Development and implementation of a tool to holistically rank Canterbury's Braided Rivers

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Contents

Executive Summary

Research Question:

- Which of Canterbury's braided rivers is most suited to become a UNESCO World Heritage or Ramsar Site?

Research Context:

- Braided Rivers are complex systems that require unique management strategies, but also deserve recognition for their diversity.
- Internationally there are few braided river systems that have retained their natural character, but they are an important part of New Zealand's landscape.
- 60% of New Zealand's braided rivers are in Canterbury, so there is a unique opportunity to gain international recognition.
- The physical, ecological and cultural values of each braided river must be taken into consideration when deciding on which of Canterbury's braided rivers should be recognised for international status.

Methods:

- To identify rivers most suited to become a UNESCO World Heritage site or a Ramsar location a combination of a decision tree and a multi-criteria analysis (MCA) was chosen.
- The MCA was then used to incorporate physical, ecological and cultural values.
- Each category identified rivers most suited according to the unique criteria, which were then weighted to identify the river that scoring the highest for each category.
- In order to identify an overall winner, each category was weighted equally in the final ranking.

Key Findings:

- The cultural significance analysis identified the Waimakariri and the Ashley river as being of outstanding cultural significance.
- The Upper Rangitata scored highest in the ecological, physical and all weighted categories, making this river the preferred choice to become a UNESCO World Heritage or Ramsar Site.

Limitations of the research:

- The main restriction for each category was the time constraint which did not allow for the analysis of all of Canterbury's braided rivers or the collection of primary data on each river.
- Secondary data had to be used, which was not available for all indicators.
- The decision of not including all of Canterbury's braided rivers was also due to the limited amount of time available.
- Time constraints meant that appropriate engagement in hui with Ngai Tahu were unable to take place.

Suggestions for future research:

- Future research should aim to include all of Canterbury's braided rivers and to collect primary data on each indicator used.
- It would also be advisable to incorporate sediment transport data and a Macro Invertebrate Community Index to add depth to the analysis.
- Codesign the cultural analysis methods with Ngai Tahu, to ensure that the methods align with the views of members of the local runanga.

1. Introduction

Braided Rivers are complex systems that require unique management strategies, but also deserve recognition for their diversity (Gray, 2018; Department of Conservation (DOC), 2016). Internationally, few braided river systems have retained their natural character, but they are an important part of New Zealand's landscape (Gray & Harding, 2007). 60% of New Zealand's braided rivers are in Canterbury, so there is a unique opportunity to gain international recognition (BRaid, 2019).

This report is a summary of the methodology developed and implemented for ranking Canterbury's braided rivers based on their ecological, physical, and cultural characteristics. Working with the Canterbury-Aoraki Conservation Board, we developed the following research question:

"Which of Canterbury's braided rivers is most suited to become a UNESCO World Heritage or Ramsar Site?".

We aimed to develop a ranking system that can be applied to braided rivers to evaluate their suitability for UNESCO/Ramsar Status and ensured that the ranking system could be re-weighted based on different values sets.

2. Literature review

The literature review identified that it is important to ensure that the physical, ecological and cultural values of each braided river is taken into consideration when deciding which of Canterbury's braided rivers should be recognised internationally.

2.1 Decision Tree

The decision tree analysis has been chosen as it is a supervised method that allows us to identify target attributes from a variety of input types (Tso &, Yau, 2007). The three factors selected as proxies for natural character were the presence of dams, flow modification, and significant abstraction which are based on Environment Canterbury's Natural Character Assessment Guidelines for Braided Rivers (Gray, 2018). The presence of a dam highly impacts the natural system, as dam induced flow regime changes alter the ability for the river to transport sediment and reduce the ability of the system to flush out contaminants (Lessard et al., 2013). Furthermore, they inhibit the river from braiding naturally (Lessard et al., 2013). The degree of flow modification due to flood control methods, such as groynes or stopbanks are important as their presence reduces the ability of the river to move laterally within the braidplain, thus limiting the creation and removal of lateral habitats typical for these types of rivers (Grove et al., 2015).

2.2 Multi-criteria Analysis

Ioana-Toroimac et al. (2017) used a multi-criteria analysis (MCA) to develop a framework for the Hydromorphological Priority Index (HRPI). It was based on three categories, which were weighted based on their perceived importance. This returned an overall percentage for each river, indicating rivers with the highest restoration needs. We adapted the MCA into a weighting system that can be used to increase the influence of any criteria that are of particular importance to our research partner, such as natural character and ecology, as well as to Māori (Communities and Local Government, 2009; Gray, 2018).

2.3 Physical Indicators

Guidelines established by Gray (2018) state that the defining determinate for a physical assessment of braided rivers is 'natural character'. Key values considered to be contributing to the natural character of braided rivers can be seen in Table 1.

