

Attn: Professor Heather Viles
Associate Editor
Earth Surface Dynamics
23 May 2020

Dear Professor Viles,

Thank you for managing our manuscript “Mātauranga Māori in Geomorphology: existing frameworks, case studies and recommendations for Earth scientists” (manuscript number esurf-2020-5). We are grateful for the valuable reviews that we received from Carolina Londono and an anonymous referee. We hope the changes to our manuscript will be satisfactory for publication in Earth Surface Dynamics.

We thank the two referees for their constructive and insightful reviews. Based on their comments, as well as the short comment we received from Dr. Marc Tadaki, we felt the most important actions to take were to:

1. Increase readability of the text in terms of Māori language terms and English translations;
2. Strengthen the explanation of Figure 4 and the associated He Awa Whiria framework;
3. Better outline the goal of reviewing frameworks and models for weaving Indigenous knowledge with Western science in the Introduction;
4. Streamline the article by condensing and removing extraneous language.

On the following pages, we address general comments from reviewers and provide a table that includes specific and technical reviewer comments, our explanation for changing or not changing the original text, and any modifications made. We also provide two .pdf versions of our updated manuscript: one with tracked changes and one without.

We also became aware of additional relevant literature since the original submission data of our manuscript and felt it appropriate to add in these references:

1. Cano Pecharroman, L.: Rights of Nature: Rivers That Can Stand in Court, Resources, 7, 13 pp., doi:10.3390/resources7010013, 2018.
2. Kauffman, C.M. and Martin, P.L.: Constructing Rights of Nature Norms in the US, Ecuador, and New Zealand, Global Environmental Politics, 18, 43-62, doi:10.1162/glep_a_00481, 2018.
3. Maxwell, K.H., Ratana, K., Davies, K.K., Taiapa, C., and Awatere, S.: Navigating towards marine co-management with Indigenous communities on-board the Waka-Taurua, Marine Policy, 111, 4 pp., doi:10.1016/j.marpol.2019.103722, 2020.
4. Wilcock, D. and Brierley, G.: It's about time: extending time-space discussion in geography through use of 'ethnogeomorphology' as an education and communication tool, Journal of Sustainability Education, 3, 2012.
5. Wilcock, D., Brierley, G., and Howitt, R.: Ethnogeomorphology: Progress in Physical Geography, doi:10.1177/0309133313483164, 2013.

Again, thank you for managing our manuscript and for facilitating the involvement of our reviewers; we greatly appreciate their feedback.

Sincerely,

Clare Wilkinson, on behalf of the authorship team.

Responses to Reviewer 1, Carolina Londono

General Comments

The paper presents a review of existing frameworks and models that have been used to incorporate Aotearoa Maori knowledge in New Zealand. It highlights case studies to exemplify how the frameworks work. It considers how the existing frameworks and studies apply to geomorphology and discuss the implications for studies outside of NZ. This is a high-quality review, it is well written and relevant. The frameworks presented should be a model for the US and the world where non-indigenous geoscientists wish to engage in research with indigenous peoples or their lands.

Thank you.

Specific and technical comments

Reviewer Comment	Original Line Number	Author Comment	Author Revision	New Line Number
I appreciate the words in the Maori language. But I found it taxing and distracting to go back and forth looking for the meaning.	Throughout	Agree	We have added short English translations for Māori terms where appropriate.	Throughout
Also, including a line or two justifying why using the words in Maori.	N/A	Respectfully Disagree—no change required	We use words in <i>te reo</i> Māori (Māori language) to be inclusive throughout our review. We intend to demonstrate—rather than justify—our dedication to weaving Māori knowledge with Western approaches, and one way to honour Māori is to learn and promote their language.	N/A
What methods did the authors use for this paper?	N/A	Sentence added	Added: “We used archival research, review and <i>wānanga</i> (discussion) to conduct this research.”	85
On line 91, the authors mentioned permissions granted by the University to do the research. What did you have to ask permission for?	91	Sentence added	At the University of Canterbury (PI Wilkinson’s institute), all research conducted by staff or students that involves Māori groups in any way must be approved by the University’s Human Ethics Committee. This literature review is part of Wilkinson’s PhD research, which includes interviews and face-to-face interactions with	91-95

			<p>individuals from different Māori iwi (tribes). Therefore, we had to gain ethics approval before conducting this research. We also felt it is important for readers to know that we complied by the policy of asking permission to discuss mātauranga, and the information provided in the review is not something we can claim as our own.</p> <p>Moreover, it is important to note that gaining permission through Human Ethics Committees helps to safeguard the Intellectual Property of Indigenous peoples. This point was raised by Reviewer 2, and we added a sentence to indicate that our Ethics approval acknowledges our obligation as researchers to respect and protect that Intellectual Property.</p>	
Thus, replace the words resurgence and re-engagement.	46	Change made	<p>Changed “resurgence” to “emergence” and “re-engagement” to “engagement”</p> <p>Note: Also in the abstract (line 10) we replaced “experiencing a resurgence” with “emerging”</p>	45-46
Define “right of nature” to readers unfamiliar.	57	Change made	Definition added	56
Move Table 1 so it appears after the first mention (it appears before so there’s no context for it). Consider adding a guide for pronunciation (phonetic guide)		Agree	Table 1 now has a phonetic guide and appears below the first mention	Page 6, near line 160
What does it mean that: Whakapapa (...) fosters credibility by	176	Change made	We changed “subjects” to “research objectives”. By subjects, we meant the subject	170

establishing connections between researchers and subjects?			of the researcher's research. We hope "research objectives" clarifies any uncertainty here.	
Section 3.2. Consider making it shorter and clearly showing how this treaty connects to the frameworks.		Partially agree	<p>We felt this section was important for highlighting modern interpretations of the Treaty of Waitangi and how it is being used in research and engagement today. This section is intended to illustrate that the principles of the treaty are being used to guide transformative policy and management schemes, so why can't we also use the principles in geomorphic research?</p> <p>We also felt it was important to establish the context for research in Aotearoa-NZ, which is guided by this governing document.</p> <p>Having said that, we condensed section 3.2 by removing section heading 3.2.1 and changing the 3.2 section heading to reflect what was in 3.2.1.</p> <p>We added a sentence in the IBRLA framework section (line 410) highlighting the Treaty of Waitangi principles woven throughout the framework.</p>	Section 3.2 (beginning line 199)
Just a comment, giving a river the legal personhood status is the way to go. I celebrate; this!	246	Agree	Thank you!	
Could Fig. 3 be referenced there?	382-383	Agree	Done	374
What is Maori phenomena?	386	Agree	individuals, culturally significant landscapes, values—we have added this in	376-377

How can conclusions be supported by both streams when one of the streams may lack the tools or paradigms of the other? What does it mean that both streams have to support findings? This is not clear to me.	426		We have changed the language we use here to be more consistent with the language used in our review of the other two frameworks. We now say: "Ultimately, when research conclusions are drawn, they must represent co-creation of knowledge using both streams."	423
States that the method allows western science to stay true to the scientific method. Is this different from the other two? What do you mean when you say that there is no "hindrance" in using the scientific method for the other two?	429	Changes made	<p>In regard to the He Poutama Whakamana and IBRLA frameworks, we changed the use of "hindrance" to "maintaining integrity". All frameworks allow the scientific method to be used.</p> <p>Historically, one of the biggest reasons for scientists to hesitate to include Indigenous knowledge in their research was the concern that Indigenous knowledge might interfere with the scientific method. We feel it is important to demonstrate that Indigenous knowledge and Western science can work together without undermining each other; we wanted to be explicit about the ability to still use the scientific method while weaving Indigenous knowledge into research projects.</p> <p>We have removed the explicit mention of the scientific method in the He Awa Whiria framework and instead use terms such as "the Western science paradigm" and "Western science analysis". We maintain our usage of the scientific method in the He</p>	Paragraph beginning line 424

			Poutama Whakamana and IBRLA frameworks.	
Figure 4: This figure needs more explanation. For example, What do the turquoise lines represent? Are we trying to connect the baskets? Do the arrows end in a particular place for a particular reason? And what do the horizontal double head arrows represent? And why using weaved baskets to represent both knowledges (i.e., western and Maori)	Figure 4	Agree	Thank you for this comment. We have added a better explanation of the imagery in the figure and why those symbols are significant (including the baskets). In the caption to Figure 4, we now state that the turquoise lines represent knowledge exchange and development throughout the research programme.	Section 4.1.3 and Figure 4 (beginning line 411)
Paragraph starting in 549 states that non-Maori researchers could include Maori values. This raises questions for me. This could lead to cultural misrepresentation or cultural appropriation of knowledge. How are westerners going to interpret the Maori values when they are not part of that culture? I suggest revising this idea, and changing the wording to make it a REQUIREMENT of having a Maori researcher on the project, instead of a desirable situation.	549-	Partially Agree	<p>Thank you for this valuable comment.</p> <p>We believe that “requiring” Māori participation in research runs the risk of perpetuating colonizing practices. We believe it is best for Māori communities to choose their level of involvement. The text relating to this comment remains unchanged.</p> <p>We have however added an indication of this important point in a later part of the text, where we discuss resources for initiating research projects with Māori (see lines 593-597).</p>	572; 593-597
Talks about “flexible” research methods. I’m concerned that this could translate as	615	Agree	Thank you for this comment—changed “flexible” to “adaptive” as you suggest.	620

making science less rigorous or lowering its quality. I know that's not what is meant. I'd suggest changing 'flexible' to inclusive, adaptive or culturally responsive research methods.				
Besides adapting, or extrapolating, the Maori models to other parts of the globe, this article shows how researchers and indigenous peoples can develop frameworks and models particular for their culture. I would add that as a contribution.	658	Agree	Thank you—we have added this in.	659-661

Responses to Reviewer 2, anonymous

General Comments

The title of the paper refers to “Matauranga Maori in geomorphology” or in other words the Knowledge held by Maori in the science of geomorphology or geomorphic processes. The second part of the title is confusing, and could be reworded to “Matauranga Maori in Geomorphology: existing frameworks, case studies and recommendations for incorporating Indigenous Knowledge in earth science”. The other interpretation of the first part of the title, which first drew me in, was the thought that the paper would review actual Matauranga Maori knowledge of geomorphic processes and phenomenon as local people. This knowledge is likely significant, as current occupiers and managers of landscapes, beyond just oral stories of past events or creation stories. The introduction of the paper could better differentiate these two versions of Matauranga Maori in geomorphology, and emphasise that the goal of the paper is to review the frameworks for knowledge incorporation in western science, rather than review the Indigenous geomorphic knowledge itself (but the brief review up front is helpful and insightful).

Thank you—we certainly don't want the title to be misleading in anyway. We have taken up your suggestion to call the review “Mātauranga Māori in geomorphology: existing frameworks, case studies and recommendations for incorporating Indigenous knowledge in Earth science”.

This in an important article needed to better inform geomorphologists of how to incorporate Indigenous knowledge in their research, or conversely, how to incorporate the science of geomorphology in education and the practical management of land by Indigenous people like the Maori . The latter could

also be emphasised to an equal degree for balanced bicultural research, with suggestions on bidirectional education in contemporary Indigenous cultures that adapt to change.

We agree that this is an important issue, but we do not feel that discussing it is appropriate for what we are trying to accomplish with our review. The frameworks and models we discuss do seek to achieve balanced bicultural geomorphology research, but we feel that delving into bidirectional *education* is beyond the scope of this review.

All too often geomorphologists (and other scientists) ignore engagement with Indigenous communities and their traditional ownership of historic estates. They disrespect Indigenous rights to know of, control or guide, and/or participate in research on their traditional land, irrespective of current ownership or tenure or laws requiring it. This is a science version of continued colonisation and suppression. It should be emphasised to the reader that no matter if or how scientists involve Indigenous Knowledge in their proper research, they have an obligation at a minimum to engage with Indigenous people and custodians while conducting research on their traditional land, and most specifically ask permission to conduct the research on traditional land according to local protocols.

Asking research permission on traditional land is the first prerequisite, with adding Indigenous community members (or guides) to the team secondary, and gaining the use of Indigenous knowledge then tertiary.

We agree that there should be a need for researchers to consider how their research may be applicable to/of interest to Indigenous communities. What we have done in our review is stress the need to engage with Indigenous groups when appropriate, and document how it is done in Aotearoa-NZ. We wish to provide general guidance to researchers that will encourage them to discover their own local engagement procedures, without being overly prescriptive. We feel it is most important for researchers to be guided by the experts in their local area. Therefore, we respectfully choose to maintain the way we have discussed engagement with Indigenous communities.

The issue of Intellectual Property of Indigenous Knowledge also needs to be reviewed more in the paper. Often Indigenous knowledge is owned by the collective of multiple generations (community), past, present and future. Having one or several Indigenous community members or leaders on a research group or board (paid or unpaid) does not automatically give permission to use or include collective Indigenous knowledge for scientific purposes, even if held in the mind and agreed to be shared by one person. Agreement from the collective is often needed, through a Memorandum of Understanding or Intellectual Property agreement with a Council of Elders, Tribal Council, or Indigenous Corporation, or others. This can become a sticky issue, and partially why some scientists often ignore the development of IP agreements. Regardless, this should become an official part of business by researchers around the world as required by funding agreements (Human Ethics even if not studying humans!), and national, regional, local and Indigenous governments. It would be great if the authors could convey some of these issues to readers, many of which are naïve to the issues.

Thank you for this comment. We feel that this point is perhaps a bit too far down the chain of engagement to include in our paper at length. We agree that this is incredibly important and have added a sentence in our introduction explaining why we had to gain Human Ethics permission to conduct our research, hoping that it illustrates this important step. Our paper aims to encourage geoscientists to embark on research journeys with Indigenous groups and, as we have stressed, we implore researchers to discuss their research ideas *early* with staff at their University or Research institute who are skilled in appropriate engagement processes. Conversations about the IP of Indigenous knowledge will stem from those discussions with cultural engagement advisors. However, we greatly value and appreciate this

comment. The last 3 sentences of our introduction now read: “We acknowledge that the *mātauranga* presented here is not our own, and that we have gained approval through the Human Ethics Committee at the University of Canterbury (Christchurch, NZ) to conduct this research. In all cases, including our own, this approval is required in order to respect the Intellectual Property of Indigenous peoples. We herein acknowledge the *mana whenua* (traditional authorities) of Aotearoa-NZ as the rightful holders of *mātauranga*.” The 2nd of the 3 provided sentences is new and the 1st and 3rd are from the original manuscript.

The section titles and outline are key to improve upon. The sections headings are as follows with suggested additions and changes in italics to the titles below. Some headings could be deleted or combined.

Thank you for these suggestions (we have moved this comment from the specific/technical corrections to here, where it is easier to address). We have made some changes where we agree that your suggestion is appropriate. We have maintained the original form of some headings where we feel further text in the heading is clunky. We removed one section heading (3.2.1) but changed the 3.2 section heading to reflect what was previously in 3.2.1. Because this is a review, we do feel the need to maintain our heading and subheading structure, so that the content of each section is clear.

