. It advances this argument through three interventions focusing on geomorphic diversity, measurement, and the concept of river health.

Beginning on the Qinghai-Tibetan Plateau, the first intervention proposes a broad understanding of geodiversity as a fundamental basis for understanding relationships between fluvial geomorphology and ecology. It highlights the role of historically-determined valley setting in the headwaters of the Yellow River as a key cross-scalar control on the contemporary river, sketching the outlines of a place-based approach to understanding relationships between form and process in the region.

Inspired by conversations with colleagues during fieldwork on the Qinghai-Tibetan Plateau, the second intervention takes a step back to investigate the assumptions and ethical implications of geomorphology’s practice as an objective science. Drawing on contemporary developments in critical environmental geographies, and building on geomorphology’s rich but often-maligned history of methodological debate, it explores possibilities for more reflexive river science and management. Recognising the mutually constitutive relationship between geomorphic enquiry and landscape, this intervention presents an open-minded, constructive engagement towards a socially situated, reflexive physical geography.
Returning specifically to freshwater, the third intervention investigates meanings of ‘good condition’ as a basis for river research and intervention. It follows the transition of river health from a holistic but hazy ethic of environmental care to specific sets of diagnostic indicators for guiding intervention. Tracing this transition from metaphor to metric, this third intervention examines how common-sense understandings of river condition were first challenged by, and then incorporated within, the scholarly and political project of river health. Arguing that a search for objectivity entrenched assumptions that naturalness was both desirable and attainable, it proposes a revitalised approach to river health as a platform for constructively renegotiating ‘what matters’ for freshwater.

Finally, I consider the contemporary meaning of place as a basis for understanding and intervening in the landscape. Looking beyond binary notions of ‘place-based’ versus ‘placeless’ approaches to knowledge, I critically examine the implications and limitations of essentialist assertions of uncertainty. I conclude by outlining potential new directions for a progressive geographical geomorphology that is grounded in scientific approaches to understanding landscapes, but which takes seriously the social and political contexts in which geomorphic knowledge is produced and used.
ACKNOWLEDGEMENTS

I greatly appreciate the financial support I have received over the course of my research. A University of Auckland Doctoral Scholarship was essential in enabling me to undertake this thesis. Funding for fieldwork in China was provided through the Three Brothers Partnership between The University of Auckland, Tsinghua University (Beijing) and Qinghai University (Xining). A collection of one-off grants have also provided valuable opportunities to attend workshops and conferences along the way: ANZGG and NZGS postgraduate student grants, the New Zealand Ecohydraulics Trust Travel Award, the Rewi Alley Scholarship in Modern Chinese Studies, and the NZASIA Postgraduate Award. Thank you also to Rebecca Lave for inviting and assisting me to attend the critical physical geography AAG pre-conference in 2016. I was recently delighted to receive the Area Prize for New Research in Geography, for which I would like to thank the RGS-IBG. Thank you also to the City of London Police, Metropolitan Police Service, and the staff at the Wheatsheaf, Borough Market, who risked their lives to save ours that weekend.

Fieldwork in China was challenging enough; it would have been impossible without our Chinese colleagues, particularly Chen Gang, Du Jun, Huang He Qing, Li Xilai, Li Zhiwei, Xie Yongli (‘Lily’), Yang Yuanwu, Yu Guo-An and Wang Zhao-Yin. I will never forget the cultural experiences, great laughs and gastric distress I shared in China with Simon Aiken, Alan Cheung and Tami Nicoll.

I have had a long association with the School of Environment, and it is not possible to name everyone there who has helped and supported me along the way. The influence of some, however, has been especially important to this thesis. I am immeasurably grateful for the supervision of Gary Brierley who has always treated me as an equal, giving me room to move while being ready to provide a guiding hand when I went off on one meander too many. Thank you also to Karen Fisher, for always being up for a soothing chat and a laugh. I greatly appreciate the longstanding support of Paul Kench, who encouraged my early steps down the pathway of physical geography. Thank you to other staff I have gone to the field with, worked with, taught with and talked with. This includes, but is not limited to:
Paul Augustinus, Gretel Boswijk, Francis Collins, Brad Coombes, Mark Dickson, JC Gaillard, Jay Gao, David Hayward, Joe Fagan, Murray Ford, Anthony Fowler, Brendan Hall, Robin Kearns, June Logie, Marie McEntee, Warren Moran, Larry Murphy, Susan Owen, George Perry, Nick Richards, Anna-Marie Simcock, Sam Trowsdale, Jon Tunnicliffe, David Wackrow, Mel Wall and Paul Williams. Particular thanks to Richard LeHeron and Nick Lewis for their instrumental feedback on an early presentation of my river health work. Thank you, also, to M-E Macdonald for lending your house for a wonderful winter of writing.

I have been very lucky to be part of a supportive network of postgraduate friends and colleagues while writing this thesis. I have been welcomed warmly to the School’s (human) geography reading group, never made to feel like I came from across the divide. Particular thanks to my colleagues in organising the Freshwater Geographies workshops: Claire Gregory, Kiely McFarlane, Petra van Limburg-Meijer, Helen Reid and Marc Tadaki. Also to the rest of ‘team fluv’, especially Stephanie Benucci, Jade Hyslop, Ashlee McCormick, Petra Pearce, and Nick Reid. Thank you, too, to a mixture of postgraduate friends: Carola Cullum, Andrea Edwards, Bill Howie, Meiqin Han, Stephen FitzHerbert, Pippa Mitchell, Hiroki Ogawa, Shi Yan, Hayley Sparks, Roseanna Spiers, Riki Taylor and Deirdre Wilcock. Special thanks to Maria Hokopaura, Katherine Hore and Emma Sharp, who I have thoroughly enjoyed teaching alongside.

Beyond the University, I have relied heavily on the companionship, support and encouragement of my family and friends. To Ashleigh and Tom Baker, James Basset, Mark Burgess, Tommy Chou, Mike Fletcher, Emma Green, Claire Gregory, Jeffrey Hawke, Shaun and Rachelanne Kearney, Alex Leslie, Ee-Heng Lim, Guy Lowe, Gemma Mathieson, Ally Palmer, Anne Simpson, Tom Venning, Kirsti Whalen and Simon Whalen: thank you for always being there, even when ‘there’ is on the other side of the world. Particular appreciation to Ash and Tom, for their warmth, energy and lasagne, and to Simon, for keeping me intellectually honest and for assisting with typesetting.

I have been fortunate to be welcomed into my partner’s family. Thank you to Viv, Ferg, Emma and Caroline Fergusson, Ed Clayton, Ami Maxwell and Julian Dawe, Dorothy Calder and June and her Sheiffs for your encouragement over many drinks and dinners. I am grateful for the company and hospitality of Alex Calder and
Sarah Sheiff, who provided nourishing meals and a warm fire just when they were needed most. Andrea and Clover Dawe, thank you for many entertaining evenings and holidays and, most importantly, for introducing me to the importance of 5:30 bubbly and chips.

Since early family holidays at Lake Taupo I have always felt part of an extended clan. Thank you to Nanna and Grandpa, Raewyn and Steve ‘Gramps’ Smith, June and John Ritchie, Tony and Sandra Christiansen, Graeme and Vicki Ritchie, the Hoogendoorns, Steven, Glenn and Megan Christiansen and Frances Bird. Thanks, too, to my Dad, Andrew Tatnell, and to Libby Goodchild, Lucas and William Tatnell, and my step-brothers Will, Alex and Nick. To Ward Friesen, for your good humour and good company, and Florence and Charlotte Crick-Friesen. To Peter Crossley: thank you for your unstinting support, and for teaching me the value of exotic species in ponds, lakes, rivers all over the North Island. To my Mum, super-proofreader Lyndsay Blue, who has inspired me to care more, to work harder, and to take time for the people that matter. To Octavia Calder-Dawe: thank you for your love and your kindness, for opening my eyes to different ways of thinking about the world, and for helping me find that perfect turn of phrase. Last of all, thank you Pipi, for always keeping it fluffy.
This thesis contains three articles already published elsewhere, which have been reformatted and lightly edited in a style consistent with the thesis.

Chapter 3 comprises an article originally published in the *Journal of Geographical Sciences*. The accepted version of the article is included in this thesis with permission from the publisher, Springer. The original source of the content is as follows:

DOI: 10.1007/s11442-013-1044-4

Chapter 5 comprises an article originally published in *Area*. The accepted version of the article is included in this thesis with permission from the publisher, Wiley-Blackwell. The original source of the content is as follows:

DOI: 10.1111/area.12249

Chapter 7 comprises a sole-authored article published in *Progress in Physical Geography*. The accepted version of the article is included in this thesis with permission from the publisher, Sage. The original source of the content is as follows:

DOI: 10.1177/0309133318783148
Co-Authorship Form

This form is to accompany the submission of any PhD that contains published or unpublished co-authored work. **Please include one copy of this form for each co-authored work.** Completed forms should be included in all copies of your thesis submitted for examination and library deposit (including digital deposit), following your thesis Acknowledgements. Co-authored works may be included in a thesis if the candidate has written all or the majority of the text and had their contribution confirmed by all co-authors as not less than 65%.

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 3: Geodiversity in the Yellow River source zone

| Nature of contribution by PhD candidate | Primary responsibility for fieldwork, analysis, conceptualisation, drafting and editing |
| Extent of contribution by PhD candidate (%) | 85 |

**CO-AUTHORS**

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gary Brierley</td>
<td>Guided framing of paper; provided multiple comments and suggestions throughout drafting, assisted with fieldwork</td>
</tr>
<tr>
<td>Yu Guo-an</td>
<td>Assisted with fieldwork, provided comments on final draft and some references</td>
</tr>
</tbody>
</table>

**Certification by Co-Authors**

The undersigned hereby certify that:
- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and
- that the candidate wrote all or the majority of the text.

<table>
<thead>
<tr>
<th>Name</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gary Brierley</td>
<td></td>
<td>07.11.2017</td>
</tr>
<tr>
<td>Yu Guo-an</td>
<td></td>
<td>3/08/2015</td>
</tr>
</tbody>
</table>

Last updated: 19 October 2015
This form is to accompany the submission of any PhD that contains published or unpublished co-authored work. Please include one copy of this form for each co-authored work. Completed forms should be included in all copies of your thesis submitted for examination and library deposit (including digital deposit), following your thesis Acknowledgements. Co-authored works may be included in a thesis if the candidate has written all or the majority of the text and had their contribution confirmed by all co-authors as not less than 65%.

Please indicate the chapter/section/pages of this thesis that are extracted from a co-authored work and give the title and publication details or details of submission of the co-authored work.

Chapter 5: But what do you measure? Prospects for a constructive critical physical geography

<table>
<thead>
<tr>
<th>Nature of contribution by PhD candidate</th>
<th>Primary responsibility for conceptualisation, analysis, drafting and editing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent of contribution by PhD candidate (%)</td>
<td>80</td>
</tr>
</tbody>
</table>

**CO-AUTHORS**

<table>
<thead>
<tr>
<th>Name</th>
<th>Nature of Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gary Brierley</td>
<td>Guided framing of paper; provided multiple comments and suggestions throughout drafting</td>
</tr>
</tbody>
</table>

**Certification by Co-Authors**

The undersigned hereby certify that:

- the above statement correctly reflects the nature and extent of the PhD candidate's contribution to this work, and the nature of the contribution of each of the co-authors; and
- that the candidate wrote all or the majority of the text.

<table>
<thead>
<tr>
<th>Name</th>
<th>Signature</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gary Brierley</td>
<td>[Signature]</td>
<td>07.11.2017</td>
</tr>
</tbody>
</table>

Last updated: 19 October 2015
FANCY AN ADVENTURE?

Some years ago now, I received an email simply titled “Fancy an adventure?”. Professor Gary Brierley had received funding for a substantial research programme on the Qinghai-Tibetan Plateau in western China, bringing with it a number of potential fluvial and grasslands research projects, and he wondered whether I might be interested in being involved. I was very interested indeed.

I had for some time been considering embarking on a PhD in geography, and it was fairly clear that I would pursue physical geography of one kind or another. I found myself, however, torn between coastal geomorphology, which had previously been my focus, and fluvial geomorphology, which I had come to appreciate through Gary’s postgraduate course. Taking the coastal pathway promised tropical reef islands and relatively straightforward, ‘properly’ scientific projects. I also already had much of the foundational knowledge and understanding of research techniques, which would enable me to get my project off the ground relatively quickly. It seemed like the sensible option.

Nonetheless, I was attracted to the prospect of visiting a new part of the world, with landscapes and people very different from those I knew. Granted, my relatively limited background in fluvial geomorphology would require more early effort to come up to speed with research techniques. But, with my sunburn-prone skin, did I even really like the beach that much? I met with Gary, applied for a scholarship, and before I knew it was arriving at Xining airport to conduct a preliminary exploration of the region. I did not realise quite what I was getting myself into.

That first trip is now something of a haze of baijou, fantastic food, terrible food, long days in tiny vans,¹ the challenges of high altitude, fear of dying in a road accident, and a bit of shouting. The latter would have a profound impact on the trajectory of my thesis. While in the field, a series of disagreements emerged between two professors over what constituted an anabranching river. Indeed, they

---

¹ On a later trip I would find myself in the rain, at 1 A.M., pushing one such van up a hill too steep for its engine after we had taken a wrong turn that added four hours to an 18-hour drive.
could not even agree whether ‘anabranching’ was a useful descriptor at all. If no particular discriminating measure could be applied in the field to support the assertion that the river before us presented an anabranching morphology, did that morphology exist at all? A quote from this argument – “But what do you measure?!” – forms part of the title of Chapter 5.

This early skirmish was a sign of things to come. Back in Beijing, a colleague presented some early insights from her work on sediment flux in the region. One of the earlier antagonists interrupted to the effect that a river presenting lower sediment flux was superior, and contention erupted again. This time, attempting to argue that a river’s historical state presented a better indicator of condition than a generalised, placeless metric, one frustrated interlocutor cried out “but what about the blind dolphins?!”.

Back home, these episodes stayed with me. In particular I continued thinking about the statement which, in the moment, had seemed most ridiculous: that one river might be superior to another because it happened to have a lower volume of suspended sediment. On one hand many of the values and attributes commonly associated with rivers emphasise the absence of sediment: swimmability, drinkability, aesthetics and so on. Perhaps it was not wrong, in an abstract sense, to suggest that a ‘cleaner’, clearer river was a superior one. On the other hand, I was studying the Yellow River: wasn’t it supposed to be that colour? These questions would drive my participation in a project formalising the development of a ‘morphological eye’ (Sauer, 1956), aiming to articulate a systematic basis for developing historically-grounded, cross-scalar understandings of riverscapes (published as Brierley et al., 2013).

Meanwhile, I joined a small group of other postgraduate students organising and running a set of three workshops on the theme of freshwater geographies. We sought to call attention to, and challenge, the ways in which freshwater was understood and managed. Initially, we hoped to build a collective vision for Aotearoa’s waterways. This proved more difficult than we had anticipated, however, as neither the participants nor the organisers found consensus on what form that vision should take. The process of negotiating these workshops provided an important lesson in itself, illustrating the challenges and opportunities of collaborating across disciplinary and political divides (we described these processes in Blue et al., 2012).
The course charted by this thesis has been greatly shaped by these encounters and disagreements, both on the Qinghai-Tibetan Plateau and back in Aotearoa, working on sticky issues of freshwater management. Experiences on the Plateau highlighted the importance of questioning the basis on which we make decisions regarding the physical environment; convening and writing about the workshops challenged me to examine my own assumptions about the meaning of ‘good’ river condition. By investigating attempts to capture something which does not exist – the ideal river – I hope that this thesis draws attention to, and constructively challenges, some of the assumptions which are embedded within contemporary river science and management.
## CONTENTS

1 INTRODUCTION  

1 GEOMORPHOLOGY AS GEOGRAPHICAL ENQUIRY  
  1.1 The rise of modern geomorphology  
  1.2 Quantification and the changing meaning of context  
  1.3 Bringing place back in  
  1.4 Changing the status quo?  
    1.4.1 Thesis structure and contributions  

II THE QINGHAI-TIBETAN PLATEAU  

2 FORM, PROCESS AND PLACE  
  2.1 Privileging stability  
  2.2 The Qinghai-Tibetan Plateau  
    2.2.1 Valuing diversity  

3 GEODIVERSITY IN THE YELLOW RIVER SOURCE ZONE  
  3.1 Introduction  
  3.2 The role of geodiversity  
  3.3 Geodiversity on the valley floor  
  3.4 Regional Setting  
  3.5 Methods  
  3.6 Broad-scale geodiversity  
  3.7 Discussion  
  3.8 Conclusion  

III CRITICAL PHYSICAL GEOGRAPHY?  

4 THE PLACE OF PEOPLE  
  4.1 Between nature and society  

5 WHAT DO YOU MEASURE?  
  5.1 Introduction  
  5.2 Measurement as knowing  

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1</td>
<td>The rise of modern geomorphology</td>
<td>4</td>
</tr>
<tr>
<td>1.2</td>
<td>Quantification and the changing meaning of context</td>
<td>7</td>
</tr>
<tr>
<td>1.3</td>
<td>Bringing place back in</td>
<td>9</td>
</tr>
<tr>
<td>1.4</td>
<td>Changing the status quo?</td>
<td>12</td>
</tr>
<tr>
<td>1.4.1</td>
<td>Thesis structure and contributions</td>
<td>13</td>
</tr>
<tr>
<td>II</td>
<td>THE QINGHAI-TIBETAN PLATEAU</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>FORM, PROCESS AND PLACE</td>
<td>19</td>
</tr>
<tr>
<td>2.1</td>
<td>Privileging stability</td>
<td>20</td>
</tr>
<tr>
<td>2.2</td>
<td>The Qinghai-Tibetan Plateau</td>
<td>23</td>
</tr>
<tr>
<td>2.2.1</td>
<td>Valuing diversity</td>
<td>23</td>
</tr>
<tr>
<td>III</td>
<td>CRITICAL PHYSICAL GEOGRAPHY?</td>
<td>49</td>
</tr>
<tr>
<td>4</td>
<td>THE PLACE OF PEOPLE</td>
<td>51</td>
</tr>
<tr>
<td>4.1</td>
<td>Between nature and society</td>
<td>53</td>
</tr>
<tr>
<td>5</td>
<td>WHAT DO YOU MEASURE?</td>
<td>57</td>
</tr>
<tr>
<td>5.1</td>
<td>Introduction</td>
<td>57</td>
</tr>
<tr>
<td>5.2</td>
<td>Measurement as knowing</td>
<td>59</td>
</tr>
<tr>
<td>5.3</td>
<td>Analysing river diversity</td>
<td>61</td>
</tr>
<tr>
<td>5.4</td>
<td>Prospects for a critical geomorphology</td>
<td>64</td>
</tr>
<tr>
<td>5.5</td>
<td>Conclusion</td>
<td>66</td>
</tr>
</tbody>
</table>

**IV** SEARCHING FOR THE IDEAL RIVER

| 6 | QUESTIONING IDEALS | 71 |
| 6.1 | Intervening in a changing world | 72 |

**7** WHAT’S WRONG WITH HEALTHY RIVERS?

| 7.1 | Introduction | 77 |
| 7.2 | The rise of river health | 79 |
| 7.3 | What’s in a name? | 81 |
| 7.3.1 | Meaningful metaphor? | 82 |
| 7.3.2 | From metaphor to metric | 83 |
| 7.4 | Naturalness: just common sense? | 84 |
| 7.4.1 | Which nature? | 85 |
| 7.4.2 | Pets, pests, or pristine? | 86 |
| 7.5 | Discussion | 88 |
| 7.5.1 | A reimagined and revitalised river health? | 90 |
| 7.6 | Conclusion | 91 |

**V** WHERE TO?

**8** REVISITING THE MEANING OF PLACE

| 8.0.1 | New directions | 99 |
| 8.1 | Reconsidering critique | 100 |
| 8.1.1 | Methodology, uncertainty and the politics of place | 102 |
| 8.1.2 | Reductionism and place | 105 |
| 8.1.3 | The nature of uncertainty | 107 |
| 8.1.4 | Uncertainty and place | 109 |
| 8.1.5 | The ambivalent politics of place | 110 |
| 8.2 | Concluding reflections | 112 |

REFERENCES | 115 |
## List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Map of the Yellow River source zone.</td>
</tr>
<tr>
<td>3.2</td>
<td>The Yellow River’s source catchment, showing elevation and the five broad-scale morphological sections of trunk stream.</td>
</tr>
<tr>
<td>3.3</td>
<td>Longitudinal profile of the Yellow River source zone’s trunk stream, downstream to Longyangxia Reservoir, showing the five broad morphological sections identifiable at the landscape scale.</td>
</tr>
<tr>
<td>3.4</td>
<td>Section one of the Yellow River source zone, near Maduo, showing characteristic braided planform morphology.</td>
</tr>
<tr>
<td>3.5</td>
<td>Section two of the Yellow River source zone near Dari showing characteristic partly confined anabranching-braided morphology.</td>
</tr>
<tr>
<td>3.6</td>
<td>Section three of the Yellow River source zone near Jiuzhi showing characteristic confined channel with regular floodplain pockets.</td>
</tr>
<tr>
<td>3.7</td>
<td>Section four of the Yellow River source zone near Maqu showing characteristic partly confined anabranching planform morphology.</td>
</tr>
<tr>
<td>3.8</td>
<td>Section five of the Yellow River source zone near Xinghai showing characteristic terrace-fan confined channel.</td>
</tr>
<tr>
<td>5.1</td>
<td>Transitional braided-anastomosing (or anabranching) morphologies of the Upper Yellow River at Dari.</td>
</tr>
</tbody>
</table>
## List of Tables

| Table 3.1 | Yellow River source zone planform morphologies and associated morphological units. | 36 |
| Table 8.1 | Some of the binary positions commonly deployed in debates regarding the application of geographical approaches to geomorphology, with exemplary or explanatory references. Note that neither I nor those cited here necessarily condone these positions. | 104 |
Part I

INTRODUCTION
During a televised national election debate in September 2017 Bill English, then Prime Minister of New Zealand, was asked to name his favourite river and to state whether he would still swim in it. Citing childhood connections to the Oreti River in Southland, he claimed that he would “swim in it now except they have taken all the swimming holes away, and pushed gravel into them” (Parsons-King and Telfer, 2017, 0:15). In an alternate world, this startling revelation of government inaction in the face of active environmental vandalism would present a major bombshell, embarrassing the government as a resurgent opposition promised a raft of geomorphological protection measures. In this world, of course, it did not.

The moment did, however, produce substantial discussion and debate, as reporters descended on English’s home town of Dipton. Locals stated that they did, in fact, regularly swim in the river: “nothing wrong with it, still pretty clean and clear so I dunno what everyone’s complaining about” (Newman, 2017, 0:45). While the region’s Fish and Game Council pointed to a substantial downstream decline in water quality, Federated Farmers Southland president Allan Baird obtained a comically large glass of river water to emphasise its clarity, although his choice of vessel did not seem to reflect a willingness to drink from it. The state of Aotearoa’s rivers had become a major issue in an election that was suddenly much tighter than expected. Yet despite this enthusiastic journalism, some important questions went unasked and unanswered. In particular, no-one appeared to wonder who had taken those swimming holes away. This tendency to overlook geomorphic condition in favour of water quality and clarity continues today: at the time of writing, the new government’s rhetoric of ‘cleaning up’ waterways remains primarily focussed on bacterial contamination.

Relationships between people and the physical environment are a – perhaps the – fundamental geographical theme: from (rather regrettable) theories of environmental determinism (discussed by Peet, 1985), to early efforts at providing a sense
of humankind’s Role in Changing the Face of the Earth (Thomas, 1956; see also Williams, 1987). As the role of people in shaping the earth’s surface has become increasingly difficult to ignore, attention has turned to the ‘human component’ of environmental alterations. Most obviously, and most recently, this has culminated in efforts to understand and mark the Anthropocene as a geological epoch in which humans have become the primary drivers of global change (see Castree, 2014; Lewis and Maslin, 2015).

These endeavours are generally framed in terms of the biophysical impacts of human activity: the negative consequences, whether intentional or not, of people’s actions (see Cook and Balayannis, 2015). Increasingly, however, efforts to mitigate and mend environmental damage attract regulation and investment (e.g. Bernhardt et al., 2005; Womble and Doyle, 2012). As individuals, organisations and governments aim to effect positive change, rather than simply mitigate the impacts of human activity, they embed into the landscape sets of claims, assumptions and aspirations regarding how the world should be (see Castree et al., 2014). The formation of these visions (see Ryder et al., 2008) is closely tied to the concepts and constructs we have available to make sense of the world, and the knowledge we produce about it (see Demeritt, 1994).

The Oreti River’s brief moment on the national stage highlights the interactions between possibility and desire at this intersection of science and politics: what do we manage the earth’s surface for? It can be tempting to set apparently simple objectives emphasising popular priorities: swimmability in rivers, for example, or the repair of certain human-induced impacts. But while setting easily measurable goals is undoubtedly appealing, doing so risks precluding other causes which are potentially deserving, but less charismatic or less easily articulated. Exploring and intervening in the politics of knowledge production in physical geography and geomorphology, this thesis explores the relationship between our accounts of what landscape is and our sense of what it should be.

1.1 THE RISE OF MODERN GEOMORPHOLOGY

The story generally goes that geomorphology took shape as a somewhat cohesive, discrete object of study in the English-speaking world some time late in the nine-
teenth century (see Chorley et al., 1964). The role played by Earth surface processes in shaping the landscape had begun to attract interest through the early 1800s, but the notion of ‘fluvialism’ – that rain and rivers might be broadly responsible for topography – did not become firmly established until the second half of the century (Chorley et al., 1964). Interest in the role of marine and subaerial erosion continued to grow within geology, until by 1888 the “genetic study of topographic forms” was being referred to as the geographic subject of geomorphology (McGee, 1888, p. 547).

This melding of the spatial distribution and historical development of landforms initiated persistent debates over the role of place in geomorphology. For those focused on relationships between people and the environment, geomorphology was primarily a spatial subject concerned with the physical characteristics of places (e.g. Barrows, 1923). To others, however, geomorphology’s proper position was within geology, explaining the historical development of the earth’s surface (Bryan, 1950). Davis integrated these interests, tying together the “assemblage of peripheral principles developed as the by-products of geology, geography, engineering and other sciences” (Chorley et al., 1973, p. 6) into the cohesive model of landscape development which dominated geomorphic thinking from the 1880s to the 1950s (Beckinsale and Chorley, 1991).

Davis’ insistence that his work was geographical seems to have reflected an often latent, but apparently enduring, interest in relationships between the physical environment and organic life (see Chorley et al., 1973). It certainly reflected a primary concern with describing and understanding the contemporary distribution of landforms on the earth’s surface: the “last part of the last chapter of Earth history” (Chorley et al., 1973, p. 839). Yet while contemporary form captured Davis’ interest, his work emphasised the historical path that landscapes had taken to arrive at their present state. This ‘historical-geographical’ or ‘evolutionary’ approach to geomorphology posited that the key to understanding contemporary landscapes lay in understanding the context within which they had developed. While the most recent pages of the earth’s history might be of primary concern, the rest of the book mattered too.

By the middle of the twentieth century, however, Davis’ evolutionary approach to geomorphology was fraying at the edges. Davis had taken the important ini-
tial steps of assembling assorted ideas about landscape development into a coherent theory which could, in principle, produce testable predictions. Rather than theoretical postulates to be adjusted in the face of evidence, however, Davis’ developmental theories became increasingly treated as rigid scripture (Baulig, 1950; Bishop, 1980). Empirical inconsistencies were explained away as localised aberrations or artefacts of overly literal readings, as an emphasis on grand meta-narratives of landscape development seemed to paper over specificities of place (see Beckinsale and Chorley, 1991; Russell, 1949).

This lack of empirical commitment is satirised by Russell (1949, p. 3): “In some ways Nature seems to have been kind to pure morphologists. English units of spacing stop at the Channel. Pure morphologists on the Continent find levels arranged according to the metric system, at 100, 200, and 300 meters.” To ameliorate this Russell proposed a geographical geomorphology which attended more closely to the specificities of place. His vision of how this might look in practice, however, was limited to mapping the earth’s surface more closely and limiting attempts at explanation. Such descriptions certainly had utility, but this less aspirational view of what geomorphology might offer presented something of a disciplinary dead end.

Meanwhile, technological advances and widespread investment in surveying, partly driven by the two world wars, were making the earth’s surface and subsurface measurable in ways they had never been before (Bernhardsen, 2002) and advances in engineering and hydrology were promising a new understanding of the processes involved in shaping the earth. Perhaps most importantly for a new generation of physical geographers wanting to make their mark on the discipline (see Taylor, 1976), these new methods promised an opportunity to turn geomorphology from a “simple, pleasant nature-lover’s hobby” to a “geophysical science of almost terrifying complexity” (Strahler, 1950, p. 210).

The ‘quantitative revolution’ which these technologies enabled was heralded as the arrival of scientific method to physical geography (Burton, 1963). Isolating the principle components of systems around a central concept of dynamic equilibrium (Strahler, 1952) could provide insight into cause and effect which, until now, had largely been the subject of speculation or, worse, left implicit. A new model of robust empiricism would shake geomorphology from its Davisian dreams of
landscape development, awakening it to the realities of a new scientific and technological dawn (Strahler, 1950).

Strahler (1950) contended that many of the developments in understanding the earth’s surface had been taking place in other fields such as engineering and hydrology, while geomorphologists had been comfortably resting within their historical-geographical paradigm. Implicit to this argument was a sense that if physical geography failed to embrace these inevitable methodological developments, and the ontological presuppositions which came with them, it would be left behind. In retrospect, perhaps nothing made this point better than Woolridge’s (1958, p. 34) attempted rebuff: “I am not willing to limit my attention and interest to the ‘functional significance’ of landforms. To such a replacement of full binocular vision by an ugly monocular squint, I can only say, as Lord Attlee recently said of television: ‘I don’t want it. I don’t like it and won’t have it.’” By 1963 the quantitative revolution in physical geography was apparently complete (Burton, 1963), just as William Hartnell graced Britain’s televisions as the first Dr Who. These different understandings of place and time were here to stay.

1.2 QUANTIFICATION AND THE CHANGING MEANING OF CONTEXT

Implicit to mid-century quantitative-dynamic geomorphology was the proposition that landscape change could be understood as the product of interactions between process and form at a given moment in time (see e.g. Summerfield, 2005a). This ‘timeless’ approach (Bucher, 1941; Strahler, 1952) essentially contends that a landscape’s potential future states are a product of its present configuration and the processes operating on it: that knowledge of past conditions is not necessary to predict and understand future change. This statement of uniformitarian, loosely Markovian principles is logically sound: past events can only affect future change through the imprint they have left on a system, so knowledge of a system’s state at a given point in time is, in principle, sufficient to predict future potential responses to changing inputs.

By rendering histories of landscape development as a set of pre-existing conditions, these approaches encouraged a geomorphology which minimised its geography. An emphasis on untangling the history of particular landscapes was super-
seded by equilibrium models which conceptualised landscapes as abstract systems responding to variable inputs (Chorley, 1962; Chorley and Kennedy, 1971; Huggett, 2007; Strahler, 1992). Rather than understanding landscape evolution through Davis’ sequence of historical transitions, geomorphologists increasingly sought to reveal generally applicable mechanisms of landform change.

While this search for universal laws is appealing in principle, in practice these approaches are constrained by problems of scale. It is generally not feasible to capture or control all potentially relevant variables in a geomorphic system, except in certain experimental settings (see e.g. Schumm and Khan, 1972; Wohl, 2013a). Landscapes are, therefore, generally conceptualised as a nested spatial and temporal hierarchy, providing a somewhat discrete basis for examining the relationships between form and process (see Boer, 1992; Schumm and Lichty, 1965). These hierarchies are pragmatic constructs which do not lay claim to foundation in ‘reality’; rather, they delineate the forms and processes of interest at the scales to which research tends to ‘clump’ (see Inkpen, 2011; Phillips, 2016). By parameterising broader contextual considerations as well as the mechanisms of change, however, they provide a valuable conceptual basis for isolating and understanding relationships between form and process at a range of scales of interest (see Church, 1996).

Rhetorical shortcuts were taken in articulating and advocating for this new paradigm, often manifesting as a tendency to position it in opposition to a dichotomous ‘other’. While Strahler (1952, p. 925) acknowledged that neither process nor historical geomorphology could “successfully be pursued independently of the other”, revolutionary eagerness tended to produce language emphasising distance and difference between the paradigms (see e.g. Burton, 1963; Kennedy, 1992). Historical revisionism was even employed to conscript turn-of-the-century figures such as Gilbert into imagined battles against historical-evolutionary geomorphology (Sack, 1992).¹ This emphasis on a dichotomy, between a modern, quantitative, process-based scientific geomorphology and antiquated, qualitative, form-based “cultural pursuits” (Strahler, 1950, p. 209), left limited space for constructive engagement between these approaches.

¹ Obliging readings of previous authors were, of course, a feature of both ‘sides’ in this debate (e.g. Kennedy, 1992).
This divide had significant implications for geomorphology as a geographical subject as, for some, the study of the earth’s surface lost its sense of place. The shift in scale which came with emphasising process, and the focus on simplified, isolated systems which this entailed, led to a sense among some (e.g. Baker and Twidale, 1991) that geomorphology had become overly theoretical: detached from the ‘real world’ connections which had led many to the field.

1.3 BRINGING PLACE BACK IN

The quantitative revolution in geography was enabled by an increasing ability to measure the earth’s surface in ways which had never previously been possible. It is, therefore, somewhat ironic that the geomorphology it facilitated has been criticised for a perceived failure to produce satisfying accounts of particular landscapes (e.g. Baker and Twidale, 1991). Geomorphologists had a greater ability to measure the world than ever before, but, for some, these approaches had failed to truly capture it: reliance on quantitative empirical techniques narrowed the scope of geomorphic research to what was directly measurable, rather than what mattered.

Early scepticism towards quantitative-dynamic methodology in geomorphology might easily be dismissed as conservative reactions to a changing discipline. Hindsight is not particularly kind, for example, to Wooldridge’s (1958, p. 32) prediction that dabbling in “elementary mathematics” would offer “very limited chances of success”. Underlying these mid-twentieth century critiques, however, was a concern for the role of place and history in geomorphology. This was at first expressed by those advocating qualitative ‘explanatory-descriptive’ understandings of landscape change in the style of Davis (e.g. Bryan, 1950; Wooldridge, 1958), although others envisioned a purely descriptive geomorphology concerned primarily with providing ‘useful’ information through detailed maps of landform distribution (e.g. Kesseli, 1950; Russell, 1949). Common to both threads was a fundamental geographical interest in what Hartshorne (1939, p. 440) describes as the “individuality”, “unique character” and even “personality” of particular places. This interest lay somewhat dormant as the quantitative revolution drove the search for general laws.
By the 1980s, a ‘reconstructed regional geography’ began to draw geographers back towards particular places (Pudup, 1988), encouraged partly by postmodernist sensibilities emphasising “heterogeneity, particularity and uniqueness” (Gregory, 1989, p. 90). Many branches of human geography increasingly abandoned quantitative empirical commitments in favour of a series of radical and critical movements (Blomley, 2006; Demeritt, 1996; Johnston, 2016). Similar reorientations away from positivism and structuralism had occurred across the social sciences: in anthropology (Ortner, 1984), for example, and in parts of psychology (see e.g. Gavey, 1989; Henriques et al., 1998). Motivated by the inability of quantitative methods to fully describe human experience, and guided by critiques of the power relations embedded in positivist frameworks of enquiry, scholars in these fields began to look towards social and cultural theory to provide the lenses for seeing, interpreting and understanding the world.

Geomorphology did not undergo such a drastic change, as the remarkably tangible nature of the earth’s surface lent itself more easily to a somewhat naturalistic pragmatic empirical realism (see Bassett, 1994; Rhoads, 1994; Richards, 1990, 1994). Instead an emphasis on form gradually returned through detailed case studies (see Lane, 2001), underpinned by evidence of the important role played by landscape configuration in mediating process (Lane and Richards, 1997). Enthusiasm for this was partly driven by increasing awareness of the often non-linear relationships between form and process, such as the various thresholds, lags, and feedbacks which influence the response of rivers to changing inputs (see Bracken and Wainwright, 2006; Phillips, 1992, 2003). Systems approaches began to encompass these more complicated relationships, while retaining the conceptual convenience of defining the imprint of history as a set of parameters (see Huggett, 2007).

As attention turned towards the detrimental impacts of humans on the earth’s surface, environmental management increasingly strove towards ecological goals (Downs and Gregory, 2004). Geomorphological knowledge was employed to guide these efforts, providing tools for assessing habitat quality and ‘naturalness’ as a basis for ‘ecological management’ (Newson and Large, 2006). This required a new set of knowledge claims: not only could geomorphology tell us how the world’s surface developed and changed over time, it could also tell us how it should be. It also raised the stakes for geomorphic theory, blurring the boundaries between
heuristic models and canonical principles for action. Earlier criticism of an apparent tendency to idealise theoretical understandings, using deterministic models to discipline a ‘naughty’ world (Kennedy, 1979), began to resonate as people intervened to drag messy landscapes into line with expectations of how they ‘should’ look and operate (e.g. Kondolf, 2006).

Through the 1990s and early 2000s, increasing awareness of the potential to conflate models describing how the world is with ideals describing how it should be brought fresh energy to arguments for a more holistic geomorphology as the basis for more cautious interventions in the world. The source of Kennedy’s concern gained a name – complexity – and a strategy for dealing with it: ‘post-normal’ science (see Funtowicz and Ravetz, 1991, 1993). The precise meaning of complexity is not easily pinned down (see Harrison et al., 2006), but it can be generally understood as the claim that ‘bottom-up’, first-principles understandings of the world can never practically be complete. This argument, contradicting reductionist claims to knowledge (e.g. Harrison, 2001), provided a rallying cry for some of those concerned that geomorphology had lost its sense of place. For these geomorphologists and physical geographers, place was essentially synonymous with physical history. It emphasised contingency, suggesting that understanding the earth’s surface required not just knowledge of contemporary processes, but a detailed sense of the landscapes in which they operate (e.g. Phillips, 2007). By emphasising the need to understand physical context, ‘place-based’ approaches to geomorphology promoted interventions tied more closely to specific catchment histories, rather than reflecting more generalised visions of what landscapes should look like (Phillips, 2010, 2011). Yet these discussions of place were generally framed as scientific questions: debating the best way to understand the earth’s surface, rather than as an alternative – and potentially more diverse – set of environmental norms. Attempts to advocate for interventions more sensitive to local context continue in the river management literature (e.g. Brierley et al., 2013; Fryirs and Brierley, 2009) and in geomorphology and geography more generally (e.g. Phillips, 2001; Preston et al., 2011), but rarely do they openly acknowledge that these are primarily questions of what we choose to value.
1.4 CHANGING THE STATUS QUO?

Talk of a ‘turn’ in academia often underplays the diversity of research occurring in a field at any point in time. Recently, however, ‘integrated’ attempts at better understanding the role of people in environmental change have gained substantial traction, partly through the attention researchers have given to conceptualising and debating the Anthropocene (Castree, 2014). Many of these efforts take a broadly positivist approach to ‘convergence research’, producing factual, apparently objective knowledge about the world in the hope of better engineering solutions to environmental problems (see Castree, 2015a; Castree et al., 2014). They encourage a more nuanced understanding of the role of place and people in environmental change, recognising the importance of local context even in addressing global challenges (e.g. DeFries et al., 2012). They might note the complexity of human-environmental systems (e.g. Liu et al., 2007), emphasising the need for resilience (e.g. Folke, 2006), or call for adaptive management in the face of uncertainty (Clark, 2002). Promoting opportunities for “truly transdisciplinary research that transcends sociology, politics, economics and environmental science” (Gillings and Hagan-Lawson, 2014, p. 8), they may also attempt to find ideologically-neutral ways of assessing which biophysical attributes people value (see Tadaki and Sinner, 2014).

Yet ‘critical’ research argues that these values are not, and can not, be ideologically neutral: that politics cannot simply be wished away, that attempts at producing objective knowledge only serve to embed certain values while obscuring others, and that this precludes possibilities for change (see Castree et al., 2014). Work in political ecology has described how economic and political structures influence the ways environmental problems are understood and solved (see Bryant, 1998). Along with these developments, attention has begun to turn towards the performative influence of how the world is studied on what is seen, what is valued, and therefore what is possible (Ashmore, 2015; Lave, 2014a; Robertson, 2006; Tadaki et al., 2015; Wainwright, 2012).

These positivist and critical approaches to research are built on rather different epistemological and methodological foundations, which can hinder constructive discussions between them. Scientists studying the changing world might accuse
critical scholars of politicising and therefore undermining environmental knowledge; critical scholars might respond that it is, in fact, already politicised. This thesis explores possibilities for crossing this divide by exploring the intersections between geomorphic research traditions which emphasise physical context, and critical research traditions which draw attention to the importance of politics and power. It does this by examining and expanding the meaning of place-based approaches to river management.

1.4.1 Thesis structure and contributions

This thesis presents a vision for a progressive geographical geomorphology which is grounded in scientific approaches to understanding landscapes, but which also takes into account the social and political contexts in which such knowledge is created and used. It does this by exploring the connections between river science and management practice, drawing attention to the politics of knowledge production in physical geography. Building on a history of geographical critique within geomorphology, it engages with recent and contemporary debates over the meaning of ‘good’ condition for waterways. Through three articles revealing and intervening in the quiet politics of river science and management, it draws attention to the constitutive power of the tools and frameworks which are used to describe, understand and intervene in the earth’s surface.

Following the present introduction (Part I), the main body of this thesis (Parts II-V) comprises seven further chapters. Chapters 3, 5 and 7 have been published elsewhere. These articles were written as stand-alone pieces, speaking to distinct audiences and conforming to the requirements of particular journals. Four years separates the publication of the first from the submission of the last. As a result, these articles do not speak in an entirely unified voice. Instead, they are best understood as representing different points along the trajectory of this project. To this end, I have only minimally edited the published papers to leave them standing as records of my thinking at the time of publication. To guide the reader along this path the published chapters are arranged chronologically into three parts, each containing a prefacing chapter. These chapters situate the articles within the thesis, narrating their key thematic influences and describing how they reflect changes in
my approach through the duration of this work. While these sections are intended
to be readable independently, themes from each are woven across the thesis and
drawn together in a final discussion.

Part II of this thesis, *The Qinghai-Tibetan Plateau*, advances an argument for
sensitivity to place and history in understandings of landscape. It begins to explore
the way models of how the world works can come to be adopted as representations
of how it should be, contrasting this with a geographical concern for place and
appropriateness in geomorphology. In doing so, it turns to a broadened concept of
geodiversity (c.f. Gray, 2004) as a way of articulating the value of contextualised
understandings of contemporary landforms (c.f. Brierley et al., 2013). Chapter 3
offers an example of such an approach, applied to the Yellow River’s headwaters
on the Qinghai-Tibetan Plateau. It highlights the role of valley setting as a key
cross-scalar control on the contemporary river, pointing to the legacy of tectonic
uplift and resulting headward retreat, and argues that this provides an essential
foundation for any account of ecological or morphological wellbeing in the region.

Part III of this thesis, *Critical physical geography?*, takes a step back to invest-
igate the assumptions and ethical implications of geomorphology’s practice as an
objective science. Building on the theme of river diversity, it engages with a re-
cent surge in interest in the practices and priorities of physical geography and the
earth sciences (Ashmore, 2015; Lave et al., 2014) as well as with existing method-
ological literature within geomorphology. It articulates the need to more actively
consider the role of people in understanding the earth’s surface, both as agents of
landscape change and as practitioners of landscape science. Emphasising the con-
stitutive role of geomorphic enquiry, this intervention presents an open-minded,
constructive engagement towards socially situated, place-based, reflexive under-
standings of landscapes.

Part IV of this thesis, *Searching for the ideal river*, returns specifically to fresh-
water to investigate assumptions of ‘good condition’ as a basis for research, and
as an outcome for intervention. It recounts the rise of river health as a manage-
ment ideal, following its transformation from a holistic but hazy ethic of envir-
onmental care to specific sets of diagnostic indicators for intervention. Tracing
this transition from metaphor to metric, this work examines how common-sense
understandings of river condition were first challenged by, and then incorporated
within, the scholarly and political project of river health. It argues that a search for objectivity entrenched assumptions that naturalness was knowable, attainable and inherently desirable, neglecting an opportunity to articulate broader possibilities for freshwater. In presenting this argument, Part IV directs constructive attention towards the ways people, and scientists in particular, intervene in the politics of the physical environment.

Part V of this thesis, Where to?, considers the implications of the three interventions, and further examines the meaning of place in geomorphology. Taking seriously the claim that how we know the world shapes what is possible, it examines both the ontological status, and the politics, of claims to place. Identifying a tendency towards falsely binary notions of ‘placed’ and ‘placeless’ knowledge, it scrutinises narratives of intractable epistemic uncertainty which re-frame place as an unlikely, and therefore unknowable, constellation of particular circumstances at a point in space and time. This discussion concludes by pointing towards potential new directions for a progressive geographical geomorphology that is grounded in scientific approaches to understanding landscapes, but which takes seriously the social and political contexts in which geomorphic knowledge is produced and used.
Part II

THE QINGHAI-TIBETAN PLATEAU
While the precise implications of geomorphology’s quantitative revolution differed across research communities (e.g. Keylock, 2003), the techniques which accompanied it brought with them a general narrowing in the scales of enquiry. Rather than the grand evolutionary meta-narratives which had dominated understandings of landscape until the 1950s, the quantitative revolution ushered in an emphasis on processes and relationships observable at smaller temporal and spatial scales. These approaches were built on the premise that, by first understanding the mechanisms governing river behaviour, we could eventually gain insight into changes occurring over longer time frames and larger spatial scales (see Montgomery, 1991). From this point of view, at the risk of upsetting Hynes (1975), understanding the river was the key to understanding the valley.

Systems approaches presented a key innovation associated with quantitative-dynamic geomorphology, enabling a catchment’s history to be defined in terms of the physical imprint it had left on the river (see Chorley and Kennedy, 1971). Rather than relying on a narrative of valley development, this allowed rivers to be understood in terms of the contemporary properties of the channel. Rendering a river’s catchment context as a set of parameters existing at a point in time provides a number of benefits, not least allowing the application of experimental principles at various scales: in both laboratory flumes and the real world (see Wohl, 2013a), as well as modelling applications (e.g. Eaton and Millar, 2017). The functional relationships elucidated are, in principle, generalisable to other systems where parameters could be adjusted appropriately.

The concept of equilibrium in rivers, for example, can be applied at the reach scale by understanding stream profile as a product of the relationship between sediment supply (quantity and grain size), slope and discharge (Lane, 1955; Mackin, 1948). This essentially redefines the contextual influences of a river’s catchment, with its potentially complicated historical legacies, in terms of their effects on sed-
iment supply, slope and discharge. The resulting relatively simple models enable analysis of the controls on river change at a particular moment in time, understanding it in terms of disturbances to a river’s equilibrium, without the need to comprehend the underlying mechanics of adjustment.