<i>Reviewer Suggestion</i>	Author comment	Current form
<i>1 Introduction</i>	No change required	1 Introduction
<i>2 Overview of International research at the interface of Indigenous knowledge and science</i>	No change required	2 Overview of international research at the interface of Indigenous knowledge and geoscience
<i>3 Mixed-method geoscience research in contemporary Aotearoa-NZ</i>	No change required	3 Mixed-method geoscience research in contemporary Aotearoa-NZ
<i>3.1 Te Ao Maori (the Maori worldview)</i>	No change required	3.1 <i>Te Ao Māori</i> (the Māori worldview)
<i>3.1.1 Whakapapa and tikanga (Validity through ancestry)</i>	Changed	3.1.1 <i>Whakapapa</i> and <i>tikanga</i> (validity through ancestry)
<i>3.1.2 Mātauranga Maori (Indigenous Knowledge)</i>	Changed	3.1.2 <i>Mātauranga</i> Māori (Māori knowledge)
<i>3.1.3 Kaitiakitanga (Well-being of people and environment)</i>	Changed	3.1.3 <i>Kaitiakitanga</i> (Well-being of people and environment)
<i>3.2 Obligations of the Aotearoa New Zealand government to Maori</i>	No change required	3.2 Obligations of the Aotearoa New Zealand government to Maori through the Treaty of Waitangi
<i>3.2.1 The Treaty of Waitangi (Maori and Crown as legal partners)</i>	Section header removed	--
<i>3.2.2 The Treaty in practice</i>	Changed subheading number	3.2.1 The Treaty in practice
<i>3.2.2.1 Te Manahuna Aoraki Project (Government Consolation)</i>	No change required (except subheading number)	3.2.1.1 <i>Te Manahuna Aoraki</i> Project

3.2.2.2 <i>Te Awa Tupua (Rivers at Legal People)</i>	No change required (except subheading number)	3.2.1.2 <i>Te Awa Tupua</i>
3.3 <i>Woven spaces at the interface of Mātauranga Māori and science</i>	No change required	3.3 Woven spaces at the interface of <i>mātauranga</i> Māori and science
3.3.1 <i>The relationship between Mātauranga and science</i>	No change required	3.3.1 The relationship between <i>mātauranga</i> and science
3.3.1.1 <i>Indigenous knowledge versus values</i>	Changed	3.3.1.1 Indigenous values
3.3.2 <i>Mutual research needs and benefits (Indigenous Management Plans)</i>	Slight change	3.3.2 Identifying mutual research needs and benefits
3.3.3 <i>Potential challenges and risks of conducting research at the cultural interface</i>	Changed	3.3.3 Potential challenges and risks of conducting research at the cultural interface
4. <i>Frameworks and models for incorporating Mātauranga Māori alongside in geomorphic research</i>	No change required	4. Frameworks and models for incorporating <i>mātauranga</i> Māori alongside in geomorphic research
4.1 <i>Theoretical Frameworks (Mātauranga Māori in geomorphic research)</i>	No change required	4.1 Theoretical frameworks for including <i>mātauranga</i> Māori in geomorphic research
4.1.1 <i>He Poutama Whakamana (Mirror-images of knowledge and understanding)</i>	Changed	4.1.1 <i>He Poutama Whakamana</i> (mirror-images of knowledge and understanding)
4.1.2 <i>IBRLA (initiation, benefits, representation, legitimisation, accountability)</i>	Changed	4.1.2 IBRLA (initiation, benefits, representation, legitimisation, accountability)
4.1.3 <i>He Awa Whiria (A Braided Rivers Approach)</i>	Changed	4.1.3 <i>He Awa Whiria</i> (a braided rivers approach)
4.2 <i>Models (Step-By-Step Guide of Including Māori values in geomorphic research)</i>	No change required	4.2 .2 Models for including Māori values in geomorphic research
4.2.1 <i>Mauri model (Sustainability and Cultural Bonds to the Environment)</i>	No change required	4.2.1 <i>Mauri</i> model
4.2.1.1 <i>Transferability to geomorphology (Mauri model)</i>	Changed	4.2.1.1 Transferability to geomorphology (<i>Mauri</i> model)
4.2.2 <i>Cultural Flow Preference Study (Cultural Practices and River Flow)</i>	No change required	4.2.2 Cultural Flow Preference Study
4.2.2.1 <i>Transferability to geomorphology (Cultural Flow)</i>	Changed	4.2.2.1 Transferability to geomorphology (CFPS)
4.2.3 <i>Sustainability Assessment Method (Values Associated with Waterway Health)</i>	No change required	4.2.3 Sustainability Assessment Method

<i>4.2.3.1 Transferability to geomorphology (Sustainability Assessment)</i>	Changed	4.2.3.1 Transferability to geomorphology (SAM)
<i>5. Critical assessment of existing frameworks and models in different conditions</i>	No change required	5. Critical assessment of existing frameworks and models in different conditions
<i>5.1 Knowledge versus values (Revisited)</i>	Changed	5.1 Framework recommendations for subdisciplines
<i>5.2 Framework and Model recommendations for Geomorphology subdisciplines</i>	No change required	5.2 Model application to include Indigenous values
<i>5.3 Guiding resources for initiating projects in Aotearoa-NZ</i>	No change required	5.3 Guiding resources for initiating projects in Aotearoa-NZ
<i>6. Lessons for the international geomorphology community</i>	No change required	6. Lessons for the international geomorphology community
<i>6.1 Direct benefits to geomorphology</i>	No change required	6.1 Direct benefits to geomorphology
<i>6.2 International application of Aotearoa-NZ bicultural research frameworks</i>	Changed	6.2 International application of Aotearoa-NZ bicultural research frameworks and models
<i>6.3 The benefit of Indigenous Knowledge and Geomorphology Science in Society</i>	Changed	6.3 Benefits of Indigenous knowledge and geomorphology to society
<i>7. Conclusions and recommendations to geomorphologists</i>	Unchanged	7. Conclusions and recommendations to geomorphologists

Specific and technical comments

Reviewer Comment	Original Line Number	Author Comment	Author Revision	New Line Number
Overall, the paper is fairly long, with many sub-headings, and is easy to get lost within...Please condense and remove any extraneous word, sentences, sections, or references, where possible?	N/A	Changes made	We have removed some repeat references and unnecessary words/sentences/phrases.	Throughout

So sentence intros like “As discussed earlier” or “As previously mentioned” do not help, as one of many examples. As another of many examples Line 390 should be reduced “He Poutama Whakamana follows a kaupapa Maori research approach,. Kaupapa Maori , described in depth by Smith (2012), can be understood as research that is “culturally safe” and that takes place within a Maori worldview (Irwin, 1994 as cited in Smith, 2012). Keep the sentences simple and straight forward and non-redundant.	N/A	Changes made	We removed as many sentence intros like this as we felt appropriate.	Throughout
The Table of Maori terms and names is very useful. However for the non-New Zealand reader, it is very hard to read the text and Maori terms and constantly go back to the table. It would be helpful to conduct two things: 1) make all Maori terms italics or otherwise to highlight to the reader the difference between English and written Maori (similar to what has been done with PNG language in the paper), and 2) at the end of key Maori words	Throughout	Agree	We have added short English translations for Māori terms where appropriate, and have italicised Māori terms.	Throughout

to have the short definition in brackets, like Iwi (tribe).				
The authors in places due this with commas, but the sentences get too complex. . . Line 237, For mana whenua, spiritual values of the Te Manahuna, the Mackenzie basin, are held as a priority to be conserved, which may be challenging to communicate to their partners. It would be easier to read as follows. For Mana whenua (people with with authority), spiritual values of the Te Manahuna (the Mackenzie basin) are held as a priority to be conserved, which may be challenging to communicate to their partners.	Throughout	Agree	<p>We have made the appropriate change.</p> <p>Note: we also changed a similar occurrence of comma and em dash usage in the abstract to include just parentheses.</p> <p>Note: again, we changed a similarly clunky sentence in original manuscript lines 99-102.</p>	Throughout
Maori terms could also be capitalised, Iwi (tribe) to make stand out, if appropriate for written Maori ?	Throughout	Respectfully disagree	We have italicised all Māori terms to make them stand out.	Throughout
Please better define the difference between a Framework and Model earlier on in the paper. Overall these uses are very confusing to a new reader. The authors cover the difference better in section 5.2, but this needs to happen earlier in the paper (introduction) in a	Throughout	Agree	<p>We provide a short definition of framework and model in the introduction (similar to the definitions included in Table 2).</p> <p>We also provide more explicit definitions of “framework” and “model” at the beginning of section 4.</p>	Section 4, beginning line 343

more concise and clear fashion. The authors mention 3 frameworks and models each, but there are lots of similarities and differences. In Table 2, a Framework is defined as a methodology, and Model is defined as a method. Theoretical vs actionable is key, but the Theoretical frameworks are actionable depending on the user and interpretation. Methodology as a general research strategy, and method as a tool to answer a question.				
In some place this use [of framework and model] is even mixed up, such as Line 354 "The models proposed by Smith (1992, 2012) can be thought of as methodologies, or guiding principles. . . .". In this case and usage the sentence should read "The framework proposed by Smith (1992, 2012) can be thought of as methodologies, or guiding principles. . . .".	Throughout	Changes made	Thank you for this helpful comment. We have made sure that we do not mix up the usage of "framework" and "model" in the revised manuscript.	Throughout
Please educate the reader why they are labelled or grouped as is, both in the abstract, introduction, and also the main sections such as section 4 in	Throughout	Changes made	We have included more explicit definitions/explanations of the use of "framework" and "model".	Throughout

paragraph Line 355 and 370, and in section 4.2. Section 5.2 does a better job at describing these differences.				
In some locations the authors intermix geologic, geomorphic(ology) and earth science. Even in the title. And at times river science and health and ecology. The paper and journal focus is on geomorphology, perhaps leave it as that and omit the others. Geomorphology is pretty broad and inclusive. Just refer to the broader earth science when talking about wider applications, and the more specific sciences like river health and environmental flow where appropriate for the example reference.	Throughout	Changes made	<p>We have clarified our use of these terms and make sure we use the appropriate term in each location.</p> <p>Note: We reorganised the paragraph beginning on Line 142 so that the mention of ecological studies is later in the paragraph rather than at the beginning. This has the effect of showing ecology is not the main topic of the paragraph, while still highlighting the importance of mentioning that Indigenous knowledge has been incorporated into ecology studies and that geomorphology might be imbedded in those studies.</p>	Throughout
This sentence needs to be broken into two. We then introduce Te Ao Maori (the Maori world), discuss obligations of the New Zealand government to Maori , and present frameworks for conducting mixed-methods scientific research with iwi and hapu (tribes and family groupingsâˆ™The principle political units with whom scientists	80-83	Agree	<p>The sentences now read: We then introduce <i>Te Ao Māori</i> (the Māori world) and some Māori concepts relevant to geomorphology. We discuss obligations of the New Zealand government to Māori groups (i.e. <i>iwi</i> and <i>hapū</i>, tribes and sub-tribes, which are the principle political units with whom scientists engage in Aotearoa-NZ). We present three theoretical frameworks</p>	79-83

en- v gage) in Aotearoa-NZ in this space.			(methodologies or general research strategies) and three value-based models (methods for answering research questions) for conducting mixed-method bicultural research.	
This sentence is vague. We then provide case studies of framework development and recommendations for framework implementation in geomorphology research.	83-84	Somewhat agree; changes made	We then provide case studies of model development and recommendations for implementation in geomorphology research.	83-84
Line 287 paragraph is connected to the discussion in Line 300 paragraph in the next section. Repetitive and confusing to repeat. Please clarify and simplify or consolidate.	287-305	Agree	We revised these two paragraphs so that the first is more focused on the relationship between mātauranga and science while the second is more focused on Indigenous knowledge and values. The second paragraph is now more concise.	283-298
Figure 3. Make sure that this image is high enough resolution in print to be readable in a condensed format in a journal paper. Even in this full page format it is hard to read, and the journal may not print it as a full page.	Figure 3, page 16		Thank you—it is 400 dpi (will discuss this further with the associate editor if necessary).	Figure 3, page 16
Knowledge of	431	Changed	Changed to “allowing the two knowledge streams to operate...”	428
Sections 5.1 Knowledge versus values (Revisited) and 5.2 Framework and Model recommendations for Geomorphology subdisciplines should	538-578	Agree	We removed the original manuscript section with the heading “ 5.1 Knowledge and values revisited” and distributed the information between the revised sections 5.1	Section 5, starting line 529

be renamed, as the first really covers model application to capture values, while the second focuses on frameworks. Same with the Section 5 title, which focuses on both frameworks and models. It just gets confusing about what each paragraph or sub-section is referring to.			and 5.2. These revised sections are: "5.1 Framework recommendations for subdisciplines" and "5.2 Model application to include Indigenous values"	
			Note: We have also changed the heading for section 5 to: "5. Embarking on the bicultural research journey" to better reflect the sections that fall beneath it.	
6.1 Direct benefits to geomorphology. Rather than just focusing on knowledge of physical events to benefit geomorphologist, the more common international benefit of working with Indigenous people is learning from their current intricate knowledge of the environment and physical and cultural and biological landscapes. If one wants to learn about all the springs in a catchment, who better to ask than local Indigenous people? Or locations of rock outcrops with valuable resources or tools? Or unique species isolated above geologic barriers? The paper missed out on a wealth of knowledge beyond past events.	605-	Agree	Added in a few sentences to the second paragraph in this section to talk about contemporary Indigenous knowledge guiding geomorphic research. In the period of time between submitting our original manuscript and receiving reviews, we became aware of a publication by Wilcock et al. (2013) that discusses a concept they call 'ethnogeomorphology'. We briefly discuss this concept here to further address your comment.	Section 6.1, specifically lines 612-619.

<p>The key recommendation should be to encourage geomorphologists interested in working with Indigenous communities to consult directly with Indigenous communities and their self-governance institutions. There is a surprising level of diversity in governance capacity of Indigenous communities around the globe. Direct consultation is best, with support of other programs and experts of course where needed.</p>	<p>685</p>	<p>Respectfully disagree</p>	<p>We believe that consultation with engagement support teams is the best way for geomorphologists to begin a bicultural research journey. The reason for this is because, as you state, there is a wide diversity in governance capacity of Indigenous communities around the globe, meaning that they will all have different expectations surrounding engagement protocols. We cannot provide specific engagement advice that would suit all Indigenous communities around the globe. Therefore, we advise researchers to talk to people at their own institutions who are knowledgeable about engagement protocols in their local area.</p> <p>In many cases, Human Ethics must be approved before researchers can engage with Indigenous communities. Cultural advisors at universities and research institutes will be able to advise researchers on how to gain ethics approval. In our experience, there are many steps that must occur first before researchers directly engage with Indigenous groups.</p>	<p>N/A</p>
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Mātauranga Māori in geomorphology: existing frameworks, case studies and recommendations for incorporating Indigenous knowledge infor Earth sciencetists

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Abstract. Mixed-method bicultural research in Aotearoa New Zealand, including the weaving of Indigenous and other knowledges, is ~~experiencing a resurgence~~emerging within many academic disciplines. However, mātauranga Māori ~~(the knowledge, culture, values and worldview of the Indigenous peoples of Aotearoa New Zealand)~~—and Te Ao Māori, ~~(the Māori world)~~, is poorly represented within geomorphological investigations. Here, we review ~~existing international~~ efforts to include Indigenous knowledge in geologic and geomorphic studies ~~from the international research community~~ and provide an overview of the current state of mātauranga Māori within research endeavours in Aotearoa New Zealand. We review three theoretical frameworks ~~(i.e., methodologies)~~ for including mātauranga Māori in research projects and three models ~~(i.e., methods)~~ for including Māori values within research. We identify direct benefits to geomorphology and discuss how these frameworks and models can be adapted for use with Indigenous knowledge systems outside of Aotearoa New Zealand. The aim of this review is to encourage geomorphologists around the world to engage with local Indigenous peoples to develop new approaches to geomorphic research. In Aotearoa New Zealand, we hope to inspire geomorphologists to embark on research journeys ~~that engenderin~~ genuine partnership with Māori ~~and that promote~~ ioitū te mātauranga, the enduring protection, promotion and respect of mātauranga Māori.

Keywords: geomorphology, mātauranga Māori, bicultural research

1 Introduction

Earth scientists are increasingly recognising the benefits of conducting mixed-methods bicultural research (e.g., Townsend et al., 2004; Tipa, 2009; Harmsworth et al., 2011; Crow et al., 2018; Hikuroa et al., 2018). Oral histories, lore and mythologies from Indigenous communities, explained through their respective worldviews, frequently feature stories of geomorphic or landscape change in their tribal lands (e.g., Gottesfeld et al., 1991; McMillan and Hutchinson, 2002; Hikuroa, 2017). Indigenous knowledge and ~~in particular~~, oral histories, have been shown to complement scientific endeavours by detailing

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specific natural events that were otherwise poorly understood or documented by scientists (e.g., Swanson, 2008; King and Goff, 2010; Reid et al., 2014; Nunn and Reid, 2016) and fill knowledge gaps that science cannot (Bohensky and Maru, 2011). As such, Indigenous knowledge can provide an observational starting point, or corroborative evidence, for scientific investigations.

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Historically, there has been discord between the scientific and Indigenous knowledge epistemologies. The science community has traditionally considered Indigenous knowledge systems and oral histories ~~unreliable~~~~untruthful and~~, inaccurate, ~~untruthful, and doubtful~~ (Durie, 2004). Until quite recently, anthropologists still promoted the unreliability of unwritten (i.e., oral) legends that refer to events more than 1000 years before present (Simic, 2002, as cited in Reid et al., 2014). On the other hand, Indigenous communities have frequently expressed opposition to science due to its inertia to recognise nature as something more than a controllable, testable, and exploitable medium (Smith, 1999; Hikuroa et al., 2011). While scientists are typically detached “observers” and analysers of natural systems (Cruikshank, 2012; ~~Hikuroa, 2017~~), Indigenous communities position themselves within an extended genealogy that considers nature as kin (Suzuki and Knudtson, 1992; Salmón, 2000). In Indigenous worldviews and knowledge systems, humans are active participants within natural systems (Hikuroa, 2017; Pingram et al., 2019). Tensions between Indigenous knowledge and science—particularly tensions around rigor of knowledge generation, credibility, worldview, and ability to be evaluated—have created challenges for integrating knowledge systems in the past (Mercier, 2007; Bohensky and Maru, 2011).

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Until recently, the historic discord between science and Indigenous knowledge prevented the synergies that do exist between the two knowledge systems from advancing new understandings. In the past 10-15 years, ~~an emergence~~ ~~resurgence~~ of sincere, respectful and reciprocal ~~re~~-engagement between scientific and Indigenous communities has generated multiple national and international guiding policies for genuinely transformative approaches to research (e.g., Hikina Whakatutuki Ministry of Business, Innovation and Employment, n.d.; Ministry of Research, Science and Technology, 2007; UN General Assembly, 2007). ~~ER~~Re-engagement has identified research needs and aspirations of both Indigenous communities and scientists, leading to co-creation and co-development of research projects with respective responsibilities clearly defined. In 2007, the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) catalysed reconsideration and rebalancing of Indigenous peoples’ rights (Hikuroa et al., 2018). The UNDRIP formalised obligations of participating governments to support and protect Indigenous communities’ rights to maintain cultural heritage, traditional knowledge, expression of their sciences, oral traditions and technologies (UN General Assembly, 2007), and created a platform on which mixed-methods research can be formulated, discussed and carried out. To date, legal and constitutional initiatives that build upon UNDRIP policies and establish the ~~r~~ights of nature—the recognition that nature has legal rights (Cano Pecharroman, 2018)—have ~~”have~~ occurred in Bolivia, India, New Zealand, Australia, ~~the United States~~ and Ecuador (Boyd, 2017; Brierley et al., 2018; Kauffman and Martin, 2018; O’Donnell and Talbot-Jones, 2018). Though these advances and recognitions are most prevalent in the policy sphere, they are transferrable to scientific research and have, in a few cases, acted as guidelines for culturally responsible and respectful research at the interface of Indigenous knowledge and Western science.

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65 The international geosciences community is increasingly demonstrating interest in Indigenous knowledge systems
and participation with Indigenous groups (e.g., Tipa, 2009; King and Goff, 2010; Harmsworth et al., 2011; Harmsworth and
Roskrige, 2014; Pardo et al., 2015; Riu-Bosoms et al., 2015; Nunn and Reid, 2016; Hikuroa, 2017; ~~Brierley et al., 2018~~; Crow
et al., 2018). Indigenous knowledge has been used to define research needs in geospatial research projects (e.g., Poole and
Biodiversity Support Program, 1995 *as cited in* Pacey, 2005; Harmsworth, 1999; Alessa et al., 2011; Te Rūnanga o Ngāi Tahu,
2019), natural hazard research (Swanson, 2008; Goff et al., 2010; King and Goff, 2010; King et al., 2018), natural hazard risk
70 reduction planning (Cronin et al., 2004; Becker et al., 2008; Walshe and Nunn, 2012; Rumbach and Foley, 2014; Hiwasaki et
al., 2014; Pardo et al., 2015; Rahman et al., 2017), climate-change resilience (Cruikshank, 2001, 2012; Ford and Smit, 2004;
Janif et al., 2016; Iloka, 2016), environmental management (Londono et al., 2016), soil classification (Oudwater and Martin,
2003; Harmsworth and Roskrige, 2014) and geomorphology/hydrology research (Londono et al., 2016; Hikuroa, 2017).
Moreover, Indigenous place names commonly indicate knowledge of landscape features and geomorphology (Carter, 2005;
75 Kharusi and Salman, 2015; Riu-Bosoms et al., 2015; Atik and Swaffield, 2017). Thus, culturally responsible and respectful
weaving of Indigenous knowledge into Earth science has the potential to corroborate, bolster and create knowledge.

This review focuses on recent efforts to include *mātauranga* Māori (Māori Indigenous knowledge, *culture, values
and worldview*) alongside geomorphology in research conducted within Aotearoa New Zealand (henceforth Aotearoa-NZ).
Although Aotearoa is a Māori name for New Zealand's North Island, to reflect the nation's bi-cultural foundation it is
80 commonly used in this context (e.g., Aotearoa-NZ) to mean all of New Zealand. *Mātauranga Māori can be described as a
detailed and complex knowledge system originating from Māori ancestry (Paul Burke et al., 2018), including culture, values
and Māori worldview (Hikuroa, 2017). This review begins with a discussion of international efforts in mixed-methods research
at the interface of Indigenous knowledge and geoscience, arriving at a focus on geomorphology. This review begins with a
discussion of international efforts in mixed-methods research at the interface of Indigenous knowledge and geoscience,
85 concluding with a focus on geomorphology.* We then introduce *Te Ao Māori* (the Māori world) and some Māori concepts
relevant to geomorphology. We discuss obligations of the New Zealand government to Māori groups (i.e. *iwi* and *hapū*, tribes
and sub-tribes, which are the principal political units with whom scientists engage in Aotearoa-NZ). We and present three
theoretical frameworks (methodologies or general research strategies) and three value-based models (methods for answering
research questions) for conducting mixed-method bicultural s-scientific research with *iwi* and *hapū* (tribes and family
90 groupings—the principle political units with whom scientists engage) in Aotearoa-NZ in this space. We then then provide case
studies of framework-model development and recommendations for framework-implementation in geomorphology research.
Finally, we provide direct examples of including Indigenous knowledge in geomorphic research and discuss how the
frameworks and models reviewed here can be applied outside of the Aotearoa-NZ context. We used archival research, review
and *wānanga* (discussion) to conduct this research. We believe that the scientific world may learn some valuable lessons from
95 Aotearoa-NZ about how Indigenous knowledge and geomorphology can work together to create new and innovative
understandings about how to live with and learn about Earth surface systems.

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100 The authors assert that there is no expectation that *mātauranga* be given away by *iwi* (tribes) and *hapū* (sub-tribes) to
scientists, ~~and acknowledge that the mātauranga presented here is not our own, and that we have gained approval through the~~
~~Human Ethics Committee at the University of Canterbury (Christchurch, NZ) to conduct this research.~~ Scientists *alone* cannot
105 rebuild or revitalise *mātauranga*; that is for Māori to do (Broughton et al., 2015). ~~Māori have been leading revitalisation~~
~~projects for over 30 years (Broughton et al., 2015), and Māori values and knowledge are being increasingly included in ecology~~
~~and resilience studies.~~ We uphold that the geoscience community is primed to contribute to further *re*invigoration of
mātauranga by welcoming it alongside science for greater understanding of Earth surface phenomena. Our intentions for this
review are to encourage inclusion of Indigenous knowledge and values for guiding scientific research. ~~We acknowledge that~~
110 ~~the mātauranga presented here is not our own, and that we have gained approval through the Human Ethics Committee at the~~
~~University of Canterbury (Christchurch, NZ) to conduct this research. In all cases, including our own, this approval is required~~
~~in order to protect the Intellectual Property of Indigenous peoples.~~ We herein acknowledge the *mana whenua* (traditional
authorities) of Aotearoa-NZ as the rightful holders of *mātauranga*.

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2 Overview of international research at the interface of Indigenous knowledge and geoscience

110 Evaluating events recorded in Indigenous peoples’ oral histories with scientific *investigations of* ~~ally-investigated~~ landforms
or processes is not a new concept. Gottesfeld et al. (1991) examined a Holocene debris flow near Hazelton, British Columbia
(ca. 3500 BP, before present) and discussed how the event could be the same as a story belonging to the local Indigenous
peoples, the Gitksan. ~~In the oral history, of the Medeek, (a devastation-wreaking grizzly bear) that~~ charged down the mountain,
uprooted ~~ing~~ trees and ~~left~~ *aving* a wide gash in the hillside. Scientists have dated the debris flow to a time when the Gitksan
115 people occupied the area. Given that both accounts describe the same event, and with scientific dating aligning with oral history
of Gitksan presence in the area, it is likely that both scientists and the oral history can contribute observations and knowledge
about the event. Similarly, Eisbacher and Clague (1984) discussed Indigenous perspectives of debris flows in the European
Alps, wherein the events were described as “...raging giants and infuriated dragons” that were responsible for “sudden roar[s]
in the gorges and the violent eruption of rubbly debris onto fields and communities” (p. 74).

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120 -More recently, scientists have recognised the plethora of land- and seascape terms within Indigenous languages (e.g.,
O’Connor and Kroefges, 2008; ~~Senft, 2008~~) and the wealth of information about dynamic Earth processes stored in Indigenous
place names (Kharusi and Salman, 2015; Riu-Bosoms et al., 2015; Atik and Swaffield, 2017). For example, Senft (2008)
indicated that the peoples of Kaile’una Island (Papua New Guinea) have specific terms for the sea at different points along a
reef barrier. *O tulupwaka* means the ‘sea between the inner and outer reef’; *omata sulusulu* means ‘sea that covers the outer
125 reef’; *omata takivi* means ‘sea between the drop-off of the outer reef and the deep sea’; and *o tulubwabwau* means the ‘deep
dark sea’ (Senft, 2008). Similarly, ~~Barrera-Bassols (2015) described a geomorphic map created by the Purhepecha peoples of~~
~~central Mexico based on Indigenous soil classification names that shows similarities to scientifically-generated relief maps;~~
~~though different criteria were used to create the maps.~~ Barrera-Bassols (2015) showed that the Purhepecha peoples *of central*

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130 ~~Mexico~~ have a geomorphic soil classification system that correlates strongly with scientific approaches to soil classification, where maps of soil distribution generated by locals using local knowledge are similar to soil maps created by scientists. Others (e.g. Payton et al., 2003; Hillyer et al., 2006) have noted similar results in other parts of the world.

135 ~~Indigenous oral histories have also aided The international~~the international geo-science community to better understand ~~has also learnt from oral histories for~~geologic hazards ~~research~~. Swanson (2008) showed that native Hawai’ian oral traditions involving the volcano goddess Pele record a detailed understanding of the Kilauea volcanic system’s eruptive history over the past 400 years. The timeline of volcanic eruptions held in oral histories aligns with scientific analysis of the volcano’s eruptive history. ~~Thus, the - indicating that~~ oral traditions accurately recorded and described geologic events (Swanson, 2008). Because of the growing recognition of oral traditions as place-based repositories of accurate geologic information, the scientific community is increasingly working with Indigenous groups to elucidate natural hazards. As a result, volcanic hazard management schemes that include elements of local Indigenous knowledge and Western science-based management have been developed in Vanuatu (Cronin et al., 2004) and Papua New Guinea (Mercer and Kelman, 2010). Indigenous knowledge and perspectives have also been used in tsunami hazard management plans in Vanuatu (Walshe and Nunn, 2012), the Pacific Northwest of the United States of America (Becker et al., 2008), Indonesia (Hiwasaki et al., 2014; Rahman et al., 2017), the Chatham Islands (Thomas, 2018), the Philippines (Hiwasaki et al., 2014), and Samoa (Rumbach and Foley, 2014). There is even more research discussing integration of Indigenous knowledge and Western science for disaster risk reduction (e.g., Mercer et al., 2007, 2010; Kelman et al., 2012), but this is outside the scope of this review.