This approach, however, is based on the premise that a river’s behaviour can be understood in terms of contemporary process alone. Increased attention to cross-scalar interactions between form and process has challenged this assumption, highlighting the often non-linear behaviour of fluvial systems (Lane and Richards, 1997; Phillips, 1992, 2003). Rather than understanding channel adjustments as the reversion towards a stable ‘attractor’ state determined by the prevailing process regime, these approaches emphasise the potential for positive feedbacks and thresholds which, given the right conditions, can produce landscape change (c.f. Kennedy, 1992).

Recognition that the relationship between form and process is bidirectional – that landscape configuration mediates the occurrence and influence of processes – highlights the importance of historical context on river character and behaviour (Lane and Richards, 1997; Phillips, 2017; Taylor Perron and Fagherazzi, 2012). In principle these influences, which can include both ‘natural’ and human-induced legacy effects (see James, 2015; Wohl, 2015), can be conceptualised simply as initial conditions at a point in time (e.g. Taylor Perron and Fagherazzi, 2012). The practical challenges of capturing full quantitative accounts of landscape configuration, however, have led to a resurgence of more qualitative concepts such as ‘landscape memory’ (see Brierley, 2010) and ‘antecedent conditions’ (Fryirs and Brierley, 2010; Newson, 1980) emphasising broad-scale narratives of landscape change. These historical understandings essentially act as proxies for initial conditions at the reach scale, enabling evaluation of potential trajectories of change (e.g. Zilian and Surian, 2012).

2.1 PRIVILEGING STABILITY

It is one thing to understand rivers as elementary systems, using simple models as heuristic devices which provide as much information when they fail as when they succeed. It is quite another thing to manage rivers on such a basis, discip-
lining them if they do not conform to expectations (see Kennedy, 1979). Theoretical models, such as those based around equilibrium, provide useful conceptual analogies for understanding system responses to disturbance, and Lane’s balance remains an important pedagogical tool (see Bracken and Wainwright, 2006). They are, however, also prone to being misunderstood as normative ideals depicting natural, optimum states.

The rise of environmentalism late in the twentieth century brought growing concern for the condition of river channels worldwide (see Downs and Gregory, 2004), manifesting as interest and investment in a growing stream restoration industry. Fluvial geomorphology was no longer simply concerned with understanding rivers, but was increasingly called on to determine how they should be. Until the 1970s, the primary concerns of river management had been hazard mitigation and water supply. These were treated as engineering problems, the subject of substantial public investment such as the US Army Corps of Engineers’ extensive programme of dam, canal and stop-bank construction across the USA (see Shallat, 1994). Aldo Leopold had advocated for a ‘land ethic’ as early as 1949, to bring “a gentler basis for perceiving the effects of our engineering capabilities” (Leopold, 1977, p. 430). Such aspirations did not gain traction until the 1980s, however, when the focus of management interventions began to shift towards environmentally sensitive design and environmentally focussed river ‘restoration’ (Downs and Gregory, 2004).

What ‘working with the river’ meant, however, was largely left to those who had already been engaged with river management. A relative vacuum of knowledge regarding how to do ecological restoration was therefore largely filled by engineers and hydrologists interested in developing ‘soft engineering’ techniques (see Lave, Doyle et al., 2010). In accordance with the traditional focus of such fields, these tended towards smaller-scale, localised interventions emphasising channel stability (Lave, 2009, 2014b). These ‘softer’ approaches used different materials but brought little change in the fundamental scales and aims of intervention, even as geomorphologists were increasingly emphasising the broader connections between rivers and their catchments.

This decoupling of theory and practice was perhaps most striking in the USA, where Rosgen’s (1994; 1996) classification scheme became the dominant approach
to river restoration in the face of direct opposition from academic geomorphologists (see Lave, 2009, 2014b; Miller and Ritter, 1996; Roper et al., 2008; Simon et al., 2007). Rosgen’s highly interventionist approach claimed to “help the river be what it wants to be” (Malakoff, 2004, p. 937), re-engineering the channel using wooden and rock structures to harden the channel into a stable, ‘correct’ form. Various criticisms were levelled at this approach (see Lave, 2009), including concerns for unclear definitions producing ambiguity (Miller and Ritter, 1996; Roper et al., 2008) and challenges regarding its emphasis on form over process (Juracek and Fitzpatrick, 2003; Kondolf, 1998; Kondolf et al., 2001; Simon et al., 2005; Simon et al., 2007).

Fundamentally, Rosgen’s standardised approach made claims as to how rivers should be (Tadaki et al., 2014). In particular it asserted that each river had a “natural, stable form” which could be elucidated from the contemporary channel (Rosgen, 1994, p. 196). In practice, this often comprised stable, sinuous streams with regular pool-riffle sequences held in place by hard structures: a reflection of cultural and aesthetic preferences rather than process regime (Kondolf, 2006). The success of these efforts was judged largely in terms of whether these rivers remained in place, despite the relative rarity of natural lateral stability in meandering channels. Some companies even offered warranties that installed structures would not move (Lave, 2009).

Rosgen justified this emphasis on preventing channel adjustment by asserting that equilibrium is an inherent, desirable property of natural channels (see Lave, 2009): that, in the absence of human impacts, rivers would tend towards a stable, ‘preferred’ form with minimal change over time. It is somewhat ironic that Rosgen used this language of equilibrium, with its overtones of process-determinism, to justify an approach which would be criticised for neglecting process (see Simon et al., 2005; Simon et al., 2007). Nonetheless ‘timeless,’ ‘placeless’ geomorphology (see Section 1.2) was no longer just a useful tool for isolating and understanding causal relationships between aspects of the landscape, but a natural ideal to which all rivers should aspire.
2.2 THE QINGHAI-TIBETAN PLATEAU

During my time working on the Qinghai-Tibetan Plateau I became increasingly aware of two key observations. The first was that the upper reaches of the Yellow River can only be comprehensively understood in terms of the history of the entire river. A history of tectonic uplift and subsequent headward incision (Craddock et al., 2010) has left a substantial imprint on the contemporary river, delimiting both where the channel has space to adjust and the conditions under which it can do so. The Yellow River of course remains subject to the relationship between sediment supply, discharge and slope. The river’s capacity to self-adjust, however, is highly constrained by the antecedent conditions (Fryirs and Brierley, 2010) produced by the operation of those laws over an extended period of time in a landscape subject to uplift.

The second observation was that, despite the importance of historical context to rivers on the Plateau, there existed a substantial risk that they might be judged, and managed, according to generalised assumptions of what a ‘good’ river should be. The most direct example of this was the statement, by a senior research collaborator in Beijing, that a river with lower sediment flux was inherently superior. For the Yellow River, named for the colour it exhibits after flowing through the highly friable Loess Plateau, and for the Yangtze, formerly home to the turbidity-adapted baiji or Yangtze River dolphin (Turvey et al., 2007), such a narrow and one-dimensional approach to river condition seems remarkably inadequate. Anecdotal accounts of interventionist management practices, emphasising stability at all costs, highlighted the potential for these assumptions to become embedded into the landscape through management practice.

2.2.1 Valuing diversity

Designing a channel that will move water and sediment towards the ocean efficiently, and in a stable fashion, is relatively straightforward. Determining appropriate interventions to enhance river condition presents a much more delicate challenge (see Fryirs, 2015). The temptation to focus on generalised, apparently desirable attributes at small scales can overshadow the broader context in which
those attributes exist. In other words, “The notion that streams can be ‘restored’ by imposing new channel forms without addressing the processes that determine alluvial channel form, and without appreciating system evolution and watershed context, is inconsistent with basic geomorphic principles” (Kondolf et al., 2001, p. 774).

These concerns for appropriateness also extend to management goals, such as enhancing ecological condition. Many interventions in river form emphasise habitat heterogeneity, seeking ecological benefits from the presence of a wider variety of stable in-stream structures (Bernhardt et al., 2005, 2007). Evidence increasingly suggests, however, that this focus on diversity of form at smaller scales does not necessarily bring significant ecological improvements (Hilderbrand et al., 2005; Palmer et al., 2010). This is likely to be in part a result of other stressors acting as limiting factors, such as pollution, connectivity or hydrology (Amoros, 2001; Palmer et al., 2010). It also reflects a problem of place: ‘improving’ within-channel heterogeneity by adding historically absent structures does not necessarily improve ecological outcomes (see Poff and Ward, 1990).

Understanding the broad set of controls operating at a site can help to predict which geomorphic features are likely to be present (e.g. Montgomery, 1999). These relatively generalised approaches cannot, however, anticipate the ecologically important discontinuities in particular streams produced by particular histories of change (see Poole, 2002). The questions of appropriateness which this raises are partly a technical challenge (e.g. Fryirs, 2015; Rinaldi et al., 2013), but also depend on understandings of what matters. A focus on apparently objective measures of river condition can easily overlook the more subjective and difficult-to-articulate forms of value associated with a sense of history and place, as well as potentially neglecting important ecological relations (Hiers et al., 2016). Re-orienting towards spatial and historical context, acknowledging the imprint left by past events (see Brierley et al., 2013), potentially provides a basis for geomorphic interventions which acknowledge that what makes landforms different can be as important as what makes them similar.

With this in mind, the next chapter presents an early step towards a geographical approach to understanding the riverscapes of the Qinghai-Tibetan Plateau. It introduces the concept of geodiversity to the Plateau, following Gray’s (2004; 2008)...
reminder that there is more to rivers than the organisms living within them. Not only do physical processes shape the conditions developing and maintaining diverse freshwater ecosystems (Poff and Ward, 1990), but long histories of change have produced abiotic features valuable in their own right (Gray, 2011). *Geodiversity in the Yellow River source zone* explores the potential of geodiversity to facilitate conceptualisations of habitat heterogeneity which appreciate not only geomorphic diversity within channels and catchments, but also between them (see Amoros, 2001; Poff and Ward, 1990). Emphasising the role of valley confinement in constraining channel and floodplain morphology, it exemplifies a context-first, place-based approach to understanding the headwaters of the Yellow River.

In doing so it makes the case for a broader appreciation of physical context in geomorphological explanation, emphasising what Hartshorne (1939) called the ‘individuality’ of place. Arguing that the naturally occurring array of broad-scale landscape controls represent important values in their own right (c.f. Gray, 2004), it makes explicit the politics of a recent resurgence in geomorphic literature emphasising the role of historical contingency in understandings of landscape.
3

INTERVENTION 1
GEODIVERSITY IN THE YELLOW RIVER SOURCE ZONE

3.1 INTRODUCTION

The Qinghai-Tibetan Plateau is a unique environment. The source of many of the world’s largest rivers including the Yellow, Yangtze, Mekong and Tsangpo-Brahmaputra, it has a mean elevation of 4500-5000 metres above sea level and contains over 80% of the world’s land over 4000 m (Fielding et al., 1994). The importance of the area was recognised in the year 2000 with the establishment of the Sanjiangyuan National Nature Reserve covering 152,300 km² (see Dong et al., 2002; Li et al., 2012): a land area similar to that of England and Wales combined. Established in response to a variety of interlinked threats including climate change, environmental degradation, and direct human pressures resulting from population growth, the stated primary aims of the reserve’s formation are to conserve biodiversity and to enhance and sustain the livelihoods of local people (Foggin, 2005).

As the second longest river in China, and the sixth longest in the world, the Yellow River is an extremely important constituent of geodiversity on the plateau. Providing freshwater to approximately 107 million people, 8.7% of China’s population (Wang et al., 2006), it is integral to China’s future: the management decisions made on the plateau will have far-reaching consequences. Grounded, systematic understandings of the landscapes, riverscapes and ecologies in the Yellow River source zone are fundamental to further research and effective management of the region.

This paper provides a broad-scale analysis of geodiversity in the trunk stream of the Yellow River source zone. It discusses the importance of geodiversity as an integral, emergent aspect of natural diversity, before moving on to an examination of geodiversity in riverine landscapes as part of a sustainable management paradigm. It discusses problems of scale in geomorphology, before proposing hierarchical
classification as a useful tool with which to deal with the complexity of fluvial morphological diversity on the Plateau. It then introduces the Yellow River source zone, presenting five broad trunk stream morphologies. Results are discussed in the context of the landscape settings within which the river is adjusting. Finally, the paper calls for further research into morphological controls and ecological linkages in the broader Yellow River source zone.

3.2 THE ROLE OF GEODIVERSITY

The wide variety of landscape settings on the earth’s surface is fundamental to life on the planet. In recent years the vast array of natural variation in geological, geomorphological and lithological settings that makes up our world has become recognised as geodiversity: an abiotic (and co-dependent) counterpart to biodiversity (Gray, 2004, 2008). Coined in the 1990s to refer to geological diversity in need of protection (see Duff, 1994), the concept of geodiversity has since broadened to incorporate the natural range of not only geological features such as rocks, minerals and fossils but also soils and, notably, geomorphological landforms and the processes that shape them (Gray, 2004). An appreciation of geodiversity therefore entails developing an understanding of the diversity of landscape settings: not only the features themselves, but the processes (re)shaping these features, the interactions and connectivities between them and the ways in which they change over time.

Knowledge of geodiversity inherently underpins assessment of ‘geosystem services’ (Gordon et al., 2012; Gray, 2004, 2008, 2011; Serrano et al., 2009), incorporating appraisal of the economic and social benefits of geotourism (see Reynard, 2008; Xun and Ting, 2003) alongside the intrinsic, aesthetic and cultural values of natural landscapes. Perhaps most notable is the importance of geodiversity to habitat diversity: natural variation in geological and geomorphological features and processes forms the range of habitats that are a major control on the distribution of life on the planet. Understanding the geomorphic feedbacks, linkages and processes operating at various scales is therefore a vital first step towards understanding controls upon biodiversity: its distribution, its resilience and its responses to disturbance.
Geodiversity is both an inherently spatial phenomenon, and a temporal one. It not only creates place, physically distinguishing one site from another, but is created by place: the landforms in any particular location are an expression of their contemporary and historical environmental context, and the interactions within it (Brierley, 2010; Brierley et al., 2013; Phillips, 2007). These relationships are highly scale-dependent: the dominant factors at a particular location will vary not only with place and time, but at different scales of enquiry (Church, 1996). Geodiversity comprises emergent phenomena produced by complex, non-linear interactions between a variety of factors operating and interacting at a range of scales (Harrison, 2001; Phillips, 2003, 2007). Responses to forcing have multiple degrees of freedom, exhibit thresholds of response and are fashioned by variable magnitude-frequency relationships that themselves are contingent upon pre-existing states (Lane and Richards, 1997; Miller et al., 2003; Phillips, 2007). As a result, inheritance from past conditions is both a characteristic of, and a control on, the landscape (Brierley, 2010; Fryirs and Brierley, 2010). Understanding geodiversity is more than a matter of simply measuring the conditions in a particular place at a particular point in time: it requires a broader understanding of the spatial and historical contingencies that produce these morphologies (Phillips, 2007).

3.3 GEODIVERSITY ON THE VALLEY FLOOR

As societies increasingly recognise the importance of the natural environment, the role of healthy fluvial systems becomes ever more apparent (see Everard and Powell, 2002). Shifts in river management priorities from a ‘hydraulic engineering’ paradigm towards a more holistic focus on sustainable management and ecological outcomes require effective understandings of the diversity, pattern, functionality and evolution of riverine environments (Brierley and Fryirs, 2005; Dong, 2003; Downs and Gregory, 2004). Valley floors contain a wide array of riverscapes consisting of unique morphologies and processes which support an assortment of aquatic and terrestrial life (Montgomery, 1999; Ward et al., 2002; Wiens, 2002); protecting this natural diversity is a growing priority worldwide. Appropriate understandings of ‘natural’ values at any given place incorporate an appreciation of the diversity inherent to appropriate heterogeneity (e.g. Fryirs and Brierley, 2009;
Reid et al., 2008), system responses to disturbance events, and likely evolutionary trajectories (Fryirs et al., 2009; Ziliani and Surian, 2012).

Holistic management of fluvial systems requires consideration of both biotic and abiotic factors, recognizing that they are inextricably interlinked. Ecological potential is highly dependent on the quality and quantity of available habitat: the local physical, chemical and biological features providing an environment for biota (Jackson et al., 2001; Maddock, 1999). Geodiversity ensures an appropriate range of available habitat in terms of both morphological features and the processes that (de)form them: varying disturbance regimes, flow periodicities and velocities, boundary exchanges and connectivities provide for particular arrays of organisms (Montgomery, 2001; Poff and Ward, 1990; Robinson et al., 2002; Ward et al., 2002; Wiens, 2002). Understanding the controls on the quantity, quality and distribution of natural habitat in and around fluvial systems provides insight into the distribution, health and resilience of associated ecosystems, and their potential for recovery if degraded (Poff and Ward, 1990).

Physical habitat heterogeneity is not the sole determinant of habitat quality, form alone is certainly not (Palmer et al., 2010) and the provision of physical habitat may not in itself produce pre-disturbance ecosystems (Hilderbrand et al., 2005). Rather, appreciation of the natural array of habitat in a particular system, the impact of human activities relative to natural behaviour regimes and the evolutionary trajectory of the system can inform successful management through the application of geomorphic principles (e.g. Brierley and Fryirs, 2009; Fryirs et al., 2009).

Holistic understandings require effective frameworks through which knowledge can be gathered, described, integrated and interpreted; without these contextual frameworks, data and the ‘answers’ they provide are at best meaningless and at worst misleading (Church and Mark, 1980). Geomorphic classification provides this structure, allowing an almost infinite diversity of fluvial landforms and processes to be grouped by common factors to aid understanding, allow comparison and simplify communication (Goodwin, 1999). As abstractions of reality, classification systems have a number of limitations and must be applied with care (e.g. Juracek and Fitzpatrick, 2003; Small and Doyle, 2011). When they are carefully designed and implemented for a specific system, however, they provide a powerful
tool for the assessment and description of variability (Buffington and Montgomery, 2013).

Scale is integral to geomorphological inquiry (Schumm and Lichty, 1965). While the 'habitat scale' may seem of greatest immediate ecological relevance, the geomorphic and ecological controls and processes producing this habitat operate at a variety of spatial and temporal scales: from the long-term influences operating across ecoregions to the near-instantaneous processes of substrate-flow interactions (Cooper et al., 1998). While rivers have been conceptualised as a continuum of biological processes from source to mouth (Vannote et al., 1980) they are much more complex, with multiple, scale-dependent (dis)connectivities, inputs, and interactions with surrounding landscapes (Newson and Newson, 2000; Poole, 2002; Thorp et al., 2006). Nested hierarchical frameworks provide a means of addressing these problems of scale by arranging riverine systems into multiple levels of characteristic assemblages of features and processes. Each of these scale-dependent layers is comprised of smaller-scale features, as well as being constrained by the larger-scale systems which they in turn constitute (Brierley and Fryirs, 2005; Frisvall et al., 1986; Naiman et al., 1992).

Brierley and Fryirs (2005) propose the ‘reach’ scale as the foundation of geomorphic enquiry, comprising the distinct components of riverine systems (e.g. channel, floodplain, vegetation) where they can be studied as distinct but interconnected systems. Reaches contain assemblages of geomorphic units and their associated processes (e.g. bars, riffles, pools), in turn containing hydraulic units and, at the finest scale, microhabitats. Importantly for holistic understandings of geodiversity, these incorporate both erosional and depositional forms and extend from the channel itself to incorporate associated floodplain features. Multiple reaches can be grouped into broader landscape units, or process zones, reflecting the broad distribution of sediment and erosional energy within a catchment (Polvi et al., 2011). Finally, catchment characteristics are influenced at the ecoregion scale by the long-term, broad-scale influences such as tectonics and climatic characteristics which produce the broad boundary conditions within which a river operates.

This paper provides an overview of the reaches and landscape units on the trunk stream of the Yellow River source zone, within the broader Qinghai-Tibetan Plateau. Most work in the region has generally focussed on channel pattern in allu-
vial rivers, with particular emphasis on understanding the potential controls on planform morphology and modelling planform change (e.g. Ni et al., 2000; Wang, 2008; Wang et al., 2000). Some of these studies have begun to explore the links between river diversity and stream biodiversity (e.g. Dong, 2003; Zhao et al., 2007). Broader-scale relationships between valley characteristics and channel pattern development on the Plateau have received relatively little attention, although Yu and colleagues (2013) present a broad review. This paper explores the role of valley confinement in influencing channel pattern development in the headwaters of the Yellow River more specifically, emphasising the role of accommodation space as an integral precondition for morphological variation at smaller scales.

3.4 REGIONAL SETTING: THE YELLOW RIVER SOURCE ZONE

Upstream of the Longyangxia reservoir, the Yellow River drains an area of approximately 135,000 km² in the northeastern section of the Qinghai-Tibetan Plateau (Figure 3.1). As it crosses the plateau it traverses a range of landscapes (see Nicoll et al., 2013), flowing southeast between the Bayan Har and Anyemaqen mountain ranges before cutting northwest through the Anyemaqen Mountains toward the Tongde and Gonghe Basins. To ensure consistency with Chinese terminology, this uppermost part of the Yellow River is referred to hereon as the Yellow River source zone.

Although the timing and mechanisms of tectonics on the plateau remain controversial (Royden et al., 2008), the northeastern region of the plateau appears to be the youngest, forming during the Pliocene 5.3-2.2 million years ago (Ma) through basin infilling (Pares et al., 2003; Tapponnier et al., 2001). It appears to have subsequently uplifted in three main stages, 2-1.5 Ma, 1 Ma and 0.15 Ma (Li, 1991), with the Yellow River beginning to incise rapidly approximately 1.8 Ma (Craddock et al., 2010). Although it has been suggested that the entire Qinghai-Tibetan Plateau was covered by a thick ice sheet during the last glacial maximum (LGM), most evidence suggests that the snowline only extended at most 1000 m below its contemporary position in the eastern plateau, with limited glacial expansion (Heyman, 2010; Lehmkuhl and Liu, 1994; Lehmkuhl et al., 1998). The increased strength of the winter monsoon during the LGM resulted in greatly increased loess deposition
in the middle reaches of the Yellow River (Zhuo et al., 1998). The river is still adjusting to this, producing the world’s fourth-highest sediment yield (Xu and Yan, 2005).

Flow data for the Yellow River source zone are patchy, however discharge at stations downstream has decreased since the early 1900s due to decreased precipitation and direct human impacts such as reservoir construction and water abstraction (Lu, 2004; Wang et al., 2006). Within this overall trend, the Yellow River shows a strong monsoon-driven seasonality in discharge (Lu, 2004), with the greatest flows occurring over summer due to increased rainfall (Yu et al., 2013). Human modification of flow in the study area is limited, with only one significant reservoir. Further downstream, the Longyangxia reservoir has a storage capacity of 24.7 billion m³ (Gao and Feng, 2002); this likely acts as a local base-level control, but any upstream impact is currently uncertain. Although the upper reaches provide 50-60% of the river’s annual discharge and comprise 49% of the total drainage basin area, they produce only 10% of its sediment load ($0.15 \times 10^9$ tonnes/yr). This is a stark contrast to the river’s middle reaches further downstream which, flow-
ing through the extremely erodible Loess Plateau, supply only 30-40% of the total discharge but 90% of the sediment load (Shi et al., 2002; Zhang et al., 1990).

Due to the high altitude of the Qinghai-Tibetan Plateau the area has a cold and dry alpine climate, with an annual mean temperature of -2.3 °C and mean precipitation of 411 mm/yr largely falling as snow or heavy rain (Feng et al., 2005). Vegetation cover is predominantly grassland, with six main land covers (Wang et al., 2001): alpine stepped meadow, swamp meadow, high-cold shrub meadow and plain meadow, high-cold desertified steppe, high-cold steppe meadow and mobile and semi-stable sand. The Qinghai-Tibetan Plateau has been described as a grazing-adapted landscape with a history of nomadic grazing possibly stretching as far as 8800 years before present (Miehe et al., 2008, 2009), however pressure on the region has increased in recent years (Li et al., 2011). Although the extent and causes of degradation are contested (Harris, 2010), grassland degradation and desertification on the plateau is significantly altering local ecologies (Wang et al., 2001).

3.5 METHODS

Morphological interpretation was carried out on the Yellow River source zone using a mixture of field-based interpretation and satellite imagery available through Google Earth. Analysis of a Shuttle Radar Topography Mission (SRTM) 90 metre Digital Elevation Model (DEM) in ArcGIS provided slope and valley width data.

The terminologies used to describe riverine systems can be varied and ambiguous, with even fundamental definitions of planform types varying greatly between authors (Lewin and Ashworth, 2013). For the purposes of this study planform types are defined as described by Brierley and Fryirs (2005).

3.6 BROAD-SCALE GEODIVERSITY IN THE YELLOW RIVER SOURCE ZONE

At the landscape unit scale, the trunk stream of the Yellow River source zone comprises five main morphological sections containing notably different morphological units, both in-channel and on the floodplain (Figure 3.2; Table 3.1). The transitions between these sections can be linked to the variations in valley width and slope that reflect the catchment’s history of basin infilling, uplift and incision (Fig-
Figure 3.2: The Yellow River’s source catchment, showing elevation (metres above sea level) and the five broad-scale morphological sections of trunk stream. Section 1: primarily unconfined, braided-anabranching. Section 2: partly-confined anabranching or braided. Section 3: confined single channel with discontinuous floodplain pockets. Section 4: partly-confined anabranching. Section 5: valley and terrace-confined single channel.

The influence of broad-scale vegetation patterns is also notable in producing different morphologies, even where boundary conditions are similar (Yu et al., 2013).

The upstream segment of the Yellow River source zone, near Maduo (section one), is largely unconfined, dominated by braided and some anabranching sections with a large number of floodplain wetlands (Figure 3.4). Because this section sits in a broad, filled valley it has excess accommodation space and is generally free to spread across its floodplain. As a result of the low slopes in this section, with an overall gradient of 0.0004 (Figure 3.3), the river has little energy to move sediment and deposits it midstream to create multiple channels. Due to the temperature-controlled short growing seasons near Maduo, vegetation has little opportunity to stabilise these bars, leaving them to be relatively easily reworked to produce braided morphologies where and when sufficient energy is available, likely during the spring thaw (Yu et al., 2013). The multiple channels of these rivers contain alternating riffle-run sequences; along with the associated periodically-inundated channels these produce a diverse array of in-stream habitat with a wide range
Table 3.1: Yellow River source zone planform morphologies and associated morphological units (sensu Brierley and Fryirs, 2005).

<table>
<thead>
<tr>
<th>Section</th>
<th>Valley confinement</th>
<th>Channels</th>
<th>Dominant planform</th>
<th>In-channel units</th>
<th>Floodplain units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (upstream)</td>
<td>Laterally unconfined</td>
<td>2-8</td>
<td>Braided, some anabranching</td>
<td>Mid-channel bars, secondary channels, riffle-run sequences</td>
<td>Multiple floodplain wetlands, dunes</td>
</tr>
<tr>
<td>2</td>
<td>Partly-confined</td>
<td>2-5</td>
<td>Anabranching-braided</td>
<td>Mid-channel bars, islands, chute channels</td>
<td>Some wetlands, flood channels</td>
</tr>
<tr>
<td>3</td>
<td>Confined</td>
<td>1</td>
<td>Confined, regular floodplain pockets</td>
<td>Occasional mid-channel bars</td>
<td>Minimal</td>
</tr>
<tr>
<td>4</td>
<td>Partly-confined</td>
<td>1-3</td>
<td>Anabranching</td>
<td>Mid-channel bars, islands</td>
<td>Terraces, abandoned channels, oxbows, back-channels</td>
</tr>
<tr>
<td>5 (downstream)</td>
<td>Confined (terrace, valley)</td>
<td>1</td>
<td>Confined</td>
<td>Minimal</td>
<td>Alluvial fans, terraces</td>
</tr>
</tbody>
</table>
of water depths, flow velocities and disturbance regimes. Wide floodplains and
the multiple lakes and wetlands in the area also provide a range of habitat, with
various degrees of fluvial input depending on their morphogenesis and position
relative to the river.

Section two of the Yellow River, near Dari, contains significant stretches of river
exhibiting both braided and anabranching characteristics (Figure 3.5). As the valley
margins begin to encroach on the river they restrict floodplain development, with
the river often taking up much of the valley floor. At 0.001, slope here is approxi-
mately double that of section one upstream (Figure 3.3), though still relatively low. A
longer growing season near Dari allows vegetation to establish itself on some bars
during the summer months, stabilising them despite higher flows at this time of
year (Yu et al., 2013). Similarly to section one, multiple channels, bars and islands
provide a wide array of hydraulic units. The smaller floodplains in the area contain
fewer wetlands than section one; instead, back-channels within the macrochannel
provide hydraulic diversity.

Section three contains a single channel that flows within a confined or partly-
confined valley with bedrock-controlled regular floodplain pockets (Figure 3.6).
The valley margin plays a key role in this transition as the river flows through a
set of foothills, restricting the river to a single channel with small pockets of flood-
Figure 3.4: Section one of the Yellow River source zone, near Maduo, showing characteristic braided planform morphology. Scale not consistent between images. (a) Satellite imagery showing representative reach; (b) satellite image with labelled geomorphic units; (c) valley cross section showing a wide, flat valley floor; (d) oblique photograph showing wide, flat valley floor containing multiple floodplain wetlands.
Figure 3.5: Section two of the Yellow River source zone near Dari showing characteristic partly confined anabranched-braided morphology. Scale not consistent between images. (a) Satellite imagery showing representative reach, (b) satellite image with labelled geomorphic units; (c) valley cross section showing narrower valley floor; (d) oblique photograph showing excised floodplain (to left of image) and braid bars (to right of image).
Figure 3.6: Section three of the Yellow River source zone near Jiuzhi showing characteristic confined channel with regular floodplain pockets. Scale not consistent between images. (a) Satellite image showing representative reach; (b) satellite image with labelled geomorphic units; (c) valley cross section showing very narrow valley floor; (d) oblique photograph showing narrow valley with small floodplain pocket.

plain inside bends. With a slope similar to section two (approximately 0.001), little distinguishes this section from upstream on the long profile (Figure 3.3). Much of the river here is lined with angular gravels, suggesting localised reworking of colluvial material. Morphology in section three is generally simpler, with a relatively symmetrical channel: habitat heterogeneity is likely to be naturally lower in these reaches.

Section four, near Maqu, contains a mixture of unconfined, partly confined and confined reaches. They are predominantly anabranching, except in the relatively short confined section where the river forms a single channel (Figure 3.7). The knickpoint downstream (Figure 3.3), which represents the upstream extent of a phase of historical incision, acts as a local baselevel control, behind which valley infilling has occurred to produce the flattest section in the Yellow River source zone (slope approximately 0.0002). The resulting loss of energy causes the river to deposit sediment in-channel, forming sinuous anabranches where accommodation space is available. As a result of the low energy in this section the river appears
to have relatively stable banks, with a high proportion of vegetated mid-channel bars/islands. The large number of abandoned meanders suggests that the river may have straightened its course in the past (see Li et al., 2013). Evidence suggests that both lateral channel migration and avulsive processes are active. Similarly to section two, the large number of channels and bars at varying depths/heights provides a range of in-stream habitat, with multiple water depths and velocities. The abandoned channels on the floodplain present significant wetland habitat, with variable inundation depending on position and elevation.

The lowermost part of the Yellow River source zone, section five flowing past Xinghai, is predominantly terrace and valley-confined, with little room to move (Figure 3.8). Historical retreat from the plateau margin has caused the Yellow River to incise into its own deposits (Craddock et al., 2010), leaving the river trapped by terraces and tributary alluvial fans at the valley margins. At a slope of 0.002, this section is an order of magnitude steeper than section four (Figure 3.3); the combination of a lack of space and higher energy generally prevents the formation of
mid-channel bars and secondary channels. Similarly to section three, the channel in section five is therefore naturally relatively homogenous, with variation in flow velocities largely limited to the channel margins and inside bends.

3.7 DISCUSSION

The Yellow River source zone exhibits a wide array of broad-scale geodiversity, with five main fluvial environments identified along the trunk stream. These sections are characterised by particular assemblages of geomorphic units, both within the channel and on the floodplain. Local variations in landscape setting produce variations in morphological controls across the catchment; the resulting range of influences produces markedly different riverscapes containing a diverse range of habitat.

The boundary conditions of valley width and slope are the major direct controls on landscape unit-scale morphology within the Yellow River source zone. These
conditions vary throughout the catchment with local tectonic and incisional histories: the excess of accommodation space and low slopes of section one are produced by uplifted basin fills, the confined valleys of section three reflect localised uplift of the Anyemaqen Shan, and the terrace confinement and steep slopes of section five are products of headward retreat into alluvial deposits (Craddock et al., 2010). The impact of confinement on the trunk stream is particularly notable, restricting the river to a single channel through sections three and five. Where accommodation space is available in sections one, two and four the river is free to adjust in response to stream power, sediment characteristics and bank strength, showing a tendency to form multiple channels near the braided/anabranching threshold (see Eaton et al., 2010; Nanson and Huang, 2008).

The headward retreat that caused section five to incise into its deposits began approximately 1.8 million years ago (Craddock et al., 2010), yet this evolutionary imprint dominates the contemporary riverscape bringing a particular set of morphologies, processes and connectivities. The river in this section is now effectively cut off from its historical floodplains, leaving it with little room to adjust or deposit sediment. While sediment in the terraces now has an indefinite residence time, sediment entering the channel from upstream or local tributaries is quickly flushed through due to the lack of storage space and high stream power (see Nicoll et al., 2013). In contrast, the broad floodplains and channels of sections one, two and four act as large sediment stores, delaying the transfer of sediment through these systems.

Vegetation plays an important role in fluvial systems, stabilising banks, bars and floodplains (Corenblit et al., 2007). This relationship is apparent in the Yellow River source zone, where regional variations in the growing season act as an important control on morphology (Yu et al., 2013). In particular, the differences in vegetation growth between sections one and four appear to affect their positions on the braided-anabranching continuum. Section one is flatter than section two (Figure 3.3), and therefore might be expected to tend more towards anabranching morphologies (Eaton et al., 2010). Its position above the permafrost threshold (Nicoll et al., 2013) produces a shorter growing season, however, inhibiting the stabilising effect of vegetation by slowing the colonisation of bars to favour braided morphologies.
The connectivity of elements within riverine systems plays an important role in modulating responses to disturbance. Highly dependent on landscape history, connectivity refers to the storage time for sediment in various components of the riverscape as it moves from hillslopes into, and through, the catchment (Brierley et al., 2006; Fryirs et al., 2007). The wide valleys of section one have produced a river that is generally laterally disconnected, with broad floodplains buffering the channel against sediment entering it from the valley margins and tributaries. The downstream constriction in valley width appears to act as a local base level control for this section, causing the valley to infill through channel aggradation and floodplain sedimentation: this largely depositional section is therefore also relatively longitudinally disconnected.

The partly confined valleys and increased slopes of section two encourage greater lateral connectivity as smaller floodplains are reworked more regularly and less space is available for tributaries to store sediment in fans. Longitudinal connectivity is also greater in section two, although localised pinch points encourage localised sediment accumulation.

The confined and partly confined section three exhibits perhaps the greatest lateral connectivity of the Yellow River source zone: the river is often in contact with both sides of the valley and tributaries have only limited room to store sediment. Longitudinal connectivity in this section is also high, with a single, deep channel able to efficiently transport sediment downstream.

The floodplains, extensive backswamps and tributary fans of section four store large volumes of sediment, disconnecting the river from the valley margins. This section has accumulated sediment over an extended period, acting as a sediment sink with long storage times.

Section five shows a sharp contrast to section four, with a steep gradient allowing sediment to move rapidly through the system. Here the extensive terrace-fan complexes of the Tongde basin disconnect the river from the valley margins and tributaries, leaving it to laterally rework these fans as well as historical valley fills (Figure 3.8).

Tributaries generally appear to have limited morphological impact on the trunk stream, making little difference to the relationship between aggradation and progradation. This implies that the energy/sediment balance in the tributaries is sim-
ilar to that of the trunk stream, or that scale limits their impact. Section five contains the most obviously morphologically significant tributaries of the studied sections, as their adjustment to the base level of the trunk stream has produced significant alluvial fans. These regularly force the trunk stream against one side of the valley (see Figure 3.8).

Understanding and effectively managing the Yellow River source zone, as well as the other fluvial systems on the Qinghai-Tibetan Plateau, requires the ability to explain geodiversity in terms of the controls and interactions occurring at multiple scales. While this paper introduces the broad context, patterns and controls of the Yellow River source zone’s trunk stream, it only presents a limited survey of the wide array of morphological features and processes operating at various spatial and temporal scales in the area. The future challenge is to further investigate the interactions between form and process, linking the broad-scale patterns and controls explored here to the processes and interactions operating at the much finer, localised scales at which people, animals and vegetation interact with the river. A multi-scalar, process-based understanding of the Yellow River source zone will provide improved explanations of geodiversity and connectivity in the region, allowing investigation into ecological relationships, evolutionary trajectory and potential sensitivity to disturbance.

It seems intuitive that morphology must act as an important ecological control: geomorphic form and its associated processes comprise and form the environments within which riverine ecologies reside. Processes and interactions at the reach-scale produce particular assemblages of morphological features such as riffle-run sequences and floodplain wetlands, determining the types and diversity of riverine habitat. These reaches comprise individual geomorphic units such as individual bars, each with particular hydrological characteristics and disturbance regimes, providing habitat to small groups of organisms. Within individual morphological units, hydraulic units characterise particular flow velocities and the substrate characteristics which determine habitat availability for individual organisms.

Despite these interactions, there exists a dearth of research systematically investigating these relationships and almost no information exists for the Qinghai-Tibetan Plateau. While reach-scale morphology can be linked to the type of habitat available at the hydraulic unit scale (Thomson et al., 2001), few attempts have
been made to investigate subsequent linkages to ecology. While Thomson et al. (2004) found that particular morphological units exhibit similar habitat and ecological characteristics across reach types, they did not address reach-scale variations in the frequency of these units. Variations in geomorphic form and condition have been linked to ecological distribution at reach-scales (Chessman et al., 2006), however this work does not extend to smaller scales. A need therefore remains for systematic, cross-scalar work examining variations in river ‘type’ at the reach scale, the assemblages of morphological and hydraulic units forming these broader riverscapes, and the habitat potential presented by these features. Pan and colleagues (2012) present an initial investigation of fluvial geo-ecological linkages on the Qinghai-Tibetan Plateau.

The ability to understand change in river systems, particularly in the context of external disturbance such as climatic and land use modification, is integral to effective management. Change in riverine systems is non-linear, occurring through the interaction of imposed, external conditions with the internal state of a particular river at a particular time (Lane and Richards, 1997). Under relatively ‘normal’ disturbance regimes these interactions produce a natural range of behaviour within certain evolutionary trajectories (Brierley et al., 2008). Contrary to traditional notions of equilibrium, however, if certain thresholds are crossed (Phillips, 2011) systems can switch between entirely different sets of process-form relationships, and change drastically (Brierley et al., 2008). Understanding the sensitivity of individual systems, how easily these thresholds might be crossed, is essential to predicting potential responses to changing boundary conditions. Such systems-specific insight needs to be ground-truthed by field-based investigation of the diversity, patterns and evolution of the system in question. Incorporating these understandings into policy and on-the-ground applications is integral to effective, sustainable river management.

3.8 CONCLUSION

Analysis of geodiversity is an important consideration in appraisals of biodiversity. A wide range of geodiversity has been demonstrated within the Yellow River source zone, reflecting the unique environmental setting and evolutionary adjustments in
this region. The imprint of historical infilling and incisional episodes has produced the contemporary broad-scale patterns of accommodation space induced by slope and valley width. Future research is required to form the basis of conservation and rehabilitation initiatives in this region, linking ecological values and associated measures of functionality to these understandings of landscape.
Part III

CRITICAL PHYSICAL GEOGRAPHY?
Ironically, bold pronouncements by post-modernists of the death of Enlightenment meta-narratives have been written in such a way that the next of kin – empiricist and positivist physical geographers – missed the funeral. If human geographers are really serious about changing the way that science is socially constructed, then they must find some way to address practising scientists. (Demeritt, 1996, p. 485)

Contemporary arguments for the primacy of place in geomorphology echo early concern about the oversimplification of quantification, but also have more proximate intellectual roots in movements criticising reductionism and naive positivism in the sciences. Mid-twentieth century regionalist defences of place-based geomorphology possessed an air of conservatism—perhaps reactionary responses to an impending Kuhnian paradigm change (see Orme, 2002). Arguments against a placeless and timeless geomorphology grew from the 1970s, influenced by scepticism towards claims to fundamental, objective knowledge that is free of its broader context. While geomorphologists might traditionally interpret context in terms of place and history (e.g. Brierley et al., 2013; Phillips, 2017), for those aiming to understand people it points primarily to the social and political conditions in which they live.

Many of the strongest contemporary objections to positivism have emerged in opposition to the application of reductionist methodologies to explain human behaviour. Critical social psychology, for example, developed partly in response to the practice of ascribing the behaviour and characteristics of individuals to limited sets of physiological or environmental variables (see e.g. Gavey, 1989). Arguing that such explanations both neglect individual experience and overlook the broader milieu within which people think and act, these researchers challenge ‘common sense’ assumptions of stable categories and controls on behaviour and draw attention to the implications of claims to such knowledge. Applied to examples such
as sexism, these post-structuralist approaches have opened up space for nuanced analysis of the ways power and privilege suffuse everyday life (e.g. Calder-Dawe, 2015; Calder-Dawe and Gavey, 2016).

Perhaps unsurprisingly given this context, it is in human rather than physical geography that critiques of reductionism have been strongest, and exerted greatest methodological influence. Harvey’s (1974) critique of ostensibly apolitical, positivist research rejected the notion of the ‘benevolent bureaucrat’ producing ostensibly neutral knowledge, arguing that focussing purely on technical proficiency obscured broader questions of social responsibility. This set the scene for a diverse array of ‘critical’ geographical scholarship, actively engaging in the politics of knowledge production from the political left (see Johnston, 2016).

Physical geographers and geomorphologists have generally been less willing to directly address the social and political contexts of their work. It would be a stretch, however, to argue that this reflects a lack of moral sensibility: such researchers have, for example, been instrumental in furthering a range of environmental causes, better understanding hazards, and predicting the impacts of climate change. Rather, it entails a position that the solution to many of these problems lies primarily in better understanding the physical world; that the production of more, better knowledge is a moral ‘good’ in its own right. Such work separates the making of such knowledge from its application, treating it as a value-free exercise divorced from the messy politics of decision-making. This is consistent with various forms of philosophical realism, largely adopted from other scientific disciplines, which strive towards increasingly true statements about the world through the iterative production and testing of falsifiable claims (see e.g. Inkpen and Wilson, 2013).

Yet this separation of knowledge production from its context is, in practice, rarely as clean and clear as might be ideal. The connections are particularly apparent in physical geography and geomorphology, where many researchers fulfil dual roles as scientists and environmental consultants, and research articles regularly emphasise any potential management implications of their findings. Bouleau’s (2014) juxtaposition of the management regimes of the Seine and Rhône Rivers, for example, highlights how the ‘scientific puzzles’ conceivable for each river are not simply the product of a disinterested assessment of facts, but relations between
people and place. The entanglements between public interest and research aims (Bouleau et al., 2009), the links between theoretical frameworks and the desires of capital (Linton, 2008; Linton and Budds, 2014), and the conflation of heuristics for research with assertions of value (see Chapter 7 as well as Kennedy, 1992) have encouraged increasing attention to the mutual feedbacks between the questions we ask of the world, and the potential futures they make possible (e.g. Harden, 2012).

4.1 BETWEEN NATURE AND SOCIETY

Much is made of geography’s history of, and potential for, interdisciplinarity (e.g. Baerwald, 2010; Kates, 1967; Thom and Woolmington, 1988). Relationships between people and the physical environment are a long-standing part – perhaps the fundamental part – of this tradition: from the uncomfortably deterministic roots of the ‘human ecology’ which intrigued Davis and his contemporaries (Barrows, 1923; Leighly, 1955) to more recent, and more progressive, calls for consolidation and revitalisation of geography around the relationships between nature and society (Stoddart, 1987; Turner, 1989; Zimmerer, 1994). Relatively fixed views of nature and society have generally persisted, however, producing visions of interdisciplinarity largely restricted to ‘bolting on’ social influences to science regarding the physical environment, or vice versa (see e.g. Castree, 2014).

Noel Castree in particular has made a series of arguments for radical interdisciplinarities which do more than simply integrate knowledges, reconsidering the relationships they make possible (Castree, 2015a,b, 2016). Potential approaches to this have developed from two primary research traditions. The first of these emerges from science and technology studies (STS) and political ecology. Both of these fields have traditionally worked at the margins of the ‘natural’ and the ‘cultural’: STS through its focus on the social and political processes of knowledge production (e.g. Lave, Mirowski et al., 2010; Sismondo, 2004), and political ecology by foregrounding the social, economic and power dynamics of human relations with the physical environment (compare Turner, 2016; Walker, 2005). As materialism and the more-than-human enjoy a renaissance in the humanities and certain parts of the social sciences (see Whatmore, 2006), researchers working from these traditions are increasingly interested in the physical world. This work has, for ex-
ample, drawn attention to the social elements of processes and phenomena which might otherwise be conceptualised as natural (e.g. Linton, 2010; Linton, 2008; Linton and Budds, 2014). This unsettling of naturalness generally emphasises human agency, with a democratising intent.

The second emergent theme approaches interdisciplinarity from the opposite direction. The relatively recent movements towards ‘socio-hydrology’ (e.g. Di Baldassarre et al., 2013; Ertsen et al., 2013; Lane, 2014; Sivapalan et al., 2012) and ‘sociogeomorphology’ (Ashmore, 2015) are primarily the work of physical scientists concerned with human impacts on the landscape (see Wesselink et al., 2017). Wesselink describes these approaches as (post)positivist, reflecting their disciplinary roots: they emphasise contingency and uncertainty, but remain broadly committed to producing objective knowledge about the physical world. Like post-normal science before them (c.f. Funtowicz and Ravetz, 1993), they enact a green, democratising politics from a primarily rationalist perspective (see Wesselink and Hoppe, 2011), emphasising the utility of supplementing scientific understanding with different forms of expertise (see e.g. Lane, 2014). They do not assert the death of modernity (c.f. Funtowicz and Ravetz, 1992), but rely on the more grounded claim that social processes play an important role in influencing physical landscapes (see Ashmore, 2015).

These forays into interdisciplinarity begin from notably different positions, but share a broader emphasis on changing relationships between people and the physical environment. They aim to do this by exploring and challenging the way naturalness is understood, and the values associated with it. This includes, for example, emphasising the ways in which ‘wildness’ can thrive even in places which are heavily modified by people, highlighting the possibilities presented by recognising and understanding this (Ashmore and Dodson, 2016; Cronon, 1996). Despite their distinct lineages, these approaches thus present a common political project based on the premise that the kinds of knowledge people create shape what is possible.