145 Indigenous knowledge is also being used to better understand climate-change, seasonal climate forecasts and climate-change resilience guidelines. Janif et al. (2016) reported that in Fiji, stories held by Indigenous locals of catching certain types of fish can indicate changes in sea surface temperatures. Similarly Cruikshank (2012) described stories of salmon migration (or lack thereof) held by Indigenous Alaskans that provided insight into glacial activity during the Little Ice Age (1550-1850 CE, common era). Their stories reflect that though climate change may be a global phenomenon, it has extremely local effects. Nyong et al. (2007) also demonstrated that local solutions to global climate change effects can bring great benefits to climate-change resilience plans. In West Africa Sahel, the ancestors of many Indigenous populations have experienced and adapted to historic climate extremes that surpassed those predicted by current International Panel for Climate Change (IPCC) models (Nyong et al., 2007). Iloka (2016) also recognised that Indigenous communities in Africa have a wealth of environmental knowledge, passed on by previous generations who endured and survived climate conditions far more extreme than current predictions. Therefore, mitigation strategies developed by previous generations may have implications for future solutions.

155 ~~To date, R~~research that explicitly includes geomorphic techniques alongside Indigenous knowledge is not ~~as~~ abundant in academic literature. ~~- as research that incorporates Indigenous knowledge and values into ecology (e.g., Rainforth and Harmsworth, 2019) or disaster risk reduction research~~. Many publications have shown the potential for conducting geomorphic research with native peoples, evidenced by the large amount of studies investigating Indigenous languages for landscape, geomorphic, pedologic, hydrologic and glacial terms or classification schemes (e.g., Payton et al., 2003; Hillyer et al., 2006; O’Connor and Kroefges, 2008; Senft, 2008; Kharusi and Salman, 2015; Riu-Bosoms et al., 2015; ~~p.; Barrera-Bassols, 2015;~~

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Atik and Swaffield, 2017). We recognise that geomorphic analysis with Indigenous communities could feature in studies covering ecology and biology because Indigenous peoples do not separate ecosystems from landscapes (e.g., Rainforth and Harmsworth, 2019), but there is a dearth of purely geomorphic studies that aim to weave Indigenous knowledge with science. Maxwell et al. (2020) outline methodologies for including Indigenous knowledge in marine management and Bohensky and Maru (2011) provide an extensive review of Indigenous knowledge and Western science integration in the resource management field, but mention of geomorphology in these approaches is limited, but, again, is largely focused on ecology. Some studies that do explicitly address geomorphic research with Indigenous communities typically cover hydrologic and environmental management (e.g., Londono et al., 2016) or soil classification (e.g., Barrera-Bassols, 2015). To our knowledge, most studies-work that explicitly incorporates Indigenous knowledge and values alongside geomorphic research have been conducted in Aotearoa-NZ, and are the focus of the remainder of this review.

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3 Mixed-method geoscience research in contemporary Aotearoa-NZ

3.1 Te Ao Māori (the Māori worldview)

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Te Ao Māori has, at its foundation, relationships between everything seen and unseen, human and more-than human, the natural and beyond-natural world, and in turn shapes Māori ways of doing and living (Clapcott et al., 2018). After Māori settling settled in Aotearoa-NZ many centuries ago (Hikuroa, 2017), Māori-formed distinct groups emerged (today, about 40 iwi and hundreds of hapū) that, all of which built their identity from the surrounding mountains, lakes and rivers (Ruru, 2018). These tribal identities have implications for mātauranga-a-iwi (iwi-specific mātauranga), tribal ancestry, credibility and iwi-specific guardianship of tribal lands. Glossaries of Māori words (Table 1) and key English terminologies used in this paper (Table 2) are provided for reference.

Table 1: Glossary of Māori terms (as used in this paper)

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Term Arohatanga	Phonetic Guide	Care, respect, love Description
Arohatanga	Ah-ror-ha-tah-nga	Care, respect, love
Atua	Ah-two-ah	Departmental gods, energies
Hapū	Hah-pooH	Sub-tribe
Hine-Titama	He-neh-Tea-tah-mah	The first human, a woman
Io-Matua-Kore	Eeyore-Mah-two-ah-Ko-reh	The supreme ‘first’ being in Māori cosmology
Iwi	E (as in letter e)-we	Tribe
Kaitiaki/kaitiakitanga	Kay (as in kayak)-tea-ah-key/ Kay (as in kayak)-tea-ah-key-tah-nga	Guardian and the act of guardianship; principle of intergenerational sustainability and the practices to achieve it
Kete	Keh-teh	Basket
Ki Uta Ki Tai	Key Oo (as in boot)-tah Key Tie	Literally, Concept expressing the importance of catchments extending from the mountains to the sea ‘To Mountain To Sea’, this is a Maori holistic philosophy that considers the environment in its entirety, expressing the importance of catchments extending from the mountains to the sea
Mahinga kai	Mah-he-nga kay (as in kayak)	Traditional food gathering practices and places
Mana	Mah-nah	Authority, prestige

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Mana whenua	<u>Mah-nah Feh-nu-ah</u>	People with traditional authority over the land
Manaakitanga	<u>Mah-nah-ah-key-tah-nga</u>	Acts of caring for and giving
Māramatanga	<u>Mah-rah-mah-tah-nga</u>	Enlightenment, understanding, a phase in which knowledge can be applied
Mātauranga Māori	<u>Mah-tow-rah-nga Mah-or-ree</u>	Knowledge, <u>culture, values and worldview</u> held by Māori, the Indigenous peoples of Aotearoa New Zealand
Mātauranga-a-iwi	<u>Mah-tow-rah-nga-ah-e-we</u>	Iwi-specific (tribal) knowledge
Mauri	<u>Mouw-ree</u>	Life force, essence
Mōhiotanga	<u>Moh-he-o-ar-tah-nga</u>	Acknowledgement, respect, awareness of potential
Pākehā	<u>Pah-keh-hah</u>	Non-Māori (European descent) New Zealander
Papatuanuku	<u>Pah-pah-two-ah-nu-ku</u>	Earth mother (<u>Primal parent</u>)
Pūrākau	<u>Puh-rah-kouh</u>	Oral record or history, <u>often in story form</u>
Ranginui	<u>Rahng-e (as in letter e)-nu-e (as in letter e)</u>	Sky father (<u>Primal parent</u>)
Rūnanga	<u>Ru-nah-nga</u>	Tribal council or governing board
Tane	<u>Tah-neh</u>	God of the forests; created the first human
Taniwha	<u>Tah-knee-fah</u>	Supernatural creatures in Māori legends, often taking the form of a serpent or water monster
Tangata whenua	<u>Tah-nga-tah fe-nu-ah</u>	People of the land
Taonga	<u>Tah-or-nga</u>	Treasure (noun), to be treasured (verb)
Te Ao Māori	<u>Teh Owe Mah-or-ree</u>	Māori worldview
Te Ao Marama	<u>Teh Owe Mah-rah-mah</u>	The world of light, the world we inhabit
Te Kore	<u>Teh Kor-reh</u>	The nothingness, the potential for life
Te Po	<u>Teh Pore</u>	The darkness, the night
Te taiao	<u>Teh Tie-Owe</u>	The natural world; the environment, <u>including people-</u>
Tikanga	<u>Tea-kah-nga</u>	Customary practices, values, protocols
Tino rangatiratanga	<u>Tea-nor Rah-nga-tea-rah-tah-nga</u>	Self-determination
Ūkaipō	<u>U (as in cue)-kay (as in kayak)-pore</u>	Roots
Wairuatanga	<u>Why-rue-ah-tah-nga</u>	Spiritual dimension
<u>Wānanga</u>	<u>Wah-nah-nga</u>	<u>Discussion</u>
Whakakotahitanga	<u>Far-kah-koh-tah-he-tah-nga</u>	Respect for differences, ability to reach consensus, participatory inclusion in decision-making
Whakapapa	<u>Far-kah-pah-pah</u>	Ancestral genealogy, applicable to all elements of nature
<u>Whakataukī</u>	<u>Far-kah-tow-key</u>	<u>Story or proverb</u>
Whānau	<u>Far-know</u>	Family or close kin network
Whānauangatanga	<u>Far-know-nga-tah-nga</u>	Family connections

a-iwi (iwi specific mātauranga), tribal ancestry, credibility and iwi specific guardianship of tribal lands. Glossaries of Māori kupu, or words (Table 1), and key English terminologies used in this paper (Table 2) are provided for reference.

Te Ao Māori has, at its foundation, relationships between everything seen and unseen, humans and more-than-humans, the natural and beyond-natural world, and in turn, shapes Māori ways of doing and living (Clapeott et al., 2018). Māori have been creating and revising their mātauranga since they first arrived to Aotearoa-NZ many centuries years ago (Hikuroa, 2017).

After settling, Māori formed distinct groups (about 40 iwi and hundreds of hapū), all of which built their identity from the surrounding mountains, lakes and rivers (Ruru, 2018). These tribal identities have implications for mātauranga.

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Table 2: Glossary of English terms (as used in this paper)

Cultural association	The cultural uses and values associated with a landscape
Framework	Theoretical guides to research; methodology ^{vies}
Geomorphic rights	Rights of a river with the status of legal personhood, understood from a geomorphic perspective
Indigenous knowledge	Knowledge generated by Indigenous peoples using Indigenous methods and usually including values, culture and worldview
Knowledge	Intellectual capital generated over time and carried through a range of channels including stories, songs, philosophies and teachings
Method	Acts by which research is conducted ^{or specific research tool}
Methodology	Philosophical approach to research ^{or general research strategy}
Model	Actionable guides to research; methods ^s
Science	The pursuit of knowledge according to the scientific method, ^{and all of the knowledge generated using that method}
Treaty of Waitangi	^{Official founding document of Aotearoa-NZ that joined Māori chiefs with the British Crown in 1840} Aotearoa New Zealand's founding document; an agreement in Māori and English, made between Māori chiefs and the British Crown
Value	Guiding principles that support or enable acceptable actions

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3.1.1 ^{Whakapapa} and ^{tikanga} (—validity through ancestry)

^{Whakapapa} (^{ancestry}) is the Māori way of understanding the world through genealogies (Forster, 2019). It links people to
190 flora, fauna, mountains, rivers, oceans and lakes through an understanding that all of nature ~~is~~ descended from the ^{atua} (^{Māori}
^{gods}) (—Fig. 1; Harmsworth and Awatere, 2013; ~~Forster, 2019~~). ^{Whakapapa} informs ^{tikanga}, ~~or~~ (cultural protocols and
habits)^s, which in turn informs how one should conduct their life (Graham, 2009).

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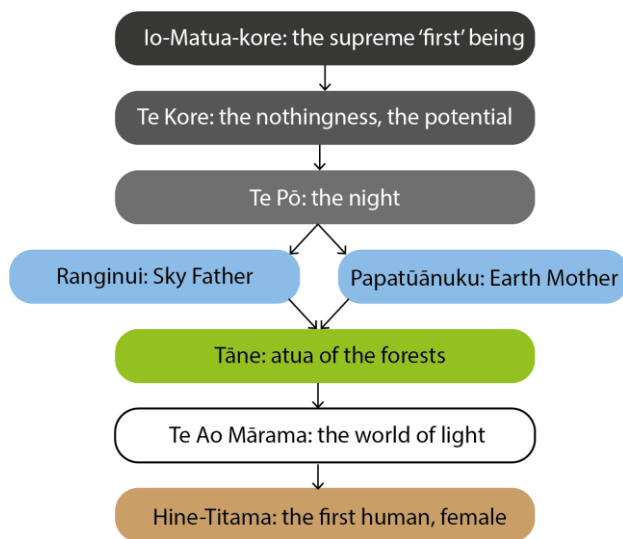


Figure 1. The pedigree of mankind in *Te Ao Māori*. Modified from Graham, 2009.

Whakapapa is at the core of Indigenous Māori knowledge generation (Graham, 2009). *Whakapapa* legitimates Māori epistemologies within research and fosters credibility by establishing connections between researchers and *subjects* research objectives, and by guiding research questions based on *fikanga* (Graham, 2009). By understanding that all things—both physical and metaphysical—are connected through genealogy (Hikuroa, 2017), it can be understood that *whakapapa* is a structured methodology for creating *mātauranga* (Royal, 1998). The relationships within *whakapapa* inform histories, stories, and interactions, which can be analysed in a Māori-centred way to create new knowledge (Fig. 2).

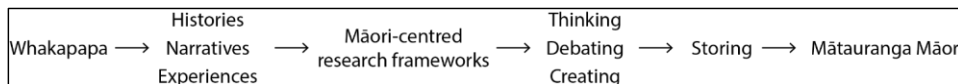


Figure 2. Generation of Māori knowledge. Modified from Graham, 2009.

3.1.2 *Mātauranga Māori* (Māori knowledge)

Mātauranga Māori is a detailed and dynamic way of knowing that has its *ikaipō* (roots) in Māori ancestry (Paul-Burke et al., 2018). *Mātauranga* is a *taonga* (treasure) that is lived, practiced, tested, updated and that grows and develops as it is passed

from generation to generation. Based on Polynesian origins (Clapcott et al., 2018), Māori have been developing their mātauranga since their arrival to Aotearoa-NZ some 800-1000 years ago (Broughton et al., 2015). Mātauranga is not only knowledge, but is also a method of expressing knowledge through language, cultural practices, values, principles and ethics (Hikuroa, 2017; Paul-Burke et al., 2018). Mātauranga iaiao (Māori environmental knowledge) is both traditional and contemporary, and reflects the totality of Māori interaction/experiences interacting with the environment during their occupation of Aotearoa-NZ (King et al., 2007).

Mātauranga-a-iwi provides local, place-based knowledge for an iwi's tribal area. This knowledge can provide intimate understandings of landscape dynamics and change through time. Mātauranga-a-iwi is informed directly by whakapapa (ancestry), because local landscape features are seen as kin through genealogical ties (Wilkinson and Macfarlane, in press; Ruru, 2018). The aim is to live with the environment in an intergenerationally sustainable way, since landscapes are part of the ancestry, in which the landscape and its resources are respected as elders. Interacting with specific landscape features has generated and developed mātauranga-a-iwi, and continues to refine local Indigenous knowledge.

3.1.3 Kaitiakitanga (well-being of people and environment)

In Te Ao Māori, mana whenua (traditional authorities) are the kaitiaki (guardians) of their lands, waters, and physical and cultural environments and waters. They are the guardians of the physical and cultural environments. Kaitiakitanga (guardianship) is a responsibility to maintain the well-being of people and environment. Contemporary kaitiakitanga can be understood as implementation of mātauranga-informed decisions and management (Clapcott et al., 2018; Paul-Burke et al., 2018). It can also be understood as the responsibility to guide research priorities in the interest of the environment and the landscape. For example, studies that consider water quality and quantity and establish baseline minimums for flow (e.g., Tipa, 2009b; Crow et al., 2018; Hikuroa et al., 2018) are expressions of kaitiakitanga in modern research and management.

3.2 Obligations of the Aotearoa New Zealand government to Māori through the Treaty of Waitangi

3.2.1 The Treaty of Waitangi

The Treaty of Waitangi is the founding document of the modern state of Aotearoa-NZ is the Treaty of Waitangi (Hudson and Russell, 2009). The Treaty represents the establishment of a formal relationship between the British Crown and Māori, in which Māori are legal partners of the Crown. Two versions of the text-Treaty exist: one in te reo Māori (Māori language) and one in English. The te reo Māori text was signed in Waitangi on 6 February 1840 by more than 40 Māori chiefs, and was then circulated to other Māori communities around the country (Anderson et al., 2015). Not all chiefs signed the Treaty, but it did receive more than 500 Māori signatures. The Treaty established that Māori taonga (treasures), including mātauranga (Māori knowledge), would be protected and that Māori had the right to participate as active citizens of Aotearoa-NZ. To Māori, the status of the Treaty remains as strong and relevant today as it did in 1840; however, the applicability of the Treaty within modern Aotearoa-NZ has changed (Durie et al. 1989; Hudson and Russel, 2009).

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235 In 1988, the Royal Commission on Social Policy made a gesture to establish interpretations of the Treaty that would
be applicable in modern Aotearoa-NZ society (Durie, 1994; Hudson and Russel, 2009). These interpretations have been further
refined (Waitangi Tribunal, 2016) and are known as the Principles of the Treaty. The Principles of the Treaty, developed by
the Waitangi Tribunal, intend to ensure that interactions between Māori and Crown entities—including research interactions—
are ethical and within the stipulations of the Treaty. Select resource-specific principles (Brierley et al., 2018) indicate that the
right to establish the spiritual and cultural significance of certain landscape features and resources remains with *tangata-mana*
240 *whenua* (traditional people with Indigenous-authorities); (Harmsworth et al., 2016).

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3.2.12 The Treaty in practice

The Principles of the Treaty mandates that scientific investigations must consider the applicability and appropriateness of
including Māori in research projects. Moreover, the Principles of the Treaty ~~appears to reflect~~ the *te reo* Māori (Māori
language) version of the Treaty, which refers to depths of knowledge and implicitly includes science within the construct of
245 *mātauranga*. Several research projects conducted within Aotearoa-NZ over the past few years exemplify the Treaty in practice.
Harmsworth et al. (2016) outline Aotearoa-NZ legislative frameworks that apply the Treaty of Waitangi to modern research
endeavours. Here, we discuss two major advances in culturally responsive legislation.

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3.2.12.1 *Te Manahuna Aoraki Project*

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250 The Department of Conservation (DOC) is Aotearoa-NZ’s government agency for conservation of national heritage, both
natural and historic. DOC has a strict consultation procedure for engaging with *iwi* (tribes), *hapū* (sub-tribes) and
~~*whānau*~~ *whānau* (family groups). The consultation process is meant to uphold DOC’s status as a Treaty partner, and employs
the principles of partnership, protection, redress and reconciliation, and informed decision making (Department of
Conservation, n.d.).

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A modern and on-going example of the DOC consultation process with *iwi* is through *Te Manahuna Aoraki* Project.
255 The players in this project are DOC, the NEXT foundation, Te Rūnanga o Waihao, Te Rūnanga o Moeraki, Te Rūnanga o
Arowhenua, and others (Te Manahuna Aoraki Project, 2018). The *iwi* are official partners, which elevates their status from
stakeholder to decision-maker (Jo McLean, in Booth et al., 2019). The consultation process is not easy, however, as not all
players will have the same priorities. For *iwi* *mana whenua*, spiritual values of the *Te Manahuna* (the Mackenzie basin) are
held as a priority to be conserved, which may be challenging to communicate to their partners (Jo McLean, in Booth et al.,
260 2019). However, both *Pākehā* (European New Zealanders) and Māori parties recognise *Te Manahuna* as a place of vitality,
which can enable mutual respect for partners and the landscape.

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The consultation process is still in its early stages (Jo McLean, in Booth et al., 2019), but, the purpose is to make a
transformational shift in the way that organisations come together to deliver outcomes (Suzette van Aswegen, in Booth et al.,
2019). Though this project is for conservation and management, there are many lessons that can be transferred to geomorphic

265 research. Early consultation, legitimate partnership with *iwi*, sustained discussions and fair consideration of all key players’ views are essential for a successful project that involves Māori and non-Māori researchers.

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3.2.12.2 *Te Awa Tupua*

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In 2017, the Whanganui River on the North Island of Aotearoa-NZ gained the status of legal personhood (Brierley et al., 2018). *Te Awa Tupua* was declared as “an indivisible and living whole from the mountains to the sea, incorporating the Whanganui River and all of its physical and metaphysical elements” (Te Awa Tupua [Whanganui River Claims Settlement] Act, section 13(b), 2017). Granting a river system personhood rights reflects a Māori approach to river system interaction and understanding. After *Te Awa Tupua* was legally recognised, Brierley et al. (2018) defined the geomorphic implications of the act. The authors posited that the river now has the following geomorphic “rights” (Brierley et al., 2018, p.4):

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1. “A right to flowing water, and associated spatial and temporal variability in hydrologic and hydraulic regime.
2. A right to convey sediment, adjusting the balance of erosional and depositional processes in any given reach, and how these reaches fit together at the catchment scale, as materials are transported from “source to sink.”
3. A right to be diverse, reflecting geographic and historical controls upon the inherent geodiversity (i.e., heterogeneity and/or homogeneity) of a river reach.
4. A right to adjust, shaped by mutual interactions between flow, sediment, riparian vegetation, wood, ecosystem engineers, and groundwater that set the dynamic habitat mosaic of river systems.
5. A right to evolve, set by responses to disturbance events and changes to boundary conditions that influence the trajectory of geomorphic adjustment of a river.
6. A right to operate at the catchment scale, as connectivity relations determine how changes to one part of a river system impact elsewhere in the catchment, and at the coastal interface, over what timeframe.
7. A right to be healthy, operating as a living river that maintains its integrity, vigour, and vitality, maximizing its resilience to impacts of disturbance.”

Essentially, Brierley et al. (2018) state that the river has the right to be a river, the right to flow freely and transport sediment from the mountains to the sea. The river has a right to be a living system (Salmond et al., 2019). Brierley et al. (2018) argue that *Te Awa Tupua* was a milestone achievement in river management and geomorphologic research because river scientists created research questions that reflected both societal and environmental values. This act has implications for future legal interactions concerning *mātauranga* Māori, Māori worldview, science, landscape research priorities and conservation efforts (Ruru, 2018; Geddis and Ruru, 2019).

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3.3 Woven spaces—the interface of *mātauranga* Māori and science

3.3.1 The relationship between *mātauranga* and science

295 Like with many Indigenous knowledge systems, *mātauranga* Māori has historically been ‘systematically dismissed and
erased... as being worthless’ (Waitangi Tribunal 1999, as cited in Broughton et al., 2015). However, when expressed in a way
to which Western scientists can relate, it is clear that pre-European Māori generated some of their knowledge in ways consistent
with the scientific method (Cunningham, 2000; Hikuroa, 2017). Over the past decade, select Māori researchers in the physical
sciences (e.g., King et al., 2007; Tipa, 2009; Harmsworth et al., 2016; Hikuroa, 2017; Hikuroa et al., 2018; Paul-Burke et al.,
300 2018) have made strides for advancing *mātauranga* alongside Western science. These researchers have promoted the *mana*
(authority) of *mātauranga* and advocated for its place in national research through their own research endeavours. As a result
of the efforts of these researchers, as well as others in different fields (e.g., Durie, 2004; Smith, 2012; Macfarlane et al., 2015),
the Aotearoa-NZ government now requires an acknowledgement and consideration of research relevance to Māori in many
major grant and funding applications, such as the *Hikina Whakatutuki* Ministry of Business Innovation and Employment’s
305 Endeavour Fund, National Science Challenges and *Te Punaha Hihiko*: Vision Mātauranga Capability Fund (Hikina
Whakatutuki Ministry of Business, Innovation and Employment, n.d.). Notably, in 2011, the Vision Mātauranga policy
statement was incorporated into the Statements of Core Purpose of Crown Research Institutes (CRIs), which requires CRIs to
enable the potential for innovative research with Māori.

Perhaps the major difference between Indigenous knowledge (here, *mātauranga*) and science ~~is~~are perceptions of
310 objectivity. In a scientific worldview, objectivity is essential for making unbiased observations to test hypotheses (Moller,
2009; Crawford, 2009). Facts and values are separated (Hikuroa, 2017). Within In a Māori worldview, humans sit in the heart
of within natural systems, along with all other components (Hikuroa, 2017). In a scientific worldview, objectivity is essential
for making unbiased observations to test hypotheses (Moller, 2009; Crawford, 2009). Facts and values are separated (Hikuroa,
2017). But in the Māori worldview, knowledge is informed by values and values are informed by knowledge. There is no
315 separation between values and facts. Theis reciprocity between values and knowledge facts may be considered another major
difference between *mātauranga* generation and Western scientific knowledge generation. However, because Māori values are
both traditional and contemporary, Māori perspectives have the potential to contribute to innovative research approaches in
which knowledge is co-created considering both Māori and Western values. Understanding this interplay, and acknowledging
and respecting the potential values that Indigenous knowledge can bring to science, is paramount for successful research at the
320 interface (Pigram et al., 2019). Rather than contesting relative validities, Durie (2004) and Peet (2006) demonstrate that work
at the interface can be a space for inventiveness and inspiration. Nevertheless, Mercier (2007) cautions that focusing on the
difference can create a position in which science and Indigenous knowledge can potentially clash.

3.3.1.1 Indigenous ~~k~~Knowledge versus values

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325 Māori values can, in part, be understood as the means by which Māori make sense of and understand their environment
(Marsden, 1989⁹ as cited in Harmsworth and Awatere, 2013). Examples of these values include *ikanga* (cultural protocols),
330 *whakapapa* (genealogy), *tino rangatiratanga* (self-determination), *mana whenua* (traditional authorities),
whānaungatanga (family connections), *kaitiakitanga* (guardianship), *manaakitanga* (acts of care),
whakakotahitanga (respect for differences), *arohatanga* (love, care) and *wairuatanga* (spirituality). (Table 1; Harmsworth
and Awatere, 2013). Māori values directly inform *mātauranga* (knowledge) Māori (Hikuroa, 2017), and *mātauranga* informs
335 Māori values (Harmsworth and Awatere, 2013). But in the Māori worldview, knowledge is informed by values and values are
informed by knowledge. This reciprocity between values and knowledge may be considered a major difference between
mātauranga generation and Western scientific knowledge generation. Western science is informed by truth and evidence,
whereas *mātauranga* is informed by fact and value (Hikuroa, 2017). However, because *mātauranga* Māori and Māori values
are both traditional and contemporary, Māori perspectives have the potential to contribute to innovative research approaches
in which knowledge is co-created considering both Māori and Western values.

335 3.3.2 Identifying mMutual research needs and benefits

In 2007, As discussed earlier, (The Aotearoa-NZ government outlined a goal for research at the interface of Western science
and *mātauranga* Māori in their 2007-Vision Mātauranga statement: *To unlock the innovation potential of Māori knowledge,
resources and people to assist New Zealanders to create a better future* (Ministry of Research, Science and Technology,
340 2007). One of the four Vision Mātauranga research themes is *Taiao*: Achieving Environmental Sustainability through *iwi* and
Hapū Relationships with Land and Sea. This theme explores *iwi* (tribe) and *hapū* (sub-tribe) relationships with land and
seascapes, and encourages Māori involvement in research relating to the sustainability of these environments. This official
document is a tool for researchers considering different projects and their applicability to Māori. Though Vision Mātauranga
does not explicitly outline how to conduct research at the interface (Macfarlane and Macfarlane, 2018), it establishes the
345 context for bicultural approaches to research.

iwi management plans (IMPs) and *iwi* environmental management plans (IEMPs) are official documents that can be
used to define *iwi*-identified research needs. Extensive work has been completed to highlight the utility of IMPs as guides and
frameworks for engagement with Māori (Saunders, 2017). IMPs provide clear, official documentation of *iwi* values and
interests that can be considered in research (Waikato Regional Council, 2019). Many IMPs and IEMPs discuss *iwi* goals for
350 minimum river flows and flood hazards (e.g., Tipa et al., 2014), which are specifically relevant to geomorphologists. Some
plans have sections with specific goals for rivers (e.g., Waikato-Tainui Te Kauhanganui Incorporated, 2013) or catchments
(e.g., Te Rūnanga o Kaikōura et al., 2005; Jolly and Ngā Papatipu Rūnanga Working Group, 2013). Most IMPs are focused
on improving the *mauri* (life force, vitality) of tribal landscapes.

IMPs provide the opportunity for *mātauranga* Māori to be included in planning and research projects as a knowledge
355 system parallel to Western science (Saunders, 2017). In addition to outlining key values and interests, IMPs provide specific
guidance to researchers and planners on how each *iwi* (tribe) proposes consultation and engagement activities might proceed.

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3.3.3 Potential challenges and risks of conducting research at the cultural interface

It is essential to note that there may be circumstances when it is inappropriate to draw upon both Western science and mātauranga Māori- (Mercier, 2007). Mika and Stewart (2017) in fact advocate that perhaps it is better to maintain a binary research sphere all together, wherein Western and Māori approaches are kept separate. There may be situations when one explanation (i.e. Indigenous) for an event does not align with another explanation (i.e. Western). For example, research concerning oral histories of meteor impact craters in Australia indicate that it is possible that events recorded in oral histories cannot be correlated with physical scientific evidence (e.g., Hamacher and Norris, 2010) or that some landscapes do not have associated oral histories (e.g., Hamacher and Goldsmith, 2013). In cases such as these, it is essential to maintain mutual respect by not using one method to prove the other method wrong (Durie, 2004). Accordingly, science and mātauranga should not be used to disprove each other- wrong (Hikuroa et al., 2011; Hikuroa, 2017). It becomes the researcher’s responsibility to determine which method-approach provides the stronger supporting evidence, but not by dismissing one knowledge base over the other due to to the exclusion of identifying and discussing inconsistencies and/or discrepancies. If done appropriately, it is possible for the two approaches to strengthen one another and provide better outcomes for all involved (Durie, 2007). These could be opportunities to explore the richness and contingency of oral traditions separate from scientifically-determined landscape events. Equally, oral traditions could be the only record of something that was perishable in the geomorphological/geological record. In cases where scientific findings and Indigenous knowledge does align-with scientific findings, the supporting evidence is purely stronger.

A Māori worldview accepts that there can be more than one explanation for an event or landform. The concept of contested knowledges and opposing viewpoints between Indigenous communities was an accepted part of life (Smith, 1999). This led to creating an environment of tolerance, mutual respect and reciprocity between Indigenous communities. Multiple ideas or explanations for an event is also common in the field of geomorphology, where landscape formation can be explored through multiple working hypotheses via the principle of equifinality. While conducting research at the interface poses many challenges, it reveals similarities such as these and presents opportunities to generate corroborative evidence for events and landforms.