The following chapter explores the notion of context, expanding it from the purely biophysical to incorporate the social and scientific practices and processes which shape our understandings of landscape. In particular, it outlines the role that simplistic classification and quantification can play in embedding and obscuring underlying assumptions: what Hiers and colleagues (2016), writing at the same
time, name the ‘precision problem’. It welcomes the momentum gained by critical physical geography in drawing attention to the role of power relations and social processes in the knowledge we create about the world (see Lave, 2014a; Lave et al., 2014). It also, however, stresses that these engagements must be seen to be constructive if they are to avoid repeating the misunderstandings which have limited the impact of similar efforts in the past (see Demeritt, 1996).
INTRODUCTION

‘BUT WHAT DO YOU MEASURE?’ PROSPECTS FOR A CONSTRUCTIVE CRITICAL PHYSICAL GEOGRAPHY

5.1 INTRODUCTION

Just as a river is the product of its valley (Hynes, 1975), constrained by it even as it modifies it, so geomorphic knowledge shapes, and is shaped by, the world around it. As we burrow deeper into the earth’s secrets, what we discover depends not only on what is there but on the questions we ask, the tools we use and the frameworks and languages we apply to give meaning to our findings (see Church, 1996; Collingwood, 1946; Rhoads and Thorn, 1993, 1996a). Geomorphic knowledge, in turn, is used to physically modify the world: our perceptions of what is possible affect how we choose to act, and how we choose to act affects our perceptions of what is possible. Understanding how and why geomorphic knowledge is manufactured and mobilised, the processes of co-production through which information, institutions and the physical world interact (Bouleau, 2014), is therefore integral to understanding the world around us. People bring a diversity of values, ideas and knowledge to questions of landscape and water: there is no single way to know the world (e.g. Linton, 2010). As geomorphology strives for the apparent objectivity of the harder sciences (Massey, 1999) it not only creates knowledge, but also shapes possibilities for action.

Drawing upon critical traditions within and beyond geography, a growing number of authors acknowledge the importance of politics and power in the analysis of landscapes and the ‘work’ that research practices do (e.g. Tadaki et al., 2015, 2012). Resonating with analyses of socio-natures (see Castree, 2013), science studies in geography (e.g. Wainwright, 2012), critical cartography in physical geography (e.g. Hamylton, 2014), the deeply political emergence of the Anthropocene (Castree, 2015a; Castree et al., 2014) and socio-geomorphology (Ashmore, 2015), these voices
draw attention to the role of researchers and research practice in the knowledge we produce (Lane, 2014). They suggest that there may be value in interrogating the framings and assumptions underpinning our understandings of the world, exploring possibilities for knowing and making it differently (Blue et al., 2012; Brierley et al., 2013; Tadaki et al., 2015). Some of this work is being compiled under the label of ‘critical physical geography’ (see Lave et al., 2014), although neither that label nor a broader ‘geographical’ one can claim a monopoly on these themes (e.g. Turner, 2016).

Geomorphology incorporates a broad array of people, projects and politics, encompassing a diverse set of activities: from pure science, concerned with unravelling processes and histories of landscape formation, to applied science modifying our surroundings to suit societal values and perceived needs. The resulting tangled connections between science, practice and policy provide fertile ground for broadly-based geographical enquiry into human-environmental relations (see Castree, 2015b). Geomorphology has a history of engagement with diverse theoretical and methodological approaches (see Butzer, 1973; Jennings, 1973; Slaymaker, 1997). This might be extended to learn from, and to change, the intricate relationships between ‘nature’, people and politics as expressed through geomorphology and physical geography. We see critical physical geography as a space for examining the role played by people, power, politics and place in physically shaping landscapes. We hope it will encourage constructive engagement with questions of contingency, context, equity and the material consequences of the ways geomorphologists understand landscapes. It might foster new, productive discussions of empirical rigour, appropriate classification and the role of scientific credibility in creating and maintaining geomorphology’s role in developing and using tools to analyse and modify landscapes.

Here we examine how approaches to geomorphic enquiry shape the questions we ask, the data we collect and the answers we produce. We briefly discuss geomorphology’s construction as an applied science, subject to demands for precision, predictability and objectivity which can be misleading in a world imbued with uncertainty, power and politics. Using the example of river diversity we explore the relationship between geomorphic knowledge and environmental outcomes, examining the role of measurement and classification in making particular environ-
ment futures possible. Finally we consider the potential for a constructive critical
physical geography to develop rigorous, place-based and democratic understand-
ings of landscapes. While we limit our discussion to English-speaking traditions
of geomorphology, these themes are likely to have broader relevance.

5.2 MEASUREMENT AS KNOWING

Not everything that can be counted counts. Not everything that counts
can be counted. (Cameron, 1963, p. 13)

Scientific knowledge has elevated status in contemporary western society. This
privilege has not been earned through, and does not rely on, neutrality and free-
dom from external influences. Scientific research is, and always has been, deeply
connected to the principles, priorities and prejudices that produce it (see Living-
stone, 2003). Rather, science earns its privilege through ideals of empiricism, open-
ness and freedom of debate. Within the confines of a clearly delineated theoret-
ical context, discrete, carefully defined systems can be examined using transpar-
ent methodologies to produce data which, upon interrogation and suitable replic-
ation, might be reliable within their given frame of reference. Quantification is
essential to contemporary geomorphology, but can also act to obscure the contex-
tual nature of geomorphic knowledge. Effectively using scientific information in
environmental decision-making requires understanding the spatial and temporal
limitations of these framings.

Commonly constructed and practised as a science (e.g. Rhoads and Thorn, 1996b),
geomorphology benefits from the associated privilege. Narratives of ‘higher sci-
ence’ are engaged to lend legitimacy to – and gain funding for – positivist aspects
of the discipline (described by Massey, 1999; Sack, 1992) epitomised by the 1950s
shift towards Earth scientists addressing ‘modern’ problems within narrow spatio-
temporal limits (Schumm and Lichty, 1965). Criticisms of scientific practices in
geomorphology and physical geography as ill-defined and implicit (Ashmore, 2015;
Castree, 2005a) suggest, however, that these advantages cannot be taken for gran-
ted.

Quantification is an integral component of geomorphology’s construction as
a science. Asserting a measured value advances an unequivocal position which,
given suitable scientific frameworks, can be compared and contrasted with existing knowledge (theory) and tested for representativeness and replicability (c.f. Richards and Clifford, 2011). Perhaps because of this potential for rigour, measuring something makes it ‘known’, providing a sense of surety, of accuracy and of scientific credibility. To borrow from comedian Stephen Colbert, measurement brings a sense of ‘truthiness’: the feeling that particular information is inherently valuable and a trustworthy basis for decision-making (Colbert et al., 2005). Doing measurement is not necessarily doing science, however (e.g. Brown et al., 2013), and, as many examples from the ‘softer’ sciences have shown, conflating measurement with knowing can be misleading. This ‘truthiness’ might encourage potentially misleading confidence in quantitative understandings of landscapes produced or applied without due regard for context.

At the simplest level, river channels are shaped by the transport of sediment by water. Perfect information about that sediment, and the flow of water around it, could in principle be used to produce mechanistic understandings of the entrainment and deposition of individual particles. In practice, however, it is rarely possible to draw upon such data, so analyses typically rely on statistical models and approximations. Even a mechanistic understanding at finer scales would likely offer only limited insight at broader scales of enquiry, such as the reach or catchment, where the imprints of contingency appear to dominate process-form interactions (Church, 1996). The resulting river behaviour has been described as emergent or complex (Harrison, 2001), although these words have diverse and contested meanings (e.g. Harrison et al., 2006). Challenges faced in addressing these concerns might be productively understood as a problem of closure, wherein our inability to isolate and capture all potentially relevant information about fluvial systems regularly leads to unexpected outcomes. Morphological conditions and parameters might be unknown, rapidly changing, or operating at scales incompatible with our investigations, threatening bottom-up attempts to understand rivers from fundamental laws (see Lane, 2001). The precision of measurement and the confident language of classification, with its clear, stable categories, belie a messy world.

When we cannot measure everything, what we measure reflects what we think is important. While these decisions are generally justified on scientific and theoretical bases they are also made within, and influenced by, a range of social, political,
personal and institutional contexts. Even when disputed (e.g. Lave, 2014b), these inadvertently value-laden and political decisions can, over time, be fossilised into the canon that informs standard, placeless, apparently objective research and management practice. Might desires for geomorphology to be seen as a legitimate science (e.g. Strahler, 1952) have inhibited broader reflexivity, for fear of admitting weakness? Focussing on particular measurable phenomena limits the possibilities for seeing and interacting with the world, with real implications for places and for people. This is manifest in the description and analysis of river form, with potential repercussions for the assessment and management of geodiversity (see Gray, 2004).

5.3 ANALYSING RIVER DIVERSITY: WHAT DO YOU MEASURE?

As river management priorities have increasingly emphasised sustainable management and improved ecological condition (Downs and Gregory, 2004; Hillman, 2009), their focus has increasingly shifted towards the importance of maintaining a broad range of physical habitat, both as a fundamental building block of ecological health and as a river management goal in its own right. The resulting need to assess and communicate river diversity, process and evolutionary trajectory leads us towards a new question: how do we measure them? What we choose to monitor and assess makes possible particular management outcomes and shapes environmental trajectories (Bouleau, 2014). What these measures should be is therefore both a scientific question and a political one, demanding broader recognition of the social contexts and implications of these decisions (see Ashmore, 2015).

The multiple, tangled connections shaping geomorphic systems make capturing all potentially relevant aspects of a system implausible: we must decide what we measure, and what we do not. Even the simplest choices, backed by the firmest scientific frameworks, are influenced by a ‘mangle’ (after Pickering, 1995) of contextual factors. These decisions reflect the knowledges, experiences, mind-sets and motivations of the researchers involved (Roper et al., 2008, 2010). They are influenced by the theory we employ, the language we use and the conceptual models and tools we have available to analyse and interpret the world (Rhoads and Thorn, 1996a). They also depend on the institutional settings within which we work, the
socio-political framing of our projects, and the values they represent (Tadaki et al., 2014). Over time the interactions, feedbacks and contestations between knowledge, people and place work to ‘co-produce’ science, society and the physical world (Ashmore, 2015; Bouleau, 2014). Acts of measurement therefore instil and embed particular sets of values and associations into the landscape. This might occur through focussing on particular scales of enquiry (Church, 1996), through privileging ‘ideal’, stable forms (Kondolf, 2006) over the processes shaping them (Buffington and Montgomery, 2013), or through insisting on prescriptively framed, measurable classes rather than open-ended sets of guiding principles framed as archetypes (e.g. Brierley et al., 2013; Tadaki et al., 2014).

A simple example of the challenges inherent to describing and understanding river geodiversity through classification is presented in Figure 5.1. Identifying and naming particular morphologies sets normative expectations as to how the river ‘should’ be, and how it should or should not change over time. If the river subsequently begins to adjust, whatever the cause, perceptions of environmental degradation may seem to justify particular interventions in the river or surrounding land use, removing features (e.g. Kondolf, 1995) or even people (e.g. Blue, 2011; Yeh, 2013) that ‘do not belong’. Rather than protecting geodiversity, such interventions might inadvertently, and ironically, act to restrict it to particular sets of named or easily measured variants.

Exploring and negotiating relationships between science and society, between politics and practice, is integral to contemporary geomorphology. Measuring the right things, in the right places at the right times and for the right reasons presents ongoing scientific, technical and ethical challenges. Geomorphology’s history of critically assessing claims to knowledge, exemplified by the rich discussions regarding morphological classification (see Buffington and Montgomery, 2013), suggests a robust capacity for this. The slow uptake of critiques of river management in the USA, however, limiting their influence on practice (Lave, 2014b), suggests that these discussions need to be more proactive, and much more explicit, than in the past. Might critical physical geography foster and expand these critiques, more effectively engaging with geomorphology’s role in shaping the world? Increased attention to what we measure, how we name the world and why, might be an important step in the right direction (see Richards and Clifford, 2011).
Figure 5.1: How do you measure river geodiversity? What attributes do you measure, and why? The Upper Yellow River at Dari in western China has a transitional form between braided and anastomosing (or anabranching) morphologies (Blue et al., 2013; Lewin and Ashworth, 2014). Braided and anastomosing rivers have different process associations, yet here elements of each are found within the same reach. The ‘transitional’ label recognises that not all rivers fit within ‘normal’ classification boundaries, and is applied to avoid inappropriate management interventions based on particular expectations of river character and behaviour. Labelling a river reach as ‘transitional’ may, however, also de-legitimise potentially important variants of geodiversity by evoking change, in space or time, towards a ‘proper’ type of river.
5.4 PROSPECTS FOR A CRITICAL GEOMORPHOLOGY

 Appropriately contextualised knowledge is essential to understanding and living in a complicated, contingent world. As increasing attention focuses on the fundamental role of humans in changing the earth’s surface, and we debate the ‘Anthropocene’ and the possibilities for doing environmental change research differently (Castree, 2015a; Castree et al., 2014), it becomes more apparent that our understanding of landscape is, itself, an essential part of that context. We contend that critical physical geography might be one way of opening up space for substantive debate within geomorphology: exploring how environmental outcomes are shaped by the questions we ask, the approaches we bring and the ways we describe them. This might include reconsidering who gets to ask these questions, renewing and extending geomorphology’s rich pluralistic traditions (see Jennings, 1973; Rhoads, 1999; Slaymaker, 1997) by encouraging diverse perspectives on what the key geomorphic questions might be. It might mean recognizing and respecting different ways of knowing the world: for different people, different places and different purposes (c.f. Wilcock et al., 2013).

Geomorphology has at times suffered from a perceived disconnection between theory and observed ‘reality’, prompting various discussions of theory’s role in a discipline so concerned with place (see Baker and Twidale, 1991; Rhoads and Thorn, 2011; Rhoads and Thorn, 1993). This “gap between the world as it is and the world as we understand it” (Rhoads and Thorn, 1993, p. 303) is integral to predominant post-positivist scientific framings of geomorphology. As theory informs the collection and interrogation of data, data may challenge theory by providing evidence for its modification or rejection. Ongoing efforts to reconcile tensions between contingent data and generalised theory are fundamental to advancing geomorphic knowledge: without theory we would wander aimlessly between incongruent case studies without guidance as to appropriate methodologies or analyses to deploy. Theory may also play a restrictive role, however, limiting the questions we ask and the understandings we can produce. What we look for in the landscape, and what we expect to find, influences what we see. In providing the frameworks for the ‘plots’ of the Earth sciences, theory influences the stories we tell (Phillips, 2012) and the data we gather. Theory is thus central to enquiry, but
must at the same time be treated flexibly in the face of contradictory data. This is integral to such a place-dependent subject concerned with un-boundable systems in which unnoticed or unknown local contingencies might be key controls (see Brierley et al., 2013; Phillips, 2007).

In recognising other ways of knowing, whether these be diverse sets and sources of data, alternative theories or entirely different frameworks of understanding, we might find new and perhaps even old ways of addressing disconnections between theory and place. Geomorphology has at times been accused of forsaking earlier approaches to research in favour of ‘bandwagons’ arriving from other disciplines, usually the ‘harder’ sciences (Jennings, 1973). These grand paradigms have brought to geomorphology new ways of seeing the world, fresh approaches to old questions, and technical and methodological innovations. They have also regularly been over-sold, however, from joyful heraldry of theory’s ostensible arrival (e.g. Burton, 1963) to the most evangelical claims that complexity and chaos theory will explain everything (see Sardar and Ravetz, 1994). Applied overzealously, they risk neglecting local difference (c.f. Baker and Twidale, 1991) and potentially leaving fruitful avenues of exploration underexplored in the “creative ahistoricism” (Sherman, 1996, p. 111) encouraged by processes of fashion (e.g. Sack, 1992). We hope that critical physical geography will not simply supplant these with a bandwagon from the ‘softer’ side, but act to bring fresh energy to questions of how we might know, and act in, the world differently.

In this spirit of pluralism we are wary of attempting to define what, exactly, critical physical geography should be (c.f. Lave et al., 2014) and exactly which questions it should bring to geomorphology. Delineating particular lines of inquiry, avoiding ‘collisions’ between them (Demeritt, 2009), risks playing into the very tendencies we are attempting to disrupt. We therefore simply hope that critical physical geography engages directly and constructively with research and management practice, and its ethical implications. This includes questioning the roles played by researchers, institutions and management in mediating our understanding of the environment, helping us to move beyond ‘mindless metrics’ towards a more flexible, more place-sensitive and more reflexive physical geography. It might also involve greater bottom-up engagement in research processes, recognising people’s ability and right to actively lead and participate in investigations.
into questions concerning them (see Appadurai, 2006). The creative possibilities for such opening-up of research processes to different people with different world-views range from relatively instrumental redistributions of expertise in problem identification and solving (e.g. Landström et al., 2011; Lane et al., 2011; Rhoads et al., 1999), to attempts to inspire alternative ways of relating with the world (e.g. Suchet-Pearson et al., 2013; Wilcock et al., 2013).

If individuals and institutions are asked to abandon wholesale the practices they are deeply invested in, dragging geomorphology through a ‘critical turn’ might prove difficult and slow. While the relationship between theory, place and practice in geomorphic enquiry has developed through much debate (e.g. Rhoads and Thorn, 1996b), and discussions of uncertainty in classification are prevalent in methodologies of morphological mapping (e.g. Evans, 2012), within geomorphology these questions and critiques rarely extend to their social and political implications (c.f. Ashmore, 2015). If Chorley’s (1978) geomorphologist felt that theory was best addressed with a soil auger, one wonders how she might face criticisms involving power relations, colonialism, race and gender. The critical physical geography we imagine would not seek the indiscriminate rejection of established perspectives and approaches, many of which have been established on good evidence via thorough discussion (if amongst rather limited audiences). It would not require that all geomorphologists refashion themselves as generalists transcending the social and natural sciences; nor would it claim to be the only answer to the questions and problems we have raised here. We do, however, contend that the responsibility lies with both geomorphologists and geographers to facilitate and engage in respectful dialogues towards socially-situated, place-based, reflexive understandings of landscapes (see Clifford, 2002). Interrogating what we measure, how, and why, is an important step towards a constructive critical physical geography.

5.5 CONCLUSION

Geomorphology has evolved pragmatically over time. Resulting practices embed particular values, influencing the questions we ask, the ways we seek answers and, as a consequence, the environmental outcomes we produce. Critique in geomorphology certainly pre-dates the existence of something called 'critical physical
geography’, but has generally been limited to ‘objective’ methodological or philosophical discussions. An emergent critical physical geography presents significant opportunities for geomorphologists to engage with questions that regularly go unasked, and unanswered, in the Earth sciences. In particular it might bring fresh energy to broader explorations of what we know, what we do not, who knows it and why.

However scientific the approaches and methods of geomorphology, results will inevitably be influenced by where and why they were produced, at what scales and by whom. In a world without closure, consisting not of neat categories but multiple continua of landforms (re)shaped by multiple processes across multiple scales, the knowledge we produce is highly contextual. Engaging with this demands that we explicitly address the limits to our claims of knowing, particularly as geomorphic research may have substantial consequences for landscapes and those who live in and interact with them. Critical physical geography might provide the energy to engage with these questions constructively through a range of theoretical and practical approaches. This could involve challenging the ways in which physical geography is constructed and practised. It might also include doing it differently: adopting more flexible, reflexive practices which explicitly acknowledge the various contexts we are working within to maintain an appropriate sense of place and purpose.
Part IV

SEARCHING FOR THE IDEAL RIVER
Growing awareness of the urgency of environmental problems has proven both a blessing and a curse for physical geography. Interest in preventing ecological decline has attracted substantial investment in improving ecological condition (e.g. Bernhardt et al., 2005), driving demand for ‘actionable’ research capable of guiding and monitoring intervention (Bernhardt et al., 2007). For a discipline which – rightly or wrongly – takes pride in the production of objective knowledge about the earth’s surface, this has blurred the boundaries between science and politics. Geomorphologists do not simply ask how the landscape changes over time, but are entangled in questions of how it should be.¹

The politics of whether to intervene in environmental problems generally receives more attention than the politics of how to intervene in them. Questions of whether to act – to prevent or repair environmental impacts – are noisy matters of public protest and discussion, often understood as battlegrounds between the interests of capital and conservation. Although debate might flare when particular standards are adjusted, especially if changes are perceived to serve political interests (e.g. Gudsell and Bramwell, 2017; McCulloch, 2017), the specifics of environmental outcomes and the means of achieving them are generally understood to present technical rather than political challenges.

This separation, of the willingness to act from the question of how to do it, creates space for a ‘quieter’ politics of environmental knowledge. I use the word quieter to describe political action which might not easily be recognised as such; previous authors have applied it to a variety of examples, from the informal influ-

¹ Of course, some would assert that this is nothing new: that all knowledge is political and contextual. Support for this position could be drawn from evidence that science has a geography (e.g. Livingstone, 2003), and that environmental knowledge is entwined with politics and power (Bryant, 1998; Lave et al., 2014). These arguments have proven generative across a range of fields. While I have some sympathy for many such accounts, they are by no means universally accepted (see e.g. Sokal and Bricmont, 2004). Regardless, resolving these debates is not necessary for my purposes. The ontological status of truth is not at stake here; rather the ways in which we create and apply knowledge about the world to intervene in it.
ence of corporate lobbying (Culpepper, 2011), to the potential power of mundane activism, intimacy or guanxi to bring about change (Askins, 2015; Zhou and White, 1995). This quieter politics influences outcomes as environmental issues settle: as the need to act is broadly accepted and the technical work of doing it begins.

Much of this quiet politics is embedded within the tools used to understand and administer environmental change. These technologies are generally understood as apolitical, pragmatic solutions to problems identified by society. In practice, however, these tools do not simply solve already-existing problems but influence how they are seen, making particular elements of the landscape visible to management regimes as problems in need of solving (see e.g. Bouleau, 2014). The decisions embedded in these frameworks, indicators and interventions represent a quiet politics of entangled institutional imperatives, the interests of capital and committed individuals. These interests might be presented through the technical, disinterested language of scientific expertise (see e.g. Bouleau et al., 2009; Lave, Doyle et al., 2010; Lave, 2014b), but they regularly rely on – and reproduce – particular sets of ideals regarding how the environment should be. These ideals represent particular ‘common sense’ understandings of how the environment should be: visions of a better world which are highly culturally specific, but which seem so self-evident that they are largely beyond debate (c.f. Crehan, 2016; Rosenfeld, 2011).

6.1 INTERVENING IN A CHANGING WORLD

Early conservation efforts were often justified as the protection of ‘wilderness’ from the destructive actions of people. Fencing off ‘nature’ for its own good would protect it, while also providing valuable recreation opportunities in parks and wildlife reserves established on otherwise ‘worthless lands’ (see Callicott and Nelson, 1998). By the 1990s, however, these ‘fortress conservation’ efforts (Adams and Hulme, 2001) were increasingly challenged from multiple sides. They were criticised for poor conservation outcomes as a focus on recreation and scenic value, rather than ecological merit, encouraged only the protection of fragmented, unrepresentative habitat (Foreman, 1995). They were challenged on social justice grounds, representing new forms of imperialism which thrust western ideals of wilderness upon colonised peoples for the pleasure of the privileged (Guha, 1989;
Neumann, 1997). They were also condemned for being prohibitively expensive to maintain, especially for developing nations, leading to demands for rationalisation, privatisation and the ‘wise use’ of park resources to improve cost-effectiveness (Inamdar et al., 1999).