4. Frameworks and models for incorporating mātauranga Māori alongside geomorphic research

Extensive work has been done by Māori researchers to develop frameworks and models for including Māori knowledge, values and tikanga (cultural protocols) in research. Smith (1992) established and promoted ways for non-Māori researchers to engage with Māori and maintain a standard of cultural responsibility. Smith (2012) later described kaupapa Māori research, or research by Māori for Māori, and detailed appropriate ways for Māori to lead their own research aspirations. The methodologies/models proposed by Smith (1992, 2012) can be thought of as frameworks; or methodologies; or guiding principles according to which researchers define research questions, select tools and approaches to address questions, and plan analyses (Harding, 1987; Smith, 2012).

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390 Harmsworth et al. (2016) and Rainforth and Harmsworth (2019) discuss models for integrating Māori values into
environmental research. The models can be thought of as methods: actions or procedures by which a researcher addresses core
research questions and collects data (Smith, 2012). These models reviewed by Harmsworth et al. (2016) and Rainforth and
Harmsworth (2019) are Indigenous approaches to research, which include Indigenous values and protocols (Smith, 2012). ~~can~~
~~be thought of as methods, actions or procedures by which a researcher addresses the core research questions and collects data~~
~~(Smith, 2012).~~ Indigenous approaches to research like these are commonly structured as models or decision support tools
395 (Morgan, 2006) that empower Indigenous values alongside Western practices (Hikuroa et al., 2018). Similarly, Rainforth and
Harmsworth (2019) provide a Harmsworth et al. (2016) and Rainforth and Harmsworth (2019) detailed and extensive review
of tools, frameworks and methods that have been developed to include *jwi* and *hapū* values into freshwater management. Like
international research that aims to weave Indigenous knowledge and values with Western scientific techniques, most of the
frameworks reviewed by Rainforth and Harmsworth (2019) reflect indicate that a strong effort to include *mātauranga* Māori
400 has been made in ecological and environmental assessments, but reveal a lack of dearth of studies that studies that weave
mātauranga Māori with geomorphic research. The models that Harmsworth et al. (2016) and Rainforth and Harmsworth (2019)
discuss are Indigenous approaches to research. These approaches include Indigenous values and cultural protocols (Smith,
2012). Indigenous approaches to research like these are commonly structured as models or decision support tools (Morgan,
2006) that empower Indigenous values alongside Western practices (Hikuroa et al., 2018).

405 This section introduces three theoretical frameworks (i.e. methodologies) for including or considering *mātauranga*
Māori in geomorphic research. The frameworks discussed here have been previously analysed in the health and education
contexts (e.g., Macfarlane et al., 2015; Macfarlane and Macfarlane, 2018). We discuss how each theoretical framework could
be transferrable to geomorphic research. Keeping in mind that *mātauranga* and values cannot always be separated, we then
introduce three models (i.e. methods) for including Māori values within science conducted according to Western practices and
410 highlight how each model could be ~~used~~transferred to in geomorphic researchology. A critical assessment of the frameworks
and models is provided in section 5, and a discussion of how these frameworks and models can be applied outside of Aotearoa-
NZ is provided in section 6.

4.1 Theoretical frameworks for including *mātauranga* Māori in geomorphic research

415 The following theoretical frameworks are ~~theoretical~~ guiding frameworks-methodologies for including *mātauranga* Māori in
research projects. The three frameworks reviewed here have been discussed by Macfarlane and Macfarlane (2018), but here
we also discuss their applicability to geomorphology. Although these frameworks were developed and promoted by researchers
seeking better outcomes in the health and education sphere, we do not believe they are necessarily only applicable to those
spaces.

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4.1.1 He Poutama Whakamana (*mirror-images of knowledge and understanding*)

435 The mirror-imaged panel symbolism of *Poutama Tukutuku*, as previously mentioned, are mirror-imaged panels. This imagery, which pre-represents a metaphorical space for the scientific method to operate alongside the kaupapa Māori theme (Fig. 3b). There is no hindrance to the scientific methodBoth themes can maintain their individual integrity and are strengthened during each level of the framework by (Fig. 3b), but it requires additional “check-ins” throughout the process that make ensure that the the Vision Mātauranga principles are being reflected in both themes. Adequately addressing Vision Mātauranga principles in both themes has the potential to ultimately produce co-created knowledge (Fig. 3c). This approach 440 also has the potential to emphasize the differences between the two approaches (e.g., Mercier, 2007), which may in its own

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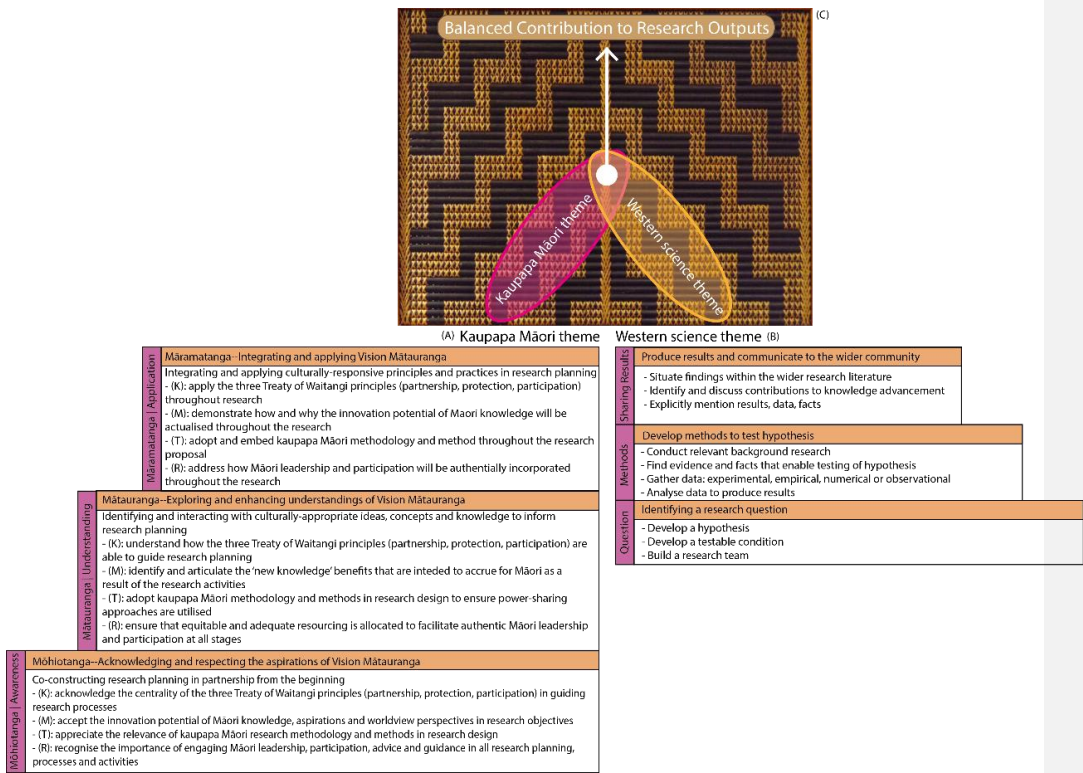


Figure 3. A) The *He Poutama Whakamana* framework (Macfarlane and Macfarlane, 2018) mirrored by B) the scientific method theory on the opposite side of the *Poutama Tukutuku*. C) represents upwards growth towards co-creation of knowledge.

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right lead to better understandings and outcomes. *He Poutama Whakamana* is suitable for geomorphic research because it is open-ended and not specialised for any one field of research. It welcomes research conducted under the guidance of the Treaty of Waitangi, and as long as each step of the framework is addressed, the research will potentially be culturally responsible and safe.

445 4.1.2 IBRLA (initiation, benefits, representation, legitimization, accountability)

The IBRLA (initiation, benefits, representation, legitimization, accountability)-framework is also an open-ended research framework that aims to ensure that Māori thinking and voice are included in research involving Māori (Bishop, 1996;

Table 3. The IBRLA framework. Adapted from Macfarlane and Macfarlane, 2018.

Table 3: The IBRLA framework. Adapted from Macfarlane and Macfarlane, 2018.

	Principle	Accountability Questions
I	Initiation	<ul style="list-style-type: none">Who conceptualised and initiated this research project?How did Māori participate in the conceptualisation and initiation process?How was the agreement to proceed with the research achieved?
B	Benefits	<ul style="list-style-type: none">How will the research (process and outcomes) accrue benefits for Māori?How has information been shared with Māori about the intended benefits?How will these benefits be determined and measured—and by whom?
R	Representation	<ul style="list-style-type: none">Whose ideas will be represented in the methodology, design and approach?How will Māori thinking and knowledge be represented at all research phases?How will this be monitored so that ongoing agreement/partnership is maintained?
L	Legitimation	<ul style="list-style-type: none">Who will legitimate the analysis and interpretation of information/research data?How will Māori understandings be legitimately represented?How will this be structured so that research fidelity is achieved/protected?
A	Accountability	<ul style="list-style-type: none">Who is accountable to whom—and in what ways?How will on-going and mutual accountability be built into the research process?How will this be monitored and evaluated to ensure safety for all stakeholders?

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Macfarlane and Macfarlane, 2018). It features a series of accountability questions within each component of the framework (Table 3). These questions are meant to guide researchers and help ensure that Māori knowledge is being included throughout the research project. These questions, such as “How did Māori participate in the conceptualisation and initiation process?” or “How will Māori thinking and knowledge be represented at all research phases?” hold researchers responsible for ensuring that Māori involvement and contribution is not only included but prioritised in the research. Principles of the Treaty of Waitangi—partnership, participation and protection—feature throughout the IBRLA framework. In this framework, Again, there is no hindrance to
450 using the scientific method within this research framework, but the accountability questions help ensure that mātauranga Māori is respected and upheld throughout the research process.

Just as the scientific method often encourages revisiting hypotheses, the IBRLA framework encourages researcher reflection during the concept design stage (similar to hypothesis formation and method development) through to the end of the research. The intent of IBRLA is to produce collaborative research stories (Bishop, 1996). This framework can provide a sense of researcher security when including Māori knowledge, while maintaining the integrity of the scientific method.

4.1.3 He Awa Whiria (a braided rivers approach)

The He Awa Whiria methodologyframework is based on the imagery of dynamic-braided river systems (iconic landscape features throughout Aotearoa-NZ) and traditional woven baskets (Fig. 4). explicitly recognises the benefits of both the Western science paradigm and kaupapa Māori principles.A research project designed under the He Awa Whiria methodology framework has two streams, one, representing the aforementioned approaches to research Western science and the other representing Māori knowledge(Fig. 4). Like a braided river, the streams may diverge, converge, and meander, but ultimately, they both flow in the same direction and towards the same goal. The streams are accompanied by the metaphor of knowledge kete (baskets), which is inspired by the Māori whakatauki (saying/proverb) “nā tō rourou, nā taku rourou, — ka ora ai te iwi” (“with your food basket and my food basket, the people will thrive”). These symbols represent the weaving of Western science and Indigenous knowledge through a Māori worldview, in which the integrity and sovereignty of each is respected.

Throughout the duration of the a research project, parts of one stream may widen or increase in strength while the other narrows and assumes a lighter role. At other times, the weaker stream may gain momentum, shifting the balance of the overall research project in the other direction. The streams may wane or grow in strength, change directions, or even die out in places, as do the channels in a braided river. Both streams have the same objective, which is to provide balanced contributions to research outcomes. It is accepted that the streams may spend more time apart than together (Macfarlane and Macfarlane, 2018). converge and diverge throughout the project, and the moments of convergence are times of learning. Though the streams may wane or grow in strength, change directions, or even die out in places (as the channels in a braided river do), both streams have the same objective, which is to provide balanced contributions to research outcomes. It is the researcher’s role to manage how and when the two streams must converge, and when it is appropriate for them to diverge. It

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480 is the also researcher’s responsibility to make the moments of convergence times of learning. Ultimately, when research conclusions are drawn, the ~~claims~~_y must ~~be supported by both streams~~_{represent co-creation of knowledge using both streams.}

485 The *He Ara Whiria* methodology allows for flexibility within a research project. It recognises the benefits of both the Western science paradigm and kaupapa Māori principles and allows the research team to determine their own checks and balances. ~~It enables Western science to stay true to the scientific method.~~ ~~It also~~ provides grounds for *mātauranga* Māori input to guide and focus the Western science analysis. Wilkinson and Macfarlane (in press) demonstrate that the *He Ara Whiria* method framework can be applied to geomorphic studies by allowing the two knowledge ~~two~~ streams to operate both independently and collaboratively. The *He Ara Whiria* methodology supports a culturally responsible and responsive approach to research and allows for variable approaches to research depending on the specific topic (Macfarlane et al., 2015; Macfarlane and Macfarlane, 2018). Methodological adaptability is essential for conducting research with Māori, because different Māori groups will have different values, priorities and interests when it comes to pursuing research questions.

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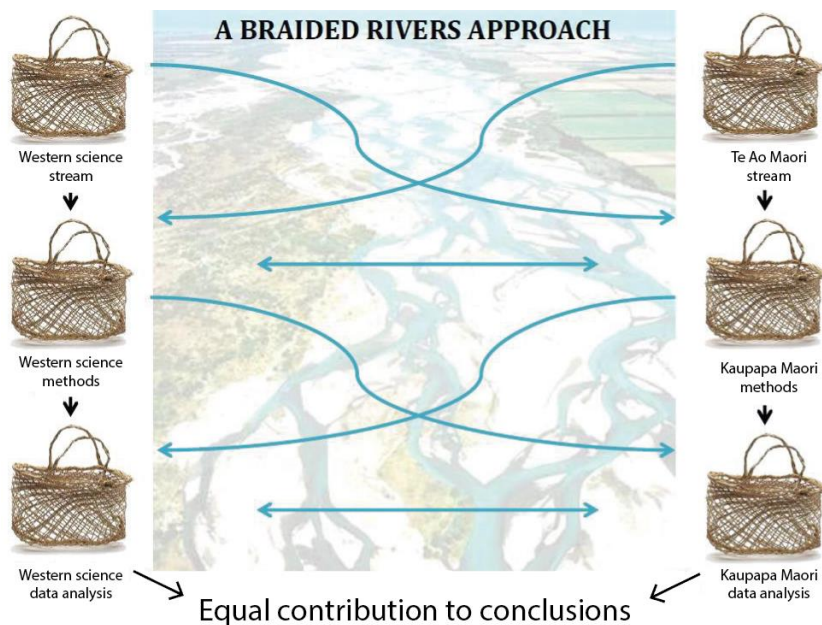


Figure 4. The *He Awa Whiria* framework. The blue lines represent knowledge exchange and development as the two streams converge and re-converge throughout the research programme. Modified from Macfarlane et al., 2015.

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4.2 Models for including Māori values in geomorphic research

The following models are step-by-step processes-methods for explicitly including Māori values into scientific research. Many of these models were originally designed to assist with environmental decision-making and management. These models can be incorporated into the knowledge-inclusion frameworks above, creating research projects with nested frameworks (methodologies) and models (methods).methods and methodologies.