Alongside these more pragmatic re-evaluations of approaches to conservation came a set of more theoretical, social constructionist critiques of notions of wilderness (c.f. Demeritt, 2002). Cronon (1996, p. 19) in particular questioned the idolisation of an imaginary ‘pristine’ nature existing only apart from human activity, suggesting that little progress would be made on environmental issues as long as “we hold up to ourselves, as the mirror of nature, a wilderness we ourselves cannot inhabit”. Instead Cronon (1996, p. 22) celebrated the wildness which can lie much closer to home, arguing for “The autonomy of non-human nature [as] an indispensable corrective to human arrogance”.

But, with the centrepieces of world conservation efforts under attack, and with visions of pristine wilderness so troubled, how might we articulate what, of the natural world, is worth caring for? Cronon’s emphasis on wildness, intimating a lack of human control, did not gain immediate traction among those tasked with managing the earth’s surface and, usually, keeping it in place. Instead, these criticisms became part of an increased emphasis on participatory management in an attempt to more effectively engage marginalised communities (e.g. Adams and Hulme, 2001; Agrawal and Gibson, 1999). This saw environmentalism increasingly framed within the broader concepts, or perhaps rhetorics, of ecological sustainability and sustainable development (O’Riordan, 2004; O’Riordan, 1999).

Concepts of sustainability, which emphasise the relationships between people and nature, can be understood as a move towards a more functionalist approach to thinking about the environment (see Callicott et al., 1999). Rather than attempting to maintain ecosystems in a stable, natural state, functionalism prioritises maintaining and enhancing the ecosystem processes which sustain life, and provide valuable ‘ecosystem services’. In its stronger forms a functionalist approach might disregard any sense of naturalness, focussing only on maintaining appropriate and useful processes regardless of how that is achieved, or which assemblages of organ-

---

2 More recent movements toward ‘room for the river’ (Warner and Buuren, 2011), restoring process (Beechie et al., 2010), or emphasising the ability of waterways to ‘heal’ themselves (Kondolf, 2013) perhaps at last begin to capture Cronon’s sense that non-human agency is inherently valuable.
isms contribute to it. Moving beyond notions of wilderness in this way provides a means of articulating the forms of value which can be ascribed even to highly modified, ‘novel’ ecosystems (Hobbs, 2016; Hobbs et al., 2014; Hobbs et al., 2009).

As narratives of the Anthropocene take hold (Castree, 2014), and ideals of unmodified ecosystems seem increasingly outdated, functionalist approaches potentially provide a way of looking forward rather than focussing on ‘paradise lost’ (Dufour and Piégay, 2009; Robbins and Moore, 2013; Wohl, 2013). Yet while an emphasis on functionality might seem to provide a more objective basis for assessing ecosystem condition in a changing world, one free of naïve sentimentality, it still requires decisions regarding which processes are worth protecting or maintaining, and where.

The most utilitarian response to this challenge has been to articulate the value of ecosystem services performed by functioning ecosystems (Costanza et al., 1997; Funtowicz and Ravetz, 1991; Turner and Daily, 2008). This explicitly anthropocentric approach aims to economically quantify environmental benefits, making them visible to mechanisms of governance (Castree, 2011; Robertson, 2006) in order to justify state investment in ‘natural assets’ (Bennett, 2002) or to support markets for environmental protection and rehabilitation (Doyle and BenDor, 2011; Doyle et al., 2015). These attempts to ascribe economic value to nature have been criticised for a range of reasons, both ideological and material. Perhaps most pertinently they bring a tendency to privilege and perpetuate the most readily quantifiable qualities, neglecting less tangible forms of cultural and social significance (Chan, Guerry et al., 2012; Chan, Satterfield et al., 2012).

To some extent, these concerns reflect how an emphasis on apparent objectivity may limit which – and whose – aspirations can be articulated (see Part III). They also, however, embody a broader ‘precision problem’ (Hiers et al., 2016) whereby a simplistic focus on generic, easily measured outcomes can homogenise diverse values, meanings and realities. This proclivity is by no means exclusive to functionalist approaches to management. Indeed, the functionalist emphasis on process potentially mitigates these concerns by articulating the agentic potential of rivers: emphasising their capacity to ‘heal themselves’ (Kondolf, 2013; see also Beechier et al., 2010) might facilitate a shift beyond fixed ideas of what constitutes an ideal river.
The final intervention included in this thesis, *What’s wrong with healthy rivers?*, explores the concept of river health as a potentially unifying basis for intervention in freshwater. The concept of health broadly fits within a functionalist paradigm (Callicott et al., 1999), but explicitly addresses both natural and human values. It offers an opportunity to bring a broader appreciation of physical structure and process alongside an emphasis on organisms and their habitat (Norris and Thoms, 1999). It has the potential to assert a broader social mandate for freshwater, looking beyond fixed concepts of naturalness while maintaining a sense of context and place (c.f. Ross et al., 1997). Chapter 7 explores the tensions between such a broad, aspirational approach to wellbeing and the realities of putting it into practice. By drawing attention to some of the contradictions represented by the now commonsense concept of river health it asks that we reconsider, or at least be open to reconsidering, what characteristics an ideal river might have.
INTERVENTION 3
WHAT’S WRONG WITH HEALTHY RIVERS?

7.1 INTRODUCTION

Contemporary capitalist democracies have been accused of co-opting and depoliticising environmental ideals, stripping them of their transformative potential (Swyngedouw, 2007). Attempts to make the world measurable are regularly implicated in these processes, in which power disparities and exclusion persist (Holmes and Cavanagh, 2016; Spink et al., 2010) and ‘pragmatism’ precludes possibilities for change (Van Puymbroeck and Oosterlynck, 2014). Logics of ‘measurementality’ (Turnhout et al., 2014) seem to reduce the physical environment to sets of variables which can be measured, modelled and optimised for common values (e.g. Tadaki and Sinner, 2014), or perhaps just for sale. Yet efforts to quantify the world usually represent genuine attempts to understand it, and to guide positive interventions in it. As ecologists wrestle with the ethics of intervention in the Anthropocene (e.g. Robbins and Moore, 2013), geographers increasingly highlight the inseparability of social, physical and biological processes (e.g. Ashmore, 2015; Emery et al., 2013; Lave, 2014b, 2015). The trajectory of river health, from novel notion to mainstream managerialism, demonstrates the challenges of renegotiating environmental ideals in the face of changing physical, chemical, biological and social contexts.

Most would agree that improved river condition is a good thing. Less clear is what, exactly, this means. The goals and scales of river management, and with them the meaning of good condition, broadened through the 1990s with the rise of ‘sustainable catchment management’ (see e.g. Brierley and Fryirs, 2008; Downs and Gregory, 2004). Building upon the catchment framing of Chorley (1969) and others, it was increasingly recognised that rivers might be best understood and managed as connected entities (Falkenmark, 1981; Hillman et al., 2008; Mant et al., 2016). After an initial emphasis on stability and flood control using ‘softer’ en-
gineering techniques, demand grew for a ‘whole-of-system science’ emphasising ecological outcomes (see Hillman, 2009). Advocacy for river health attempted to reframe management on this basis, reconceptualising rivers as not just networks of habitats and organisms but living entities capable of experiencing variable states of wellbeing.

But what does it mean for a river to be healthy? This question produced a moment of doubt, in which assumptions and ambiguities were laid bare as different narratives of wellbeing collided (see Chapman, 1992). Was a healthy river well stocked with exotic game fish, or should it contain a diverse array of native species free of introduced predators? Would it be untouched by human activity, or should it support the various demands of a vibrant local community? At a time when steady-state ecologies were increasingly disputed (Zimmerer, 1994) and dualistic management paradigms emphasising either preservation or utility were being challenged in favour of ‘sustainable development’ (Meyer, 1997; O’Riordan, 1999), debates regarding river health highlighted the subjective, political nature of river condition (see Ross et al., 1997).

These reservations did not deter attempts to quantify river health, producing two key competing approaches. A functional approach, linked to ecological economics, focused on ecosystem structure, function and resilience (Costanza and Mageau, 1999). The other, emerging more directly from aquatic ecology, emphasised the ‘integrity’ of unmodified biotic assemblages (Karr, 1999). Crucially, both of these models asserted scientific foundations and also claimed to represent the social values associated with healthy rivers. Debate cooled with a special issue of Freshwater Biology supporting the latter approach (Norris and Thoms, 1999), and the meaning of river health largely congealed around measurable proxies for naturalness.¹

Meanwhile, geomorphic approaches to river condition have shifted away from stable natural reference conditions as a primary guiding ideal. Instead, pragmatic steps toward ‘best achievable condition’ (e.g. Rinaldi et al., 2015) build on frameworks emphasising local histories and trajectories of change to maximise morphological ‘quality’ (Brierley and Fryirs, 2005, 2016; Graf, 2001). Yet quality is in the

¹ More recently, increased attention to ecosystem economics is producing something of a resurgence in functional approaches to ecosystem health (Costanza, 2012, e.g.). River health more specifically, however, remains generally understood in terms of compositional indices (O’Brien et al., 2016, see).
eye of the beholder: much of this work relies on expert judgement of ‘appropriate’ character (e.g. Fryirs, 2015). Searching for a firmer grounding, Wohl (2011) attempted to pin this nebulous concept down by linking it back to naturalness. Definitions of ‘good ecological quality’ for the European Water Framework Directive similarly emphasise ‘natural’ hydromorphological reference conditions (Bouleau and Pont, 2015; Newson and Large, 2006). Dufour and Piégay (2009) take a rather different approach, emphasising human needs and values alongside ecological wellbeing; they frame this in terms of river health.

Responding to calls for constructive intradisciplinary geographies that critically examine how possibilities for the physical world are made (Ashmore, 2015; Blue and Brierley, 2016; Castree et al., 2014; Lave et al., 2014; Tadaki, 2016; Tadaki et al., 2012), here I take seriously the notion that the world is shaped by the questions we ask of it. Tracing the (re)definition of river health in the anglophone academy, from a holistic but hazy ethic of environmental care to specific sets of indicators for intervention, I examine how ‘common-sense’ understandings of river condition were first challenged by, and then incorporated within, the political and scientific project of river health. I argue that the way river health was framed and made measurable, as a compromise between naturalness on one hand and human values on the other, overlooked an opportunity to articulate more inclusive understandings of wellbeing. I conclude by considering possibilities for a revitalised river health; one which integrates quantitative and qualitative understandings of landscape to renegotiate what matters for freshwater.

7.2 THE RISE OF RIVER HEALTH

By the early 1980s, the extent and severity of human impacts on the environment were becoming ever more apparent. These effects were concentrated in freshwater systems: drastic morphological change threatened habitat (Gregory, 2006), water pollution jeopardised human health (Falkenmark, 1990) and biodiversity loss was widespread (Moyle and Leidy, 1992). Fragmented management reliant on predictive understandings of small-scale physical interactions had struggled to prevent or remediate problems (Hillman and Brierley, 2005), and treating management as a purely technical process had further disconnected communities from waterways
A new, more integrated approach to river management seemed increasingly necessary.

Demand was growing to do something about river condition, but tools to support intervention were unavailable or inaccessible (Lave, Doyle et al., 2010). River engineering had long focused on creating stable channels capable of moving water to the sea as efficiently as possible, and was unprepared for these radically different design requirements. Sets of guidelines for more ‘natural’ stream restoration emerged to fill this vacuum, including the controversial Natural Channel Design (NCD) in the USA (Lave, Doyle et al., 2010; Lave, 2014b). Rosgen’s (1994) approach promised to achieve the long-standing hazard prevention goals of river management, while also promising to restore ‘good’ ecological condition. This meant ‘softer’ engineering aiming to meet hazard prevention goals while mimicking ‘natural’ habitat. Though utilising wood and rocks instead of concrete and steel, the underlying premise of control remained (Kondolf et al., 2001). These attempts to create ecosystems by emulating habitat often failed to meet expectations, particularly for improved biodiversity (Palmer et al., 2010).

Around the same time, the cornerstone principles of conservation ecology were becoming more difficult to defend (Callicott, 1992). Theoretical and physical attempts to separate people from nature were increasingly criticised (see Castree, 2005b, for a comprehensive introduction). Ideals of stable, ‘pristine’ wilderness were criticised as Eurocentric flights of fancy counterproductive to environmental interests (Cronon, 1996) and implicated in the colonial disenfranchisement of indigenous peoples (e.g. Guha, 1989; Spence, 1999). Growing awareness of global climate change emphasised the all-encompassing impacts of human activity, and flourishing exotic organisms demanded increasingly active management of protected spaces and species (e.g. Clout and Saunders, 1995). A fixed idea of nature was no longer tenable, and a new ethic of environmental care was required: “ecosystem health to the rescue!” (Callicott, 1992, p. 47).

By the 1980s, ecologists had begun to apply medicalised language to describe ecosystem responses to external pressures (e.g. Rapport et al., 1985, 1981). These interventions recognised that health was not a property that ecosystems could exhibit per se (Rapport, 1989). Rather, for these authors, health was a conceptual and rhetorical device presenting a normative call for action to prevent and remedy eco-
logical degradation. It recognised the inseparability of humans from nature, and argued that these interactions could not be dealt with in isolation. As a ‘functionalist’ approach to conservation (Callicott et al., 1999), ecosystem health encouraged treating causes rather than symptoms of degradation, and recognised that change is not necessarily detrimental (e.g. Brierley et al., 2008). It endeavoured to shift management practices beyond individual values and short term goals, towards more the holistic approaches advocated much earlier by Aldo Leopold (e.g. 1949).

The concept of health seemed to offer a broader, less anthropocentric basis for river management. It both challenged a perceived focus on physical form in river restoration (see Palmer et al., 2010; Simon et al., 2007), and apparently enabled a more progressive environmentalism as ideals of wilderness came increasingly under question (see e.g. Castree, 2003). It suggested that we could improve freshwater systems by healing the physical, chemical, biological and social factors ailing them, rather than focussing on physical characteristics or charismatic species alone. River health promised a fundamental, all-encompassing ideal with popular appeal.

Despite this appeal – or perhaps because of it – the meaning and appropriateness of river health were always contested (see e.g. Shrader-Frechette, 1994). This partly reflected broader debates about the role of politics in science, and the nature of scientific knowledge. For those keen to assert ecology’s scientific status the explicitly subjective nature of health, and the fact that it was not directly observable, produced a dangerous level of ambiguity (e.g. Scrimgeour and Wicklum, 1996; Suter, 1993; Wicklum and Davies, 1995). Responses to this critique developed along two lines: that the strength of river health was as a broad, aspirational vision furthering a political (rather than scientific) project intent on changing the relationships between society and freshwater (e.g. Elosegí et al., 2017; Fairweather, 1999), or that it could be quantified to provide a more literal, tangible basis for science and management (see e.g. Norris and Thoms, 1999).
7.3.1 *Meaningful metaphor?*

Consistent across most approaches to river health was an acknowledgement that it meant more than simply biophysical condition: that a stream was not just the product of its physical valley, but of its ‘societal watershed’ (Hynes, 1975; Meyer, 1997). This highlighted an opportunity for intervention: perhaps an ethic of river health could shape attitudes and approaches to freshwater, influencing the interactions between society and streams. As an easily understood metaphor, “packed with shared meaning and normative direction” (Ross et al., 1997, p. 122), river health might convince people that waterways were worth looking after, and it might provide the framework for a river science better suited to understanding relationships between freshwater ecosystems and human activity. This meant understanding not only physical and biological processes, but social and economic interactions with waterways.

This broad approach accepted that healthiness was not an objective property, but argued that this did not matter. River health was as much a political tool as a scientific one, and it could play a significant role in influencing public discourse regardless of definition (Chapman, 1992). The value of river health was in framing the vocabulary of river science and management, influencing interactions with freshwater by providing an overarching theme for conservation and rehabilitation efforts. Indeed attempts to define river health might detract from its generative potential, limiting its scope to what was measurable and presenting a misleading sense of objectivity. Instead, river health offered a flexible foundation for place-specific aspirational visions of what rivers could, and should, become.

River health was, then, partly a call to action for communities who might otherwise not engage with their local waterways. It incorporated not only physical and ecological attributes, but the wellbeing of those living nearby. Many of these themes later developed into a paradigm of direct public engagement with freshwater through volunteer labour (e.g. Ellis and Waterton, 2004; Overdevest et al., 2004), various forms of participatory governance (see Cook et al., 2013; Gregory et al., 2011), and the democratisation of knowledge (e.g. Lane et al., 2011; Whitman

---

2 Of course, this shift towards volunteerism also represented a pragmatic response to insufficient government funding.
et al., 2015). To support effective public engagement with freshwater, and to produce more socially just outcomes, many advocates of river health hoped to change the way river science was carried out. They spoke of more holistic approaches to understanding rivers than the ‘reductionist’, small-scale approaches dominant since the quantitative revolution. Ross and colleagues (1997, p. 116), for example, called for “a postmodern ecology which emphasizes, among other things, complexity and a holism that necessarily includes humanity in the study of nature.” Raising the spectre of the science wars with such language may be of doubtful benefit today, but the need for more inclusive and socially aware river science persists.

7.3.2 From metaphor to metric

Many of the most vocal advocates recognised the utility of river health in advancing an ecological agenda for freshwater but also wanted to pin it down, ‘operationalising’ it into “more than just a rhetorical tool” (Boulton, 1999, p. 469). River health might offer not just an aspirational goal for how rivers might one day be, but could provide ways of understanding, measuring and comparing the changing state of waterways. As health is not a property which can be measured directly, in practice this meant using indicators to evaluate and compare rivers. Despite general acknowledgement that river health is more than simply a biophysical property – that it inherently incorporates human norms and expectations (see Hull and Robertson, 2000) – most attempts to capture it avoided directly questioning what those values might be. Instead, two key approaches to river health emerged: the first focused around functional ecological principles, and the second emphasising proxies for naturalness.

Searching for a theoretical basis for health, Costanza and colleagues argued that healthy ecosystems must be capable of maintaining structure and function in the face of stress (Costanza, 1992; Costanza and Mageau, 1999; Haskell et al., 1992; Mageau et al., 1995). They presented health as the “comprehensive, multiscale, dynamic, hierarchical” product of the ecological principles of organisation, vigour and resilience (Costanza and Mageau, 1999, p. 106). Yet while many apparently healthy ecosystems might certainly have these characteristics, they are also subject to a number of contradictions. Not all ecosystems with low diversity are in poor
condition, metabolic measures of function might misleadingly favour nutrient-rich systems, and resilience privileges the status quo (Karr, 1999). Nor is it clear that more natural systems are, in fact, more stable (Pimm, 1984). Such principles may have value, and may be easily measurable, but are insufficient to encompass the multiple and diverse ways freshwater matters in different places, at different times and for different people (c.f. Blue and Brierley, 2016).

A popular array of more pragmatically minded approaches to river condition build on Karr’s (1981) indices of biotic integrity (IBI). These initially used fish assemblages as integrative biological indicators, but have since been expanded to include a range of metrics such as macroinvertebrates, hydrology and riparian vegetation (Ladson et al., 1999), diatoms (Chessman et al., 1999), water quality (e.g. Hart et al., 1999) and physical habitat (Chessman et al., 2006; Maddock, 1999). Multivariate indices emerging from this work continue to be developed to support river management, and have become largely synonymous with good condition in a wide range of contexts (Beck and Hatch, 2009; Bunn et al., 2010; Ruaoro and Gubiani, 2013; Vollmer et al., 2016; Vugteveen et al., 2006).

7.4 NATURALNESS: JUST COMMON SENSE?

Understanding and intervening in the pressures facing freshwater requires monitoring river condition (Bernhardt et al., 2005; Bunn et al., 2010; Morandini et al., 2014; Palmer et al., 2005). Such monitoring, however, is more than the passive collection of data: feedbacks between measurement and intervention shape what is possible. Monitoring mediates interactions between people and freshwater as management efforts concentrate on particular indicators, and individuals and institutions are held accountable for them (Bouleau, 2014). This, of course, is a feature rather than a bug: making certain attributes measurable encourages effort and resources to be allocated to improving them, or at least preventing their decline. It also allows us to learn which actions enhance particular attributes, and intervene more effectively towards desirable ends. Making river health a measurable attribute, emphasising the concept of integrity, allowed it to meet the growing demand for tools of freshwater governance.
IBIs prioritise a natural ideal for freshwater through their focus on integrity as “the product of evolutionary and biogeographic processes with minimal influence from modern human society” (Karr, 1999, p. 223). Undisturbed states provide an ostensibly objective hook on which environmentalists can hang their hats while dealing with people’s fickle preferences and needs. If we can ascertain how rivers were before humans interfered with them, it might provide a firm foundation from which to negotiate their restoration. Integrity allows river health to be reframed as primarily a technical challenge: a set of design and implementation challenges working towards an apparently objective, common-sense ideal. Yet, it still relies on a sense that we know a healthy river when we see one: the representations of naturalness we rely on are partly acts of imagination and assumption.

7.4.1 Which nature?

As our ability to understand and model past environmental conditions grows, our perceptions of what is natural are increasingly challenged. What might appear to be stable ‘climax’ ecosystems or landforms are often simply points along pathways of evolution and human influence (Montgomery, 2008; Wilmshurst et al., 2014). Historical trajectories are integral to understanding what is physically and biologically possible for particular waterways (Brierley and Fryirs, 2016), but previous and indeed present regimes present a multitude of potentially desirable states and behaviours (Balaguer et al., 2014). Whichever point in the stratigraphic record eventually bounds the Anthropocene (Brown et al., 2017; Castree, 2014; Lewis and Maslin, 2015), identifying good condition is more than a matter of reaching beyond a particular moment of human intervention. Healthy rivers cannot simply be plucked from an undisturbed past, but must be negotiated from a range of potential possibilities (see Stoddard et al., 2006). Which baseline do we choose?

This question can have significant conservation and ethical implications, especially where extended histories of human occupation have had marked effects on the landscape. China’s recently formed Sanjiangyuan National Nature Reserve, for example, foregrounds the ecological values of the Qinghai-Tibetan Plateau (Li et al., 2012). While reports of controls on river morphology have emphasised the role of temperature gradients in controlling vegetation-stream responses on the Plateau
(Li et al., 2016; Yu et al., 2014), these relationships exist in a context of up to 8800 years of grazing by nomadic Tibetan herders (Miehe et al., 2008, 2009). A focus on conserving the region’s naturalness, made explicit in the Reserve’s name, along with concerns for soil loss and river sedimentation, drove efforts to concentrate herders into fixed settlements after grassland degradation was linked to changes in pastoral regime (Xin, 2008). By idealising a fixed concept of naturalness such efforts not only impact herder livelihoods and neglect cultural values within that landscape, but disrupt ecosystems which have adjusted to a long history of human influence. Even if restoration to pre-human condition was possible for the Qinghai-Tibetan Plateau, surely this could not be straightforwardly regarded as an improvement in condition.

This assumption of an identifiable, inherently good naturalness reflects the shortcomings of overlaying global values onto local issues. Centralising particular visions of apparently untouched nature within a quantifiable river health privileges certain forms of value and precludes others. Carefully constructed at local scales, records of past environments can indicate potential outcomes of rehabilitation measures while acknowledging biophysical context and historical legacy (see Higgs et al., 2014). Narratives of wilderness, however, risk embedding value judgements into the landscape. As Bouleau and Pont (2015) discuss in the context of the Water Framework Directive, designations of apparently natural reference conditions are often a product of preconceptions, politics and pragmatism rather than coherent theoretical foundations. Treating river health as a technical problem, as a question of compromise from a set of innate natural values, can limit the ways freshwater is able to matter. Better to debate these influences in the open, rather than hide them behind false notions of wilderness.

7.4.2 Pets, pests, or pristine?

In practice, despite its focus on naturalness, the paradigm of river health has allowed certain non-‘pristine’ values to persist. Making space in this way requires certain kinds of charisma, however, which only a limited range of causes can draw on. Introduced from the late 1800s, rainbow and brown trout have colonised many waterways in Aotearoa (Walrond, 2008). While they were introduced by European
settlers, and they eat and out-compete an array of native species (McDowall, 2003), trout have become embedded into discourses of naturalness for these rivers. As in North America (e.g. Wheaton et al., 2004), they have become important actors in framing debates on river health. They are integral to habitat-focused rehabilitation, and the protection of salmonid habitat has been instrumental in justifying minimum flow regulations which have maintained internationally significant braided rivers (see Mosley, 1983). They are regularly included in IBIs as positive indicators of river condition (e.g. Joy, 2007), and enjoy specific protection in environmental law.

One might “wonder by what obscure contingencies of lobbying in corridors of power [trout and salmon] came to have this hallowed status of being mentioned by name” in legislation (O’Connor, 1994, p. 254). These charismatic, hard-fighting sport fish have attracted a vocal following of local fishers. They also earn their protection as the basis of a significant tourism industry attracting ‘high-value’ international visitors seeking a pristine backcountry experience (Walrond, 2007). This cultural and economic value led in 1990 to the creation of a public entity, Fish and Game New Zealand, partly devoted to their propagation and protection.

But what of the native freshwater fish species which trout eat and out-compete? Habitat loss, predation and competition has led 75% of these species to be considered at risk (Goodman et al., 2014). Concern for Aotearoa’s mostly small, unobtrusive indigenous fish has gradually risen since the 1960s (see McDowall, 2003), but it has not reached the levels of enthusiasm and influence inspired by trout and salmon. Certain native species – the various migratory galaxiids commonly known as whitebait – have inspired limited conservation efforts by earning value as ingredients in a fritter (Haggerty, 2007). While trout are legally protected and actively restocked, however, whitebait comprise one of the least regulated fisheries in Aotearoa with no catch limits or restrictions on sale.

Trout represent a fundamental paradox of river health. On one hand, with their outspoken public support, their reliance on morphologically dynamic streams and their need for clean water, thriving trout populations provide the perfect ambassadors for the rivers of Aotearoa. They represent important cultural and economic values for sport and food, and provide a popular justification for protecting waterways. On the other hand trout physically dominate an array of native fish species,
contributing to their threatened status (Flecker and Townsend, 1994). Rather than treating this contradiction as a question open for negotiation, however, an emphasis on particular metrics has overlooked the impact of exotic predatory fish on indigenous assemblages (Hermoso and Clavero, 2013). The conflation of trout with natural rivers has made them an apparently unmitigated, common-sense good, limiting recognition of their impact and precluding alternative visions for healthy rivers in Aotearoa. Trout may now belong in many of these waterways (Steer, 2016), but they might also make some space for other species.

7.5 DISCUSSION

River health represented an attempt to change the world through knowing it differently: an intervention in the science, politics and practice of river management. Advocates opened up the question of how freshwater could and should be, hoping to establish more ecologically focused norms for science and management (c.f. Bouleau, 2014; Linton and Budds, 2014). To a significant extent, this normative project was successful: indices for health became central to the repertoire of river management, framing aspirations for freshwater worldwide. Integral to the mainstreaming of river health, however, was the loss of much of its transformative potential. The meaning of river health was pinned down, tied to limited sets of proxies privileging particular understandings and representations of value in freshwater.

The drive towards an apparently objective, quantified river health is consistent with the increasing role of metrics in contemporary western governance. Faith in experts has been replaced by trust in datasets, as fear of bias encourages demands for transparency, replicability and falsifiability (Porter, 1995; Turnhout et al., 2014). As the marketisation of environmental mitigation and rehabilitation continues, effective monitoring, accounting and accountability become increasingly obligatory (Lave, Doyle et al., 2010; Womble and Doyle, 2012). In principle, this shift from authority to observation might be commendable as part of a shift towards democratising governance. As demonstrated by the rise of Rosgen’s NCD framework in spite of substantial scientific criticism, however, political and institutional demands for clear, simple and defensible decision-making can overshadow questions of suitability (Lave, Doyle et al., 2010; Lave, 2014b). While narrow representations
of wellbeing might suit managerial imperatives, they also obscure complexities and contradictions beneath “one number with a reassuring name” (Suter, 1993, p. 1533).

Perhaps the most fundamental property of river health – that it does not exist – has not prevented it being made measurable. At a moment in which river condition had become contested, as dissatisfaction with the outcomes of management interventions grew, an operationalised river health cooled the controversy (c.f. Callon, 1998; Donaldson et al., 2013) by offering an easily articulated, common-sense solution. The incorporation of conventional meanings and values, such as fixed ideals of naturalness and the presence of large predatory fish, eased the acceptance of metrics for integrity as a pragmatic solution to a complicated problem (e.g. Karr, 1999). This quantification of common-sense values facilitated the uptake of river health, but also limited the kinds of change it could bring.

Tadaki and Sinner (2014) describe how attempts to give voice to the diverse ways people value freshwater can unintentionally embed predominant depictions of what matters. Unlike the intervention they describe, which endeavoured to provide a neutral platform for already-existing values, river health was always an explicitly normative project attempting to influence attitudes to freshwater. Like their example, however, the array of potential meanings for river health was constrained by the perceived need to produce actionable understandings of freshwater.

Part of the job of an operationalised river health was to reproduce judgements of what matters, making those aspects of freshwater more visible through quantification. Rather than beginning with a fresh examination of what good condition might mean, however, creating visions of a healthy river was largely approached as a technical challenge. Based on the assumption that human influences could be separated out to model an ecologically pure system, advocates designed sets of reference conditions representing more natural states. Prioritising naturalness in this way overlooked long histories of entanglement between people and landscapes, and failed to acknowledge the subjectivity of what is seen to be natural. Treating river health as something which already existed, to be revealed simply by making it measurable (c.f. Blue and Brierley, 2016), drew a veil over contested ideals and neglected an opportunity to articulate different possibilities for freshwater.
7.5.1 *A reimagined and revitalised river health?*

In 2017 the Whanganui River, in Aotearoa, and the Ganges and Yamuna Rivers, in India, became the first in the world to be granted the legal rights of ‘personhood’ (see Hutchison, 2014). The precise implications for these rivers are unclear, and the politics of ‘rights for nature’ discourses remain unresolved (e.g. Rawson, 2015), but these moves to break down nature-human binaries could offer an opportunity to juxtapose environmental wellbeing alongside ongoing discussions of what it means for *people* to be healthy. This could draw attention to the social context in which understandings of wellbeing are created, and in which questions of desirability are contested (see Canguilhem, 1978; Hull and Robertson, 2000). The reimagined and revitalised river health which could result might provide the basis for a broader re-examination of relationships between people and freshwater.

A reimagined river health might recognise that not everyone agrees on what a healthy river looks like: that ‘good condition’ must be derived through negotiating contested and often contradictory visions. This might challenge the privilege of placeless metrics, recognising that quantitative approaches do not have a monopoly on what matters. It does not simply mean exchanging them for an ad hoc localism, however; rather it might emphasise the broader physical, biological and social contexts of local problems (Brierley et al., 2013; Wilcock, 2013). By understanding the social and physical processes shaping landscapes we might produce a clearer picture of what alternatives are possible. This might incorporate understandings of how landscapes could be without human influence (see e.g. Lyver et al., 2015), but also of other potentially desirable states (see, for example, the nuanced and contested visions for an urban river described by Holifield and Schuelke, 2015). It might also challenge assumptions that the ability to shape the world confers the right to do so, building, for example, on post-colonial and more-than-human geographies (e.g. Thomas, 2015).

A revitalised river health could be place-based and dynamic, recognising the contingent geographic relationships underpinning contemporary condition (see Brierley et al., 2013) and emphasising the processes which continue to shape landscapes (see Beechie et al., 2010). Rather than relying on naturalness, a revitalised river health might be framed as maintaining the character and agency of rivers as
living entities. This begins to open possibilities for an ethics which recognises not just the diverse ways in which people value freshwater, but that the physical world deserves a voice beyond charisma-dependent forms of ‘intrinsic value’. It might make use of metrics for understanding changes over time and place, but it would also recognise that health cannot be encompassed or addressed through limited sets of generic variables. It might mean renegotiating what matters, recognising less easily articulated meanings and values. A revitalised river health might build on, and nurture, scientific understandings of physical-ecological relationships to provide a firmer foundation for democratic, place-specific interventions in freshwater.

7.6 CONCLUSION

The concept of river health arose at a time when the assumptions underpinning conservation efforts were increasingly contested. Efforts to fence nature off, to preserve pristine wilderness, were being superseded by attempts to more actively develop sustainable relationships between people and the physical environment beyond a dualistic emphasis on either utilisation or preservation (O’Riordan, 2004; O’Riordan, 1999). As narratives of the Anthropocene take hold (Castree, 2014), and ideals of unmodified ecosystems seem increasingly outdated, functionalist approaches potentially provide a way of looking forward rather than focussing on ‘paradise lost’ (Dufour and Piégay, 2009; Robbins and Moore, 2013; Wohl, 2013b).

The concept of river health represented this reappraisal of environmental values and norms, embodying a potentially broadened understanding of good condition as a basis for intervention in freshwater. Yet, while the multifaceted and contestable connotations of health opened up possibilities for destabilising and renegotiating the ideals of river management, broader and more dynamic accounts of its meaning were soon flattened-down into common-sense, quantifiable understandings of wellbeing. Debate in ecology continues over the relative merit of functionalist versus compositionalist norms (see Callicott et al., 1999; Hobbs et al., 2009), but remains primarily focused on providing ostensibly objective indicators with which to control environmental outcomes (e.g. Costanza, 2012). It might be time for
a broader, geographical re-examination of relationships possible between people and freshwater.
Part V

WHERE TO?
Understanding contemporary landscapes requires grappling with elements and processes which are both deeply social and undeniably material. Geomorphic knowledge must therefore transgress boundaries between the human and the nonhuman, as well as between scientific knowledge and management practice. This thesis works between these spaces to closely examine a set of key challenges facing predominant approaches to understanding landscape: the limitations of focusing on small-scale controls without regard for broader context (Part II), the easily neglected role of people and places in the production of knowledge about the world (Part III), and the risks associated with creating and applying simplistic notions of what is valuable (Part IV).

These challenges present a microcosm of broader debates which are playing out across a range of disciplines, institutions and communities regarding how we understand and approach not just environmental issues, but also more fundamental relationships between science and society. As scientific (and pseudo-scientific) knowledge becomes further embedded in regional and global systems of governance, and as scientific authority to explain the world is increasingly disputed in ways it has not been before, these methodological and ethical questions become increasingly urgent.

In essence, these debates centre around a modernist desire to generate and refine knowledge about the world with the aim, implicit or explicit, of making it a better place. This desire, which in itself might be a perfectly reasonable one, raises two key questions: to what extent can knowledge produced in one context be generalised while maintaining its integrity, and how do we decide what a better world might look like? Physical geographers have long been concerned with the first question, with regionalists and Davisians in particular arguing against ‘generic’ process-based understandings of landscape in favour of approaches which foreground the physical history of particular places (see Chapter 1). The second
question, however, offers a more explicitly political challenge: even given perfect understanding and control over the world, on what basis might people decide how it should be?

While these two questions are on the surface rather different, one a question for science and another for politics, they overflow into each other. Beneath claims of irreducible uncertainty in landscapes, for example, lies an implicit political position not just that this is how landscapes are, but that it is how they should be: that their unpredictability, or wildness as Cronon (1996) puts it, is integral to their value. This sense that individuality and mercuriality are in themselves important features which should be embraced, rather than suppressed, has motivated various attempts to assemble facts which emphasise the limitations of ‘reductionist’ understandings of landscape (e.g. Harrison, 2001; Phillips, 2007, 2010). Yet, as Massey (2006) points out, we cannot assume that our favoured reading of the facts will always prevail: simply demonstrating the importance of physical history to the existing characteristics of particular places is not, in itself, sufficient to produce a progressive politics for freshwater. Instead, then, this thesis addresses both the practice and the politics of geomorphology for river management to advance a vision for a progressive, geographical geomorphology.

After an introduction outlining past debates over the role of historical context in geomorphology, Part II of this thesis examines the headwaters of the Yellow River through the lens of geodiversity. Highlighting the importance of the Qinghai-Tibetan Plateau’s historical development in influencing the river’s contemporary form, this section presents a positive vision for a river science which recognises the value of the diverse landscapes that have been produced by this history. It asserts that management of the Yellow River source zone should take greater account of the particular characteristics of the rivers which are there, rather than prioritising preconceived notions of what those rivers should look like. It asserts that facilitating this requires a different approach to river science in the region: one which emphasises the broad-scale morphological controls on these landscapes, understanding them as places with both pasts and futures. In doing so it broadens the concept of geodiversity beyond simply preserving particular ‘natural’ features of the landscape, acknowledging that these features are the product of long histori-
ies of entangled physical and social processes which – along with their potential futures – might be valuable in their own right.

Part III of this thesis more explicitly addresses the politics of geomorphic knowledge, directing the growing momentum behind ‘critical physical geography’ towards a constructive discussion of the social and scientific underpinnings of geomorphic research and practice. It argues that the models we create of the world, and the measures we choose to incorporate within them, reflect our sense of what matters. This sense of what matters is the product of past scientific endeavours, but also of the values we bring to our work. This thesis therefore suggests that through a closer examination of what we choose to measure, we might learn something about ourselves. It does not suggest specific measures which should or should not be used, as these will vary with circumstance. Rather, it encourages careful, open consideration of the measures we choose to measure the physical environment, especially in the context of management applications, as these choices will shape not only environmental outcomes, but also social ones.

The questions raised in Part III are relevant to any discipline which makes claims about the natural world as the basis for intervening in it. They are most pertinent, however, for subjects in which effect sizes are both relatively weak, and are difficult to isolate from an array of potential environmental influences. Geomorphologists have at times argued for the particular complexity of landscapes, but these conditions are perhaps most apparent in the quantitative social sciences: psychology, for example, has long grappled with the misuse of data to make deterministic claims about human capacity and behaviour (see e.g. Gould, 1996), false objectivity in the diagnosis of mental illness embedding sexism and homophobia (see Lafrance and McKenzie-Mohr, 2013; Marecek and Gavey, 2013), and poor statistical practices affected by confirmation bias (Wagenmakers et al., 2011) producing results which do not replicate (Open Science Collaboration, 2015). While these concerns have only entered the mainstream relatively recently, and the response to them has primarily comprised efforts to improve methodological and statistical rigour, critical psychologists have been critical of these practices, and the forms of common sense they embed, for some time (e.g. Henriques et al., 1998).

It is one thing to claim that choice of management targets influences environmental outcomes (e.g. Bouleau, 2014), with resulting impacts on the people who
live in and interact with those places. It is more challenging to directly link these temporally diffuse and highly contextual effects to injustices caused by geomorphic practice. The relatively small population of researchers motivated to point out injustices from within geomorphology can also make it difficult to point to specific instances of the problems intimated in Part III. Increasing evidence, however, suggests that not only are women and people of colour underrepresented in the earth and environmental sciences, but that those who do persist in the field continue to face ‘chilly climates’ which inhibit participation (e.g. King et al., 2018). It is tempting to assume that increased diversity in the field will produce a discipline which is more sensitive and more just, both internally and in its interactions with the world. Yet, while a more diverse field is desirable in itself, it is only through recognising the values and subjectivities embedded within our work, acknowledging them for what they are, that the questions raised by this thesis might be addressed.

Part IV of this thesis presents an example of how values can be expressed through measurement, moving beyond geomorphology to explore the trajectory of an attempt to advance a different politics for freshwater. It recounts the rise of river health as a well-intended concept, following its transition from metaphor to metric. It argues that the process of quantifying an otherwise intangible concept closed-off the question of what health means, embedding assumptions of what is desirable in river management. These assumptions tend to reflect ‘common sense’ accounts of what is valuable, reproducing a paradoxical desire for rivers which are natural, stable, and teeming with introduced fish.

By challenging these accounts, and by drawing attention to these assumptions, Part IV of the thesis provides a starting point for a broader public and academic discussion of what a healthy river might look like for particular places, and for particular people. For rivers in Aotearoa such a discussion must be substantially driven by Indigenous Māori understandings of environmental wellbeing (see Hikuroa, 2017; Ruru, 2018). Mātauranga Māori approaches to wai ora have much in common with the broadest understandings of river health, conceptualising rivers as entire beings capable of experiencing variable states and emphasising connections between people and freshwater rather than attempting to separate them (Brierley et al., In Press; Hikuroa et al., In Press). Efforts to coproduce knowledge as the basis for interacting with the Waipā River show particular promise, with the tani-
wha Waiwaia explicitly identified as a focal point for management efforts, although there remains some way to go in reconciling western and Indigenous knowledge traditions in the context of the catchment (Parsons et al., 2017).

8.0.1 New directions

Attempts to understand relationships between people and the physical environment understandably tend to focus on the negative impacts of human activity. Increasingly, though, efforts to mitigate and mend environmental damage attract substantial public and private investment. The Anthropocene is not simply a story of environmental devastation: it is also one of human goals, values and aspirations. As humans become the primary drivers of global change, it is important to understand not just stories of environmental exploitation, but how visions of how the world should be are created are negotiated, and how they manifest. These political questions have been the domain of human geographers, political ecologists and science and technology studies scholars for some time, but, as the earth sciences drift away from geography, it seems increasingly difficult for insights from these disciplines to influence our understanding of the earth’s surface.

It can be tempting to blame this on the environmental scientists themselves, casting them as agents in a modernist project of dominance over the natural world who, at best, refuse to acknowledge their complicity in producing technologies of control and exploitation. This approach, however, may be neither very helpful nor particularly accurate. Many environmental scientists do, in fact, recognise the politics of their work, actively intervening through it to shape the values and motivations which underpin and impel scientific inquiry. This thesis, therefore, in part represents a call for physical geographers concerned with the relationships between people and the physical environment to attend to the role of contemporary research practices in maintaining those relations. It also, however, demonstrates that efforts to reconfigure the science of the environment from within – what Tadaki (2016) describes as a ‘critical through’ mode of research – are already underway.

These activities take various forms, but three particular expressions of political action through environmental science can be identified from the examples presen-
ted in this thesis. The first entails efforts to actively shape scientific agendas: to influence the kinds of knowledge which are produced about the earth’s surface. An example of this can be seen through the history of ‘place’ in geomorphology, and will be further discussed later in this chapter. The second, represented here by the concept of geodiversity, involves the creation of different knowledge about the world: striving to draw attention to the presence, and in this case the uniqueness, of particular aspects of the landscape or the living things in it in the hope of influencing management priorities. The third form of political action puts environmental knowledge to work, creating tools intended to be used to influence the environment directly through prioritising management efforts and measuring their effects. Examples of such technologies addressed by this thesis include the attempts to operationalise river health described in Chapter 7, as well as river classification schemes designed to guide management efforts (e.g. Brierley and Fryirs, 2005; Rosgen, 1994).

These forms of scientific activism represent important instances of political action within the scientific community, as well as having substantial potential for impact beyond it. As the example of river health in this thesis demonstrates (Chapter 7), however, they are also products of their scientific, social and institutional contexts. The ‘better’ worlds they imagine reflect particular points of view, and the technologies created in an attempt to realise these visions tend to fit within, rather than challenge, existing logics of action and accountability (see e.g. Turnhout et al., 2014). Regardless, as attention increasingly turns towards the social dynamics of the environmental sciences (e.g. Wesselink et al., 2017), it is important to recognise that these might be product of a politics which is hopeful rather than hidden. Perhaps an opportunity remains to bridge the space between the critical social sciences and the environmental sciences by focusing on the visions and values which motivate attempts to understand and intervene in the physical world.

8.1 RECONSIDERING CRITIQUE

Or should we rather bring the sword of criticism to criticism itself and do a bit of soul searching here: what were we really after when we
were so intent on showing the social construction of scientific facts?
(Latour, 2004, p. 227)

This thesis began by laying out an agenda for a geomorphology more explicitly grounded in a sense of place and history. In doing so, it has further developed a political project which has been ongoing in physical geography for some time. This emphasis on the local and the specific began as a rather conservative response from regionalist geographers to a rapidly changing research paradigm (see Chapter 1). It has, however, been taken up as a progressive intervention against a generalising, contempocentric emphasis on process in geomorphology: recognising that it may be normal for landscapes to change over time, and that difference can itself be valuable (e.g. Kennedy, 1992). This call to place also reflects a broader dissatisfaction with the perceived failures of contemporary approaches to scientific endeavour; or, more precisely, with the silencing, depoliticising and controlling impact that claims to ‘knowing’ can have. An emphasis on the particularity of things is a call to slow down, to reassess what we know, what we do not, and who gets to know it.

Yet it is easier to point out the shaky foundations of ideas we disagree with, to express concern for their momentum, than to acknowledge the politics of our own. Massey (2006, p. 36) notes that claims “about the producedness of science and of our understandings of the physical world [are] in practice most often mobilized in criticism of those readings which, for some reason or another, we reject”. Critique of science and scientism has long been owned by the left, in geography at least since Harvey’s (1974; 1984) calls to arms against ostensibly apolitical, repressive knowledge. Notions of knowledge as socially constructed have created spaces for heterogeneous accounts of otherwise marginalised ideals, ideas and identities to flourish (see e.g. Bracken and Oughton, 2013; Demeritt, 2002; Gavey, 1989). Increasingly, however, it seems that the exclusive use of these rhetorical tools cannot be taken for granted. They have, for example, provided the tools of doubt, uncertainty and accusations of bias with which climate science has been cynically undermined (Latour, 2004).

In 2002, the then Secretary of Defense of the United States of America Donald Rumsfeld infamously justified the imminent invasion of Iraq by emphasising the difference between ‘known unknowns’ and ‘unknown unknowns’ (Morris, 2014).
In 2011 John Key, then Prime Minister of New Zealand, claimed that the country’s waterways were “100 percent pure”, stating that an outspoken, critical freshwater scientist was “one academic, and like lawyers, I can provide you with another one that will give you a counterview” (Sackur, 2011, 11:20). These incidents echo the language, if not the spirit, of critique. Rumsfeld’s vaguely postmodernist ‘unknowns’ seem disconcertingly familiar to those accustomed to the language of postnormal science (c.f. Funtowicz and Ravetz, 1993; Funtowicz and Ravetz, 1992), and Key might simply have been acknowledging the existence of multiple, contested ways of knowing the world.

This potential for critique to be co-opted demands a note of caution as we advocate for particular concepts or ways of thinking which fulfil our immediate purposes. Is it acceptable to advance critiques of contemporary science in order to achieve a worthy social goal, for example, if those same arguments might then be used to deny climate change? In response to this concern, this final chapter therefore turns the lens back towards critiques of ‘placelessness’, investigating the implications of emphasising the individuality of landforms and exploring the potential consequences of deploying somewhat essentialist notions of uncertainty. It concludes by critically considering the politics of place as an ethical basis for intervening in the landscape.

8.1.1 Methodology, uncertainty and the politics of place

Throughout the history of geography, its practitioners have been variously perceived as very scientific, pseudoscientific, or antiscientific.

(Bauer, 1996, p. 384)

It is regularly declared that geomorphologists view theoretical questions with a degree of ambivalence, or even hostility (e.g. Rhoads and Thorn, 1994, 1996c; Slaymaker, 2009). Despite this supposed aversion, commentary and debate regularly resurface regarding the role of theory, scale and place in geomorphic enquiry (see Brierley et al., 2013; Lane and Richards, 1997; Rhoads and Thorn, 1993; Richards, 1994; Schumm and Lichty, 1965, to name only a few). While these discussions might not take an explicitly philosophical tone, and their influence on the actual practice
of geomorphic knowledge production can be difficult to ascertain, they represent a substantial history of methodological reflection.