4.2.1 *Mauri Model*

The *Mauri Model* was developed as a tool for creating sustainable solutions for environmental decision-making in Aotearoa-NZ (Morgan, 2006; Faaui et al., 2017). It is grounded in the Māori concept of *mauri*, which can be best understood as an ethereal bond that links all elements of the natural world, the binding force between the physical and the metaphysical, the life-supporting capacity of soil and water. The *Mauri Model* is a decision-making *framework-model* and provides a template for the explicit inclusion of Indigenous values with Western knowledge (Morgan, 2006; Hikuroa et al., 2011). The aim of the *Mauri Model* is to define the degree of sustainability of proposed projects or activities by assessing the impact of an action on the *mauri* of an area (Hikuroa et al., 2011). The model considers a wide range of environmental, cultural, social, and economic indicators for use in analysis. Each indicator receives a value from a scale of -2 to +2, with -2 being *mauri noho/mate* (denigrated), -1 being *mauri heke* (diminishing), 0 being maintaining, 1 being *mauri piki* (enhancing) and 2 being *mauri tu/ora* (restored) (Fig. 5). The *Mauri Model* can work independently of science but is most effective when science is integrated into the analysis.

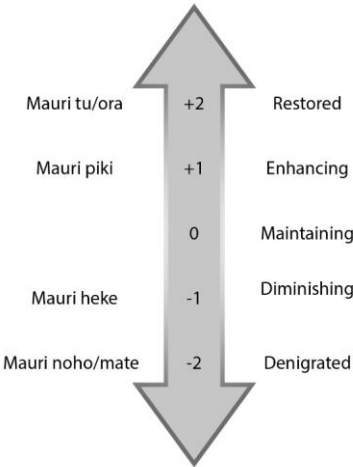


Figure 5. “*Mauri Meter*” (Morgan, 2006);
Infographic of the valuing system in the *Mauri*
Model. Modified from Hikuroa et al., 2011.

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510 To complete the assessment, each indicator is listed in a table and the integer values of each indicator are summed to
determine the impact on the area of interest's *Mauri*. ~~This model provides a semi-quantitative assessment of the impact~~
~~on Mauri. This~~ method could be appealing to researchers or project managers working in bicultural spaces because it combines
stakeholder interests with Indigenous values in a semi-quantitative *framework-model* (Morgan and Fa'aui, 2018).

515 Morgan (2006) originally developed the *Mauri* Model to create a tool that could be utilised to include Māori input on
water management issues in Aotearoa-NZ. It has since been used nationally and internationally to conduct environmental
assessments in post-disaster maritime settings (Faau et al., 2017), in geothermal development areas (Hikuroa et al., 2010) in
areas of high anthropogenic modification (Hikuroa et al., 2018) and in dam impact studies (Morgan et al., 2012). Hikuroa et
al. (2018) provide an extensive list of studies that have utilised the *Mauri* Model both within and beyond Aotearoa-NZ.

4.2.1.1 Transferability to geomorphology (*Mauri model*)

520 Although the *Mauri* Model was designed as an assessment for the impact of human activities on an area, the ideas of
denigrated and diminishing, or ~~enhancing-enhanced~~ and ~~restoring~~ landscapes can be transferred to geomorphology research.
For example, in 2016 an M_w 7.8 earthquake struck the Kaikōura region on the South Island of Aotearoa-NZ (Hamling et al.,
2017). The earthquake caused over 20,000 landslides that delivered mass amounts of sediment to river catchments (Massey et
al., 2018). Fine sediment has been carried to the sea, and has smothered and suffocated tidal to intertidal shallow-marine
ecosystems (Schiel et al., 2019). ~~HCoupled-high~~ sedimentation ~~coupled with~~ and coastal uplift has caused the
525 biogeomorphology of the region to change dramatically following the earthquake (Schiel et al., 2019). The ongoing stability
of marine species has the potential to indicate sedimentation rates and the effect that the geomorphology of the area has on
marine populations. In a study of *Te Awa o te Atua* (Tarawera River), Hikuroa et al. (2018) show that sedimentation is a
contributing factor in the *Mauri* ~~MM~~Model assessment. Therefore, we hypothesise that the *Mauri* ~~MM~~Model could be applied to
research investigating the effects of a natural geologic ~~and-or~~ geomorphic event (rather than a specifically human-induced act)
530 on an ecosystem or landscape.

4.2.2 Cultural Flow Preference Study

535 The Cultural Flow Preference Study (CFPS) model was developed as a tool for Māori to assess their ability to engage in
cultural practices within catchments at certain river flow levels (Tipa and Nelson, 2012) and to engage with freshwater resource
management decisions (Crow et al., 2018). The CFPS model falls under the process of Cultural Opportunity Mapping,
Assessments and Responses (COMAR), which are integrated processes that empower *mana whenua* (traditional authorities)
to engage in freshwater studies and management (Tipa and Nelson, 2008). ~~A CFPS can be used to help Māori engage with~~
~~research projects and management plans for freshwater environments~~ (Crow et al., 2018).

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As the CFPS is heavily site-specific, it demonstrates the benefits that *iwi* (tribe) and *hapū* (sub-tribe) and *iwi* knowledge and values can bring to modern river management and scientific endeavours (Tipa, 2009b; Crow et al., 2018). The CFPS methodology accounts for variations in cultural values between *whānau* (family groupings), *hapū* and *iwi* by providing a method framework that can be transferred and applied for different studies. The first step of a CFPS is to identify the *tangata whenua* team (Māori or Indigenous participants), who act as the leading experts for a specific river or area, and determine the cultural values held by that team. After the *tangata whenua* team has been formed, a series of steps are followed in order to create a CFPS (Fig. 6). The ultimate aim of a CFPS is to link cultural values to variations in river flow, and to determine how cultural values change depending on the flow of the river.

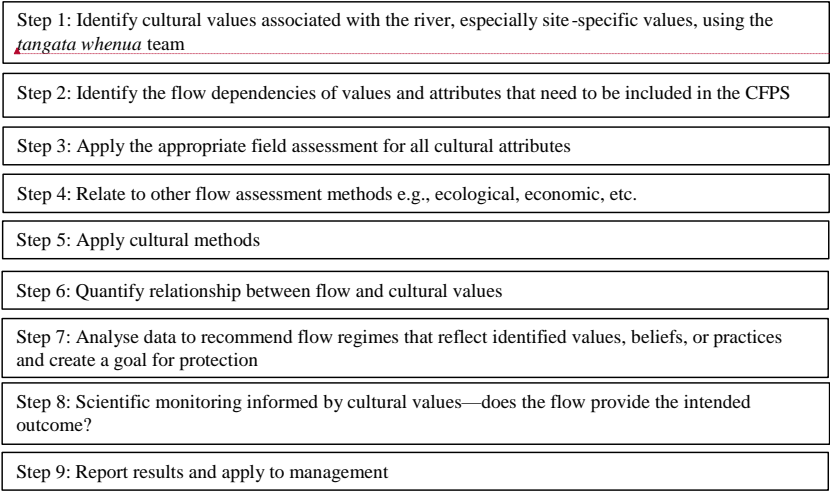


Figure 6. Steps to complete a CFPS. Modified from Crow et al., 2018.

4.2.2.1 Transferability to geomorphology (CFPS)

CFPSs are applicable to geomorphic studies, specifically fluvial geomorphology. Tipa and Nelson (2012) demonstrate the utility of applying a CFPS in a study concerning the Kakaunui Catchment, South Island Aotearoa-NZ. During this process, they followed the CFPS method to: 1) identify their *tangata whenua* team (Te Rūnanga o Moeraki); 2) have the *tangata whenua* team define their cultural association with the river; 3) conduct a participatory mapping exercise to identify how the local *iwi* (tribe) valued the river, what hydrological characteristics the local *iwi* believed to be essential to protect those values, how current and historic hydrologic and geomorphic characteristics differ, and how the current flow rates affect cultural values and

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uses; 4) identify and analyse *tangata whenua*-identified flow issues; and 5) calculate minimum flows that would satisfy cultural flow preferences. Through this method, Tipa and Nelson (2012) concluded that the current minimum flow in the Kakaunui Catchment (250 L/s) is likely too low to maintain Te Rūnanga o Moeraki's values within the catchment. This study allowed geomorphic, hydraulic, ecologic and cultural values to be considered in tandem. Identified *tangata whenua* values helped drive the research intentions and resulted in an outcome that could have application in future management of the Kakaunui catchment.

4.2.3 Sustainability Assessment Method

The Sustainability Assessment Method (SAM) is another environmental monitoring tool for assessing freshwater catchment healths that can be used to include Māori values alongside more traditional monitoring assessments (Tipa, 2009b). The SAM explicitly includes social, cultural, economic and environmental values. This multi-dimensional assessment is laid-out in a step-by-step guideline that enables researchers to document cultural values and associations with river catchments alongside scientific monitoring techniques (Fig. 7). The cultural dimension of this model focuses strongly on water quality and typically uses *mahinga kai* (traditional food gathering practices and places) as an the most important indicator of the health of waterways.

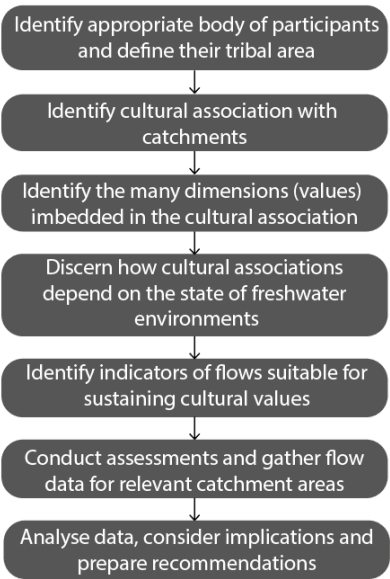


Figure 7. Steps in a SAM. Modified from Tipa, 2009.

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The SAM follows a similar trajectory as other research frameworks involving Māori. The first step is to identify the appropriate group of *tangata whenua* participants, document their cultural relationships with a catchment, and ultimately determine baseline water quality and quantity standards compliant with Māori preferences. Tipa (2009) suggests that this model can be used as an alternative to strictly Western-style freshwater assessments, but it is possible that this model could be included alongside a Western-style analysis to build a more comprehensive assessment. Māori involvement is required, and the final step—analyse data, evaluate implications, prepare strategies and recommendations—should include both Māori and Western interpretations of the results.

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4.2.3.1 Transferability to geomorphology (SAM)

In 2005, the SAM was adapted for use in an assessment of New Zealand river catchments from Māori perspectives (Tipa 2007 as cited in Tipa, 2009). Lists of Māori values, beliefs and practices associated with three river catchments in the South Island of Aotearoa-NZ were accumulated from analyses of contemporary writings and historical accounts. From the lists, tables were constructed to describe all concepts that ~~described~~*portrayed* a value, belief or practice that surfaced from the initial analyses. Using the SAM allowed Māori concepts to be organised in a way that each element could be examined separately, in the context of each individual river. Beauty, *mahinga kai*, water quality and *Ki Uta Ki Tai* (from the mountains to the sea) are a few examples of the many identified by *tangata whenua* as important values within these catchments (Tipa, 2009). The result of this exercise was to show that the SAM could give resource managers the opportunity to consider cultural values alongside westernised resource management priorities. The SAM promotes a tool for policy makers that incorporates a place-based approach, allowing for more specialised outcomes.

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As indicated by Tipa (2009), it would be possible to also include geomorphic values alongside a SAM analysis. Recalling Brierly et al.'s (2018) geomorphic rights of the river, the SAM would enable river geomorphologists and managers to apply equitable consideration to both Indigenous and scientific values in river management strategies or research projects. The requirement would be that the team includes members who are experts—either individually or collectively—in both *mātauranga* and scientific techniques. That way, geomorphic values can be considered alongside the cultural values proposed by the *tangata whenua* team. This sort of approach could yield better river management outcomes for both Māori and non-Māori.

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5. Critical assessment of existing frameworks in different conditions Embarking on the bicultural research journey

These frameworks and models ~~reviewed here~~ *do, ideally, -ideally-* require Māori guidance and Māori participation on the research team. In many cases, it may be appropriate to select a theoretical framework to guide research methodologies and, if appropriate, apply a value-based model within the research framework to act as a guide for the project's methods. This section provides an analysis of the presented theoretical knowledge frameworks and the value-based models, offers recommendations

for geomorphic subdisciplines, and provides information about how researchers can identify research questions using Māori priorities.

5.1 Knowledge versus values revisited

The theoretical research frameworks (e.g. *He Poutama Whakamana*, IBRLA, *He Awa Whiria*) are systems to weave Māori worldview and knowledge into or alongside many research disciplines, including geomorphology. These frameworks can be thought of as methodologies, or philosophical processes according to which research is conducted (Harding, 1987; Smith, 2012). These frameworks support and promote Māori knowledge and ensure that *mātauranga* is prioritised throughout the research process.

Explicitly including Māori values into research can be achieved by nesting value-based models (e.g., *Mauri Model*, CFPS, SAM) within the aforementioned research frameworks. Value-based models can be thought of as methods, or specific steps, actions or procedures that researchers can follow to answer core research questions and collect data (Smith, 2012). Indigenous methods include values, customs, protocols and existing knowledge. When value-based models are nested in Māori focused theoretical research frameworks, the interconnectedness between values and knowledge becomes apparent.

There may be times when it is easier for non-Māori researchers to include Māori knowledge by way of Māori values. Value-based models are an adequate way to follow step-by-step processes (similar to research processes produced according to the scientific method) that address Māori ways of knowing and living. However, regardless of how Māori knowledge is included, it is ideal to have a Māori researcher on the project leadership team and to have initial consultations with university or research organisation *whi* engagement and support teams. Early Māori involvement is key for identifying appropriate *tangata whenua* groups, who can aid in new knowledge generation (Broughton et al., 2015).

5.1.2 Framework recommendations for subdisciplines

The theoretical research frameworks (e.g. *He Poutama Whakamana*, IBRLA, *He Awa Whiria*) are methodologies for weaving Māori worldview and knowledge into or alongside many research disciplines, including geomorphology. These frameworks support and promote Māori knowledge and ensure that *mātauranga* is prioritised throughout the research process. The three theoretical frameworks presented here all have the ability to be transferred to geomorphic research. They do not preclude researchers from using the scientific method to produce knowledge, but they do require that researchers also use a *kaupapa* Māori approach to also co-create knowledge with Māori.

It may be best to select theoretical frameworks based on the distribution of Māori to non-Māori researchers involved in the research project. The *He Poutama Whakamana* and IBRLA models may be most appropriate for research teams where the research team has a majority of non-Māori leadership, because they are not strictly expressed through a Māori worldview. These frameworks/policies are rooted in Aotearoa-NZ government policy—the Treaty of Waitangi and Vision Mātauranga—and provide explicit checks and balances for researchers. Researcher reflection is a major element of these frameworks. The *He Awa Whiria* model-framework may be suitable for research teams comprising any ratio of Māori to non-Māori leaders.

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630 Because the two research streams converge, diverge, and act dynamically for the entirety of the project (Macfarlane et al., 2015; Macfarlane and Macfarlane, 2018), it may be possible for one stream to have a larger sub-leadership team than the other. This framework specifically allows for *mātauranga* Māori to focus the Western science stream. This balance will vary from project to project, but a project will successfully adhere to this framework as long as the interactions that do occur between the two streams foster learning and new knowledge generation (Macfarlane and Macfarlane, 2018).

635 ~~So what~~So, w~~hich~~ framework might a glaciologist, or a fluvial geomorphologist, or a pedologist, choose to ensure that they include Māori knowledge in their research? Selecting the right framework will stem from conversations with the appropriate *iwi* groups or Māori researchers early in the research process, and it will depend on the expertise of the research team. There is a common theme throughout frameworks and ~~value-based~~models that the first step is to identify the appropriate group of Māori participants, or *tangata whenua*, to act as the leading experts for their tribal areas. Once these individuals are identified, framework selection can happen cooperatively between scientists and *tangata whenua*. Each of the frameworks discussed here allow flexibility within the project and allow *kaupapa* Māori principles to excel alongside the scientific method.

640 We therefore propose that framework selection must be done on a case-by-case basis, and the correct framework for any given research endeavour will be the one that suits all parties.

5.2 Model application to include Indigenous values

645 Explicitly including Māori values in research can be achieved by nesting value-based models (e.g., *Mauri Model*, CFPS, SAM) within the aforementioned theoretical frameworks. When value-based models are nested in Māori-focused theoretical frameworks, the interconnectedness between values and knowledge becomes apparent.

650 The models are useful tools to assist non-Māori researchers in including Māori knowledge by way of Māori values. Value-based models are an adequate way to follow step-by-step processes (similar to research processes produced according to the scientific method) that address Māori ways of knowing and living. The *Mauri Model*, CFPS, and SAM allow for explicit inclusion of *iwi*-identified cultural, environmental, and research values in geomorphic investigations. Model selection, like framework selection, will depend on the research questions at hand and must be done on a case-by-case basis as a joint decision between the Māori community from whom the *mātauranga* is sourced. Regardless of how Māori knowledge is included, -it is essentialideal to have a Māori researcher on the project leadership team in-order-to avoidminimise risk of cultural misrepresentation or appropriation of knowledge. Early consultations with university or research organisation *iwi* engagement and support teams is key for identifying appropriate *tangata whenua* groups, who can aid in new knowledge generation (Broughton et al., 2015).

5.3 Guiding resources for initiating projects in Aotearoa-NZ

As previously discussed, many *iwi* (tribes) and *hapū* (sub-tribes) in Aotearoa-NZ have published *iwi* management plans or *iwi* environmental management plans that can outline research priorities for scientists (Saunders, 2017). Many IMPs contain information specifically relevant to geomorphologists. For example, most IMPs discuss *iwi* goals for minimum river flows

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660 and mitigating flood hazards (e.g., Tipa et al., 2014). Other iwi environmental management plans have sections with specific goals for rivers (e.g., Waikato-Tainui Te Kauhanganui Incorporated, 2013) or catchments (e.g., Te Rūnanga o Kaikōura et al., 2005; Jolly and Ngā Papatipu Rūnanga Working Group, 2013). Most IMPs focus on improving the mauri (life force, vitality) of tribal-landscapes over which the authoring organisation (typically a rūnanga, tribal council) possesses kaitiakitanga (guardianship). Researchers can use information outlined in IMPs and IEMPs to identify the appropriate research leadership

665 team and select the appropriate research framework.

Research funding guidelines for projects that aim to include mātauranga Māori alongside Western science can be found through Aotearoa-NZ’s Ministry of Research, Science and Technology. Specifically, the Ministry of Business, Innovation and Education (MBIE) operates Te Punaha Hihiko, the Vision Mātauranga Capability Fund, which provides guidelines for research projects in its application process (Ministry of Research, Science and Technology, 2007). The Marsden Fund, through the Royal Society of New Zealand, also provides for how proposals should include consideration of Māori involvement in research (Royal Society Te Apārangi, n.d.).

Many universities and research organisations have iwi engagement and support teams. These teams are an excellent resource for gaining guidance on identifying the best tangata whenua team for research needs, and how to appropriately engage with that iwi or hapū. In Aotearoa-NZ, the universities and CRIs, in particular, have excellent resources for connecting researchers with Māori. We recommend early and, ideally, regular interaction with these resource groups. -It is worth noting that an argument exists to make Māori representation on research project teams mandatory, but ultimately, forcing Māori involvement runs the risk of perpetuating colonizing practices. Instead, we maintain that the Māori community should decide how much—or how little—they wish to contribute to research projects. Engagement and support teams will be able to advise on this subject.

680 **6. Lessons for the international geomorphology community**

Indigenous knowledge around the globe is a valid source of information because it has endured for generations, keeping populations alive and securing their livelihoods. Moreover, Indigenous knowledge has been shown to be accurate and precise (Hikuroa, 2017). In this section, we outline some direct benefits of including Indigenous knowledge in geomorphic research, discuss how the frameworks detailed in this review can be adapted for use outside of Aotearoa-NZ, and discuss how Indigenous knowledge and geomorphic research can and are working together to inform sustainability policy and legislation.

6.1 Direct benefits to geomorphology

A clear benefit to geomorphology is the temporal extension of observations of geomorphic events into pre-history. The 400-year volcanic record discussed by Swanson (2008) and the cycles of flood and channel avulsion evaluated by Hikuroa (2017) indicate that Indigenous knowledge can bolster scientifically-investigated geomorphic histories. King and Goff (2006) further demonstrated that Māori oral histories frequently discuss multiple geomorphic phenomena happening in tandem or as

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695 cascading events. Recognition of the interconnectedness of landscape processes is a common theme in many Indigenous societies (Riggs, 2005) and this recognition has resulted in a way of life that responds to, interacts with and learns from concurrent or cascading suites of local landscape processes.

700 Another key benefit of including Indigenous knowledge in geomorphic endeavours is the opportunity to co-create new approaches to research that build holistic and more complete understandings of landscape processes, ~~with Indigenous knowledge and traditional narratives providing signposts for initiating and conducting geomorphic research.~~ Contemporary Indigenous knowledge and narratives can provide signposts for initiating and conducting geomorphic research by indicating geographic areas or research questions that are of interest to Indigenous groups. The concept of ‘ethnogeomorphology’ (Wilcock and Brierley, 2012; Wilcock et al., 2013) draws upon modern Indigenous knowledge and relationships with landscapes to guide geomorphic research questions and methodologies. The dynamic and adaptive nature of Indigenous knowledge generation (Berkes, 2009) has the potential to ~~guide-influence flexible-adaptive~~ research methods, which ~~are well suited to the interdisciplinary field of geomorphology.~~ Flexible research methods, in turn, have the potential to generate robust data collection with information from a variety of sources.

705 A prime example of how ~~flexible-adaptive~~ research methods incorporating Indigenous knowledge can provide significant contributions to geomorphic research is the New Zealand Palaeotsunami Database. The database aims to catalogue all tsunamis that occurred prior to written historical records and uses three types of evidence to identify palaeotsunami events: sedimentary/artefactual (“primary”), geomorphic (“secondary”) and anthropological/~~pūrākau~~ (“cultural”) (Goff, 2008; New Zealand Palaeotsunami Database, 2017). The cultural information allowed the database compilers to better constrain the age of palaeotsunami events by dating archaeological sites that were associated with the cultural information (Goff, 2008). A typical prehistoric Māori response to big waves was to abandon coastal settlements and move to higher elevations (Goff and Chagué-Goff, 2015). Cultural knowledge of the locations of abandoned sites allowed researchers to conduct archaeological investigations and date the time at which such sites had been occupied, thus providing a well-constrained date for the tsunami event. Māori ~~pūrākau~~ (oral histories/stories) often provide even more detailed information (McFadgen and Goff, 2007); ~~Goff and Chagué-Goff, 2015~~. Stories of ~~taniwha~~ (supernatural creatures in Māori mythology) may indicate big wave events that wreaked havoc on coastal communities, causing changes in settlement and local geomorphology (King and Goff, 2010; Goff and Chagué-Goff, 2015). Currently, cultural information is included for 14% of recorded tsunami events in the database, most of which have come from ~~pūrākau~~ (New Zealand Palaeotsunami Database, 2017). The cultural information, alongside geomorphic and sedimentary information, provide key data for the generation of a robust and comprehensive palaeotsunami database for Aotearoa New Zealand (Goff et al., 2010).

720 **6.2 International application of Aotearoa-NZ bicultural research frameworks and models**

Indigenous communities around the world share many fundamental principles, including their interconnectedness with and inseparability from nature (Salmón, 2000; Wambrauw and Morgan, 2016). ~~Other~~ cultural values, such as environmental stewardship and sustainability, are also common Indigenous values that guide ways of living and ways of knowing. Common

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725 values among Indigenous cultures enable and encourage transferability of established frameworks outside of the place where
they have been developed. The three theoretical frameworks discussed in this review—*He Poutama Whakamana*, IBRLA and
730 *He Awa Whiria*—can potentially be applied outside of Aotearoa-NZ; due to their flexible nature and adaptability for different
research groups and purposes. Likewise, the value-based models—the *Mauri MModel*, the CFPS and SAM—can be modified
to incorporate Indigenous values and priorities outside of the Aotearoa-NZ context, because the models are ~~created-specified~~
with Indigenous groups on a case-by-case basis. Indigenous groups anywhere can ~~specify~~identify which values they consider
essential for the frameworks and models.

The *Mauri MModel*, developed in Aotearoa-NZ, has been successfully applied in Papua, Indonesia to evaluate the
potential effects of a new agricultural development scheme in the Merauke regency; in the lowlands of Papua (Wambrauw and
Morgan, 2014, 2016). Due to its ability to incorporate Indigenous and Western values, the *Mauri MModel* was deemed an
appropriate tool to assess the potential environmental and cultural impacts of the development scheme. The first step to
735 successfully applying the model was to understand the new context in which it would be used. After confirming the *Mauri*
MModel would be appropriate, stakeholders for the project were selected, which included the Malind Anim Indigenous
peoples. The *Mauri MModel* was adjusted to have a minimum value of -3 and a maximum value of +3 (rather than -2 and +2,
respectively), based on local values and requirements. The results from using the *Mauri MModel* indicated that the cultural
values associated with the site would be denigrated if the development scheme proceeded. The *Mauri MModel* provided semi-
740 quantitative evidence that the development scheme would have serious negative impacts on the Malind Anim.

It is challenging to review the applicability of Aotearoa-NZ frameworks and models to international geomorphic
research because, to our knowledge, there are extremely few studies that explicitly use the ~~frameworks-tools~~ to conduct
geomorphic research outside of Aotearoa-NZ. However, we believe that there is great potential for these frameworks and
models to be adapted outside of Aotearoa-NZ, ~~or for these tools to act as inspiration for the generation of new frameworks and~~
745 ~~models for use with Indigenous groups in other parts of the world~~. The case of using the *Mauri MModel* in Papua indicates
that this model is transferrable, which suggests that the others could be as well. If the models are adapted appropriately and in
accordance with local Indigenous communities' values and desires, we see no encumbrance to using these models in
international geomorphic research.

6.3 The modern role of Earth surface science in societyBenefits of Indigenous knowledge and geomorphology to society

750 There is a growing understanding that long-term sustainability on Earth is not achievable with monodisciplinary or reductionist
scientific approaches (Pingram et al., 2019). Increasingly, geomorphology and Earth surface science are playing stronger roles
in modern society and policy, guiding legislative action towards a more sustainable future. Sustainability is also at the core of
many Indigenous cultures, which has enabled Indigenous knowledge and ways of life to persist for generations. We propose
that both Indigenous concepts and values and Westernised understandings of landscape processes have the potential to generate
755 significant changes in the way ~~humans (including scientists)~~people interact with the ~~worldEarth's surface~~. More-so, if these

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two streams of knowledge work together from the onset of a research project, there is the possibility of making discoveries that could not be made by either approach alone.

760 ~~As previously discussed,~~ landmark policy achievements that consider both scientific and Indigenous concepts emphasise the human and non-human elements of landscapes (Brierley et al., 2018; Aho, 2019; Pingram et al., 2019). These policies prioritise sustainability by acknowledging the integrity of both geomorphic science and Indigenous knowledge. These policies include legal personhood for rivers and the legal rights of nature (Brierley et al., 2018; O'Donnell and Talbot-Jones, 2018; Eckstein et al., 2019). Policies such as these provide opportunities for geomorphologists and Indigenous communities to act as advocates for the landscape, which is a relatively novel approach to sustainable landscape management and interaction within Westernised societies.

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765 **7. Conclusions and recommendations to geomorphologists**

Incorporating Indigenous knowledge with Western science has the potential to bring mutual benefits to scientists, Indigenous communities and governments. This review highlighted theoretical frameworks for including *mātauranga* Māori and Māori value-based models into geomorphic research in Aotearoa-NZ. Each of the theoretical frameworks (~~He Poutama Whakamana~~, IBRLA and ~~He Awa Whiria~~) ~~and value-based models (the (the Mauri M) Model, the Cultural Flow Preference Study and the the Sustainability Assessment Model)~~ provide different benefits to scientists and Māori, ~~and~~ the most appropriate framework selection for projects will occur on a case-by-case basis with Māori involvement. Though this review mostly focused on the Aotearoa-NZ context, these frameworks are all capable of being applied in bicultural research contexts across the globe, so long as they accurately reflect the values and knowledge of the local Indigenous peoples. We encourage geomorphologists interested in working with Indigenous communities to consult with Indigenous peoples engagement support teams or Indigenous studies departments at their local research institutes. Additionally, in Aotearoa-NZ, we encourage researchers embarking on geomorphic research to consult *iwi* management plans and national funding guidelines for assistance in identifying potential research avenues that may include *mātauranga*. The potential for including these frameworks tools in geomorphic research is promising, particularly where such work overlaps with *iwi* aspirations.

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775 We hope this review encourages and inspires geomorphologists to explore landscapes in Aotearoa-NZ and the world through a bicultural lens, one that includes both Indigenous knowledge and modern scientific techniques to acknowledge and respect the uniqueness of the world's landscapes. Using the approaches reviewed here have high potential to yield better outcomes, as drawing from both knowledge systems will realise new understandings and solutions that neither body of knowledge could reach in isolation.

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8. Author contribution statement

785 Wilkinson and Hikuroa developed the original ideas and organisation of this review. Macfarlane provided translations for Māori terminology and developed ideas for theoretical framework analysis. Hughes contributed concepts that also improved framework and model analysis. Wilkinson prepared the manuscript with contributions from all co-authors.

The authors declare that they have no conflict of interest.

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