Assertions that geomorphological research should be concerned with the underlying physics of landscape change, rather than the specifics of place and time, were central to the rise of quantitative-dynamic geomorphology (see Chapters 1 and 2). For some, this represented the long-awaited arrival of science to the study of the earth’s surface (e.g. Strahler, 1950). For others, this emphasis on ‘timeless’ geomorphology smacked of ‘physics envy’ and an indifference to the character and histories of particular places (see Massey, 1999). At first glance, these positions seem irreconcilable: “The notion of dynamic as employed by Strahler clearly is antithetical to the Davisian concept of successional development of landforms over time, or, for that matter, to un-successional historical changes in landscape morphology over time” (Rhoads, 2006, p. 15).

Fundamentally, many of these debates concern the extent to which geomorphology is, or should be, geographical. Arguments broadly fall into one of two visions for the subject: a discipline modelled on physics which aims to minimise circumstance through conceptual or experimental means in the pursuit of more general relationships, or a geographical geomorphology which foregrounds the role of context and contingency in landscape development (see e.g. Bauer, 1996). These positions are regularly justified in terms of a range of binary associations which serve to emphasise differences between the approaches (see Table 8.1).

As can be seen in debates over the role of place and time in geomorphology (see Part I), these dichotomies have been regularly deployed by both ‘sides’. Quantitative geomorphologies might be accused of ignoring history, of naïve positivism, of an over-reliance on theory (Baker and Twidale, 1991), and associated with a tendency to discipline, control and colonise the landscape (Kennedy, 1979; Suchet, 2002). Qualitative geomorphologies might be criticised as the anti-scientific and exceptionalist work of hobbyists (Schaefer, 1953; Strahler, 1950), or lauded as emancipatory frameworks recognising already-existing subjectivities and power relations (see Wilcock et al., 2013).

Digging deeper into these dichotomies, however, begins to uncover a number of contradictions which make these characterisations seem more like caricatures. Gilbert and Davis had much more in common than might be generally acknowledged
Table 8.1: Some of the binary positions commonly deployed in debates regarding the application of geographical approaches to geomorphology, with exemplary or explanatory references. Note that neither I nor those cited here necessarily condone these positions.

<table>
<thead>
<tr>
<th>Scientific</th>
<th>Unscientific</th>
<th>Rhoads and Thorn, 1996b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative</td>
<td>Qualitative</td>
<td>Strahler, 1950, 1952</td>
</tr>
<tr>
<td>Placeless</td>
<td>Place-based</td>
<td>Brierley et al., 2013; Preston et al., 2011</td>
</tr>
<tr>
<td>Timeless</td>
<td>Time-bound</td>
<td>Strahler, 1952</td>
</tr>
<tr>
<td>Dynamic</td>
<td>Historical</td>
<td>Strahler, 1950, 1952</td>
</tr>
<tr>
<td>Geological</td>
<td>Geographical</td>
<td>Bauer, 1996</td>
</tr>
<tr>
<td>Process</td>
<td>Form</td>
<td>Lane and Richards, 1997</td>
</tr>
<tr>
<td>Gilbert</td>
<td>Davis</td>
<td>Sack, 1992</td>
</tr>
<tr>
<td>Positivist</td>
<td>Realist</td>
<td>Richards, 1996</td>
</tr>
<tr>
<td>Theoretical</td>
<td>Empirical</td>
<td>Baker and Twidale, 1991; Burton, 1963</td>
</tr>
<tr>
<td>Open systems</td>
<td>Closed systems</td>
<td>Chorley, 1962</td>
</tr>
<tr>
<td>Equilibrium</td>
<td>Non-equilibrium</td>
<td>Bracken and Wainwright, 2006; Phillips, 1992</td>
</tr>
<tr>
<td>Large-N</td>
<td>Small-N</td>
<td>Richards, 1996</td>
</tr>
<tr>
<td>Deterministic</td>
<td>Contingent</td>
<td>Phillips, 2007</td>
</tr>
<tr>
<td>Modernist</td>
<td>Post-modernist</td>
<td>Bracken and Wainwright, 2006; Massey, 1999</td>
</tr>
<tr>
<td>Linear</td>
<td>Non-linear</td>
<td>Lane and Richards, 1997; Phillips, 2003</td>
</tr>
<tr>
<td>Reductionist</td>
<td>Holistic</td>
<td>Harrison, 2001</td>
</tr>
<tr>
<td>Knowable</td>
<td>Uncertain</td>
<td>Phillips, 1994</td>
</tr>
<tr>
<td>Hubristic</td>
<td>Precautionary</td>
<td>Holling and Meffe, 1996; MacGarvin, 1994</td>
</tr>
<tr>
<td>Objective</td>
<td>Subjective</td>
<td>Blue and Brierley, 2016</td>
</tr>
<tr>
<td>Colonising</td>
<td>Decolonising</td>
<td>Suchet, 2002</td>
</tr>
</tbody>
</table>
(Sack, 1992). Davis was accused of ignoring reality in the pursuit of conceptual elegance, just like the quantitative theorists who would come later (compare Baker and Twidale, 1991; Baulig, 1950). Non-linearity and chaos might hint at disobedience, yet refer to deterministic, albeit sensitive, systems. These approaches are also borrowed from other fields, most notably physics: not a discipline known for its aversion to reductionism. While qualitative methods might be more amenable to integrating Indigenous understandings of landscape (e.g. Wilcock et al., 2013), the men to whom these approaches are attributed were not paragons of liberal thought, regularly espousing the environmental determinism of their time (Peet, 1985).

In practice, these positions reflect rhetorical extremes rather than the majority of research actually undertaken. Much geomorphological research does not operate at the level of individual particles and fluid dynamics, and understanding landscape change requires explicitly addressing the time-integrated interactions between form and process over a range of spatial and temporal scales (Lane and Richards, 1997). Isolating these dynamics, breaking them down to their component parts to focus on processes of sediment erosion, transport and deposition is fundamental to most geomorphological knowledge today, but few would deny the need to understand the circumstances within which these dynamics operate (see e.g. Dietrich et al., 2003). Perhaps in recognition of this disconnect between rhetoric and practice, substantial effort has gone into providing integrative philosophical justification for the practical realities of geomorphic research (see e.g. Bauer, 1996; Rhoads and Thorn, 1996b; Richards and Clifford, 2011).

8.1.2 Reductionism and place

Despite the pragmatic, integrative tone of these methodological discussions, tension persists between the search for generalised understandings of the world and the need to attend closely to particular places. This strain is felt most intensely at the intersections of science and management, where perceived failures of interventionist practices highlight the need for understandings of landscape more sensitive to their context (see Part II). While debates over the geographical nature of geomorphology have continued since at least the middle of last century (Bryan, 1950; Russell, 1949), they took on renewed significance as people increasingly intervened in
landscapes intentionally to protect or ‘improve’ them (see e.g. Downs and Gregory, 2004). The increased urgency of environmental problems, coinciding with broader challenges to scientific knowledge associated with Kuhn (e.g. 1970) and the rise of postmodernism, produced a number of critiques of ‘reductionist’ geomorphology and attempts to offer alternative ways of understanding landscape.

Reductionism has several meanings, but is most often used as a pejorative term deployed to describe approaches to enquiry which a writer feels oversimplify a phenomena of interest. The criticism implicit in Barnes’ (2009, p. 626) fairly typical definition exemplifies this: “The methodological presumption that complex phenomena or events can be explained by their reduction to simpler, more fundamental entities”. Of course, all attempts to understand the world in some sense fit this definition: even the broadest, most inclusive representations must exclude information seen as extraneous. Generally, however, reductionism describes the systematic, often quantitative, paring-down of contextual information to uncover general laws. This might be attempted through working at smaller scales to understand fundamental processes, or by isolating generalised associations and causal mechanisms across multiple, aggregated phenomena.

Critiques of reductionism essentially argue that details matter. This is not a statement of scale per se, as these details can exist anywhere from the broadest historical influences on valley evolution (see Part II), to the mechanics of hydraulics and riparian vegetation in river bank stability (e.g. Simon and Collison, 2002). Rather, it is the assertion that landscapes are the product of the unlikely coincidence of a certain set of circumstances at a range of scales, and that these circumstances introduce a level of unpredictability into understandings of any particular landscape (Phillips, 2007).

The case for attending to this context has been advanced through a range of means. While some researchers focus on the potential of historically based approaches to landscape change (Baker and Twidale, 1991); more recently others have attempted to develop and justify frameworks for more holistic ways of producing knowledge about the world. Asserting that complete mechanistic or functional explanations of ‘complex’ systems are unrealistic (Funtowicz and Ravetz, 1994), researchers working along these lines attempt to provide the conceptual tools with which to approach the complications of the earth’s surface (see Murray
et al., 2009). Concepts such as emergence (Harrison, 2001; Harrison et al., 2006), non-linearity (Phillips, 2003), chaos and self-organisation (Phillips, 1999, 2006) have been used to highlight the limitations of normative models of landscape development (see, for example, the discussion of pseudo-equilibrium by Phillips, 2011). While these approaches might be understood as opposing reductionist geomorphology, they do not preclude the search for general laws. An appreciation of context does, however, suggest that any such laws will, in practice, be highly dependent on the particular conditions occurring at a particular place at a particular time (see Richards and Clifford, 2011). The primacy of context in these accounts calls attention to the limitations of deterministic understandings of landscape, often expressed in terms of uncertainty.

8.1.3 The nature of uncertainty

In arguing for a geographic geomorphology it can be tempting to claim that landscapes are fundamentally uncertain. Harrison (2001, p. 336), for example, argues for the need “to acknowledge unknowability and the irreducible uncertainty in landscape evolution”, and Baker and Twidale (1991, p. 83) point to the “discovery of absolute uncertainty of explanation by modern quantum mechanics” in their call for wariness of universal laws. These assertions that complete explanations from physical principles are impossible have significant implications, implying that there is little progress to be made through exploring the mechanisms of landscape change, and that research should instead focus on the empirical realities of particular places. There is, however, a difference between things we do not know and things we cannot know.

Sources of uncertainty can be helpfully understood as either epistemic or ontic. Epistemic uncertainty refers to things we do not know: failures of prediction which are not necessarily the product of fundamental dynamics, but might simply be caused by a lack of information (after Walker et al., 2003). Ontic uncertainty, on the other hand, relates to things we cannot know: fundamental randomness which would persist even with perfect knowledge of a system. This distinction partly depends on how systems of interest are defined (see Lane, 2001), as phenomena which seem to be fundamentally unpredictable at one scale might simply result from a
lack of knowledge at another, but these claims to uncertainty have significantly different implications for how we approach knowing the world.

For those primarily concerned with the implications of reductionist approaches to environmental decision-making, what matters are the extant limitations in our knowledge about the world. The source of this uncertainty, whether a result of inherent variability in landscapes or simply an inability to predict change, is largely irrelevant. Neither do these arguments require predicting the future of geomorphic knowledge: the presence of existing uncertainty of outcome is sufficient to justify cautious management practices (see Clark, 2002; Kriebel et al., 2001). If relying on uncertainty for justification, however, critiques of reductionist approaches to research must demonstrate not just that knowledge of the world is unreliable now, but that substantial uncertainty will persist regardless of efforts to resolve it. Absent evidence of this, epistemic uncertainty presents opportunities for research rather than a reason to limit efforts at understanding.

Despite these very different implications, critiques of reductionism often blur the line between epistemic and ontic uncertainty. Wooldridge (1958, p. 32), anticipating contemporary notions of complexity, asserted that “the direct attack by mathematical methods would seem to offer very limited chances of success. Dealing as we inevitably are with infinitely variable mixtures of solids, liquids and gases, it is manifest that the parameters in our imagined equations will not be constant, but themselves unmanageably variable.” Almost fifty years later, Phillips (2007, p. 167), describes the “perfect landscape... [as] only one possible outcome – albeit strongly constrained by applicable laws – of a given set of processes and boundary conditions, which is determined by a specific, perhaps irreproducible set of contingencies.”

These somewhat ambiguous statements perhaps fall into a third position: that successful prediction of relationships between process and form might be possible in principle, given perfect information, but that this level of insight is not practically attainable for real-world examples in the foreseeable future. This posture, which could be described as ‘intractable epistemic uncertainty’, is weaker but more defensible than assertions of ontic uncertainty. It makes no claim to fundamental unpredictability, and does not preclude the search for universal laws. Rather, it relies on the assertion that differences in ‘initial conditions’ complicate generic
understandings of landscape change in ways which are, at least for now, unresolvable (see Phillips, 2007).

8.1.4 Uncertainty and place

But what if yesterday’s intractable problem might become tomorrow’s treatable inconvenience? Arguing that the frontiers of geomorphological research exist at the largest and the smallest scales, increasingly the domains of geophysicists and Earth scientists respectively, Church (2005) suggests that the interpretive and predictive power of approaches once labelled ‘placeless’ threatens to overshadow – or perhaps already has – those which emphasise history and geography (see also Summerfield, 2005a,b). Church’s concern is primarily pedagogical, suggesting that geography no longer provides the skills and techniques required for contemporary geomorphological research. This has been a familiar trope, at least since Strahler (1950, p. 210) stated “It is difficult enough to find geology students whose aptitudes and interests enable them to follow [a quantitative-dynamic] program; it seems almost out of the question that this program can be carried on by geographers.” But Church’s argument presents a far more fundamental challenge to geographical geomorphology than this focus on pedagogy implies. As technological developments facilitate improved measurement and modelling of the earth’s surface, bringing an increasing ability to capture landscape configuration and behaviour, conceptions of place founded on epistemic uncertainty risk losing their meaning.

The rapidly increasing availability of empirical data describing the earth’s surface, and the growing ability to use that data, has the potential to redefine our understandings of landscape. Traditionally, remotely sensed data has been limited to detecting relatively broad patterns in landscape development, has been prohibitively expensive for covering large areas in detail, or has suffered from disconnections between remotely sensed and field-based data (Mertes, 2002). Increasingly, however, a combination of improved resolution, decreased cost and new technologies bring the ability to capture extensive and intensive information about landscapes (Carbonneau and Piégay, 2012). In particular, field-based technologies such as unmanned aerial systems both expand the spatial extent of traditional field-based surveying methods and potentially offer greater topographical resolution
and accuracy for geomorphic and hydraulic surveys (e.g. Woodget et al., 2015, 2016).

Carbonneau and colleagues (2012) argue that the increasingly comprehensive, multi-scalar nature of these datasets brings a paradigm shift in the way riverscapes can be understood. Alongside this ability to collect highly detailed and spatially extensive data, developments in spatial analysis promise a growing ability to examine relationships among these data (e.g. Cheung et al., 2016). While these techniques cannot in themselves identify the processes responsible for change, they can point to the existence of processes and relations which might otherwise have gone unnoticed.

The influences of context and history present very real challenges to understanding landscapes: the physical and ecological significance of valley setting, for example (e.g. Fryirs and Brierley, 2010; Hynes, 1975), and the complicated cross-scalar relations between form and process (e.g. Lane and Richards, 1997). Notions of place can provide useful analytical and pedagogical tools to aid in understanding these challenges (e.g. Brierley et al., 2013; Phillips, 2017). They can also offer pertinent reminders of the limitations and risks of management interventions, drawing attention to ‘local’ factors which might easily be overlooked by generalised approaches to river management (Brierley and Fryirs, 2009, 2016). But if physical associations previously understood as contextual or contingent can increasingly be captured quantitatively, do they represent problems of place, or of spatial analysis?

I raise this question not to argue that a geomorphology which emphasises place is no longer relevant, but in an attempt to refocus it. Attempting to justify a place-based geomorphology through the language of uncertainty and contingency, by framing place purely in terms of the biophysical, neglects an opportunity to ask, and to articulate, what place is for.

8.1.5 The ambivalent politics of place

Physical geography’s concern with physical, tangible aspects of the world imbues it with a certain common-sense resistance to the explicitly political. After all, it might be unwise to challenge the implications of Newtonian physics while relying
on those same laws to stay upright in a stream (see Lane, 2001). Instead, challenges to research philosophy and practice are typically framed in terms of the relationship between theory and observation (e.g. Baker and Twidale, 1991), spurred on by advances in technological capability. But this emphasis on the matter-of-fact can obscure not only the politics underpinning practices of knowledge production in physical geography (see Part III), but also the politics of efforts to change them.

In the context of globalisation, Massey (2005, p. 5) notes, “a ‘retreat to place’ represents a protective pulling-up of drawbridges and a building of walls against the new invasions.” Could place be similarly understood as a reactionary concept, fostering parochial hostility to landscape change? Claims of contingency might be intended as a caution against the ‘sin of hubris’ (MacGarvin, 1994), countering urges to control the physical environment, but do they represent a conservative return to idealised notions of wilderness as untouched, and untouchable (c.f. Cronon, 1996)? Biophysical notions of place which look to how the world was to guide how it should be (e.g. Fryirs and Brierley, 2009; Wohl, 2011; see also Part IV of this thesis) certainly could be read as somewhat essentialist and potentially reactionary moorings for visions of how the world should be.

Yet for Kennedy, focussing on history and place is a progressive act, countering an emphasis on short-term processes which reframes “perfectly straightforward high-magnitude/low-frequency events” as catastrophic disturbances to an apparently natural equilibrium (Kennedy, 1992, p. 248). This “conservative focus on the significance of the present as the desirable status quo” encourages, Kennedy (1992, p. 247) argues, the privileging of the contemporary over the past. By providing reminders of the role of historical events – large and small, frequent and infrequent – in constructing existing landscapes, rather than destroying them, this vision of place is open to a range of possible futures.

If place can cut both ways, perhaps what differentiates progressive notions of place is their intent as antidotes to intolerance of change (see Holling and Meffe, 1996): as indicators of past and therefore potential variability (e.g. Fryirs and Brierley, 2009; Wohl, 2011), rather than – and indeed in opposition to – fixed assertions of what should be. But while this openness to variability might be welcome, it represents one potential reading of a particular set of facts rather than an inherent property of place. What is to prevent a place-based geomorphology (see Brierley
et al., 2013) being (mis)used as a way of ending conversations, rather than beginning them? The risk, perhaps, is that understandings of place become just another way of producing common-sense statements about how the world should be: a way of closing down possibilities, rather than opening them up.

8.2 CONCLUDING REFLECTIONS: A PROGRESSIVE GEOGRAPHICAL GEOMORPHOLOGY?

The prescription of methodology by a practising geomorphologist is both an audacity and a disfigurement... It requires a strong conviction that there is indeed one best way to approach the study of landforms. I offer, in contrast, no prescription here, preferring the anarchical vision of the skeptic. (Sherman, 1999, p. 694)

On one hand, debates over the role of place in geomorphology have changed drastically since the initial, defensive reactions to systems geomorphology and the quantitative revolution (see Part I). In particular, efforts by geographical geomorphologists through the 1990s drew attention to the importance of landscape configuration in mediating responses to process (e.g. Lane and Richards, 1997), gathering mainstream recognition of the need for explanations of landscape change to reference spatial and temporal circumstance. On the other hand, many of the concerns motivating critiques of 'placeless' geomorphology as the basis of river management remain strikingly similar to those of the past.

Frustrated by the perceived failings of management efforts, whether a tendency to overstate cause-and-effect relations or neglect the values of local people, it can be tempting to turn to place as a panacea. To some extent that is where this thesis began, with Part II employing place as a means of diversifying perceptions of value on the riverscapes of the Yellow River’s headwaters. By foregrounding physical context and the role of history, notions of place potentially play an important role in informing management interventions sensitive to their surroundings.

As this thesis has demonstrated, many of the strongest arguments for place centre around the application of geomorphic knowledge to intervening in the physical world. Place-based approaches to landscape provide an important reminder that our models of the world do not necessarily represent how it should be: that riverscapes, for example, can represent values and meanings which might easily
be overlooked in the search for generalised, quantitative understandings of landscape (Brierley et al., 2013). Instead of managing landscapes for pre-determined, generic priorities (see Part IV), place offers an emphasis on maintaining a diverse array of geomorphic processes and forms across multiple scales.

At the same time, however, foregrounding the individuality of place might be viewed as leading toward an exceptionalist dead-end that threatens attempts to better understand the physical world (see e.g. Schaefer, 1953). A focus on the individuality of landscapes denies the possibility of experimental replication, constraining the ability to make, and to test, claims about the world (Montgomery, 1991). It is, therefore, reasonable that a discipline which understands itself as scientific might prioritise the development of formal tools and methods for testing generalised propositions using case studies, rather than on explaining the case studies themselves (see Richards, 1996).

Arguing that geographical geomorphology has become “marooned on a passive margin”, its emphasis on place rendered obsolete by the quantitative, law-seeking Earth sciences, Church (2005, p. 129) anticipates one possible future for the subject as, essentially, an applied science. This prescription comes from a place of perceived weakness: an alleged failure to keep up with the ‘cutting edge’ of scientific progress. It nevertheless presents a substantial opportunity to take a fresh look at the intersections between people and landscape: to explore the relationship between the scientific and the political, the unique and the general, towards an ethical basis for intervening in the landscape.

In this thesis I have attempted to seize this opportunity, illuminating and actively engaging with the quiet politics of environmental knowledge production and decision-making in geomorphology. Presenting three interventions employing and exploring the notion of place, I have sought to trouble essentialist claims to nature as a basis for management, moving towards more inclusive approaches which foreground the relationships between people and landscape. In doing so I have built on efforts to recognise and understand the role of people in shaping contemporary landscapes (Ashmore, 2015), while diving deeper into the philosophies underpinning these interventions. I have recognised the need to deal with complexity and uncertainty in the short term (Funtowicz and Ravetz, 1993), while also acknowledging that these concepts might be deployed to excuse inaction and limit
future attempts at explanation. I have learnt from critical physical geography’s emphasis on the material applications of political ecology and science and technology studies (Lave et al., 2014), while recognising the value of scientific approaches to knowing the world.

My efforts could potentially be read in two ways. They could be understood as an attempt to separate out the objective from the subjective: to take the politics out of geomorphology, and the geomorphology out of politics. They could also, however, be perceived as aiming to politicise geomorphology and to turn an apparently objective science into a merely descriptive cultural pursuit (c.f. Strahler, 1950). In the eyes of some, the former might be unrealistic; for others, the latter might be inexcusable. Perhaps the promise of a progressive geographical geomorphology lies in an openness to learning from both of these critiques, helping us learn to “live in a world crafted by people but always beyond human control” (Robbins and Moore, 2013, p. 14).
REFERENCES


Chan, K. M., Satterfield, T., and Goldstein, J. (2012). ‘Rethinking ecosystem services to better address and navigate cultural values.’ Ecological Economics 74, pp. 8–18 (cit. on p. 74).


Clifford, N. J. (2002). ‘The future of geography: when the whole is less than the sum of its parts.’ *Geoforum* 33.4, pp. 431–436 (cit. on p. 66).


Cook, B. R., Kesby, M., Fazey, I., and Spray, C. (2013). ‘The persistence of ‘normal’ catchment management despite the participatory turn: Exploring the power ef-
fects of competing frames of reference.’ *Social Studies of Science* 43.5, pp. 754–779 (cit. on p. 82).


Jackson, D. A., Peres-Neto, P. R., and Olden, J. D. (2001). ‘What controls who is where in freshwater fish communities: The roles of biotic, abiotic, and spatial
factors.' Canadian Journal of Fisheries and Aquatic Sciences 58, pp. 157–170 (cit. on p. 30).


COLOPHON

This thesis was typeset in 12pt Linux Libertine, using \TeX and \LaTeX. Formatting errors were introduced by Brendon Blue, and repaired by Simon Whalen.

*Final version* as of August 7, 2018