Table 1. Factors contributing to the natural character of braided rivers (Gray et al, 2018).

Factors that Contribute to Natural Character
Natural processes (movement of sediment, water, etc)
Bed substrate
Natural life-supporting capacity
Water quality & quantity
Biodiversity and ecosystems
Historical, spiritual or cultural significance to Māori

Water quality is an important factor for determining the overall health of a river system, due to the impacts of poor water quality on the natural river (Larned et al., 2016). The flow of a river highly influences its natural character as unaltered river flow ensures that nutrients, contaminants, and excess sediment are flushed out, and allows for movement within the braidplain (Hoyle, 2019). This horizontal movement of the channels produces the varied lateral habitats found within braided river systems (Hoyle, 2019). Therefore, the natural character of a river can be broadly assessed in terms of flow modification and abstraction, rather than specific flow rate data which can be highly variable within braided river systems (Gray, 2019).

Changes to these values are thought to have extensive impacts on the natural character of braided rivers. For example, encroachment into the active riverbed results in the reduction of the wider braidplain and will limit future lateral movement of the river. This reduces the river's braiding ability and the lateral habitats many species depend on (Hoyle, 2019).

Natural character is also used to describe the naturalness of an environment, regarding the level of modification (Gray, 2018). From the literature, we decided that the ideal method for assessing the physical significance of braided rivers is one which primarily focuses on morphology and hydrology but incorporates factors such as water quality and ecology (Berletti et al., 2015).

2.4 Ecological Indicators

Braided rivers showcase an impressive variety of aquatic, terrestrial and wetland habitats that contain significant merit of biodiversity (Gray et al., 2018). For example, Canterbury's braided rivers support ~85 bird species, with many of these species being endemic and/or threatened (O'Donnell &, Moore, 1983). Hughey et al. (2010) identified several indicators which we have adapted in the ecological analysis.

2.5 Cultural Indicators

The Canterbury Conservation Management Strategy describes not only the ecological significance of braided rivers but also how they are fundamental to the identity of Ngāi Tahu in Canterbury (DOC, 2016). Water, including that in braided rivers, is an essential part of the culture and economy for Ngāi Tahu. They value mahinga kai and particularly ancient trails as they were used to safeguard travel (DOC, 2016). Additionally, Tipa and Associates (2015) identified settlement sites, place names, mahinga kai, important mountains, and important freshwater areas as wahi tapu/wahi taonga to Ngāi Tahu. They also identified the mountain to the sea philosophy as being fundamental to Ngāi Tahu's holistic worldview recognising that a river connects the entire landscape (Tipa &, Associates, 2015).

3. Methods

3.1 Methodological Framework

To identify the rivers most suited to become a UNESCO World Heritage site or a Ramsar location a combination of a decision tree and an MCA was chosen.

3.1.1 Tree Diagram

The first part of the methodology was designed to determine which rivers could be eligible for UNESCO/Ramsar status by applying a broad natural character assessment based on the criteria for each form of recognition (Appendix A). The initial rivers chosen to be assessed were sourced from the Braided River Aid website due to being outlined as more significant than others, and included the following 13 rivers: Ashburton, Ashley, Conway, Hurunui, Kowai, Opihi, Orari, Rakaia, Rangitata, Tasman, Waimakariri, Waipara, and Waitaki (BRaid, 2019). Each river was split into upper and lower reaches, and each reach was assessed separately using the decision tree as depicted in Figure 1.

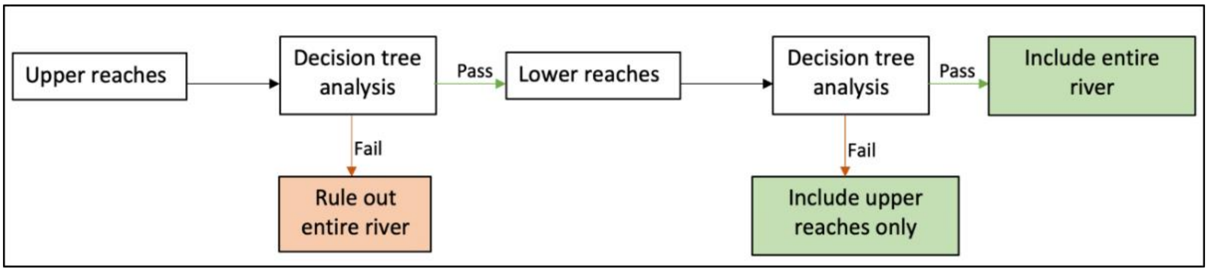

Figure 1: Decision used to identify if whole rivers or upper reaches of rivers were included in the analysis.

The three factors selected as proxies for natural character were the presence of dams, flow modification, and significant abstraction (see Figure 2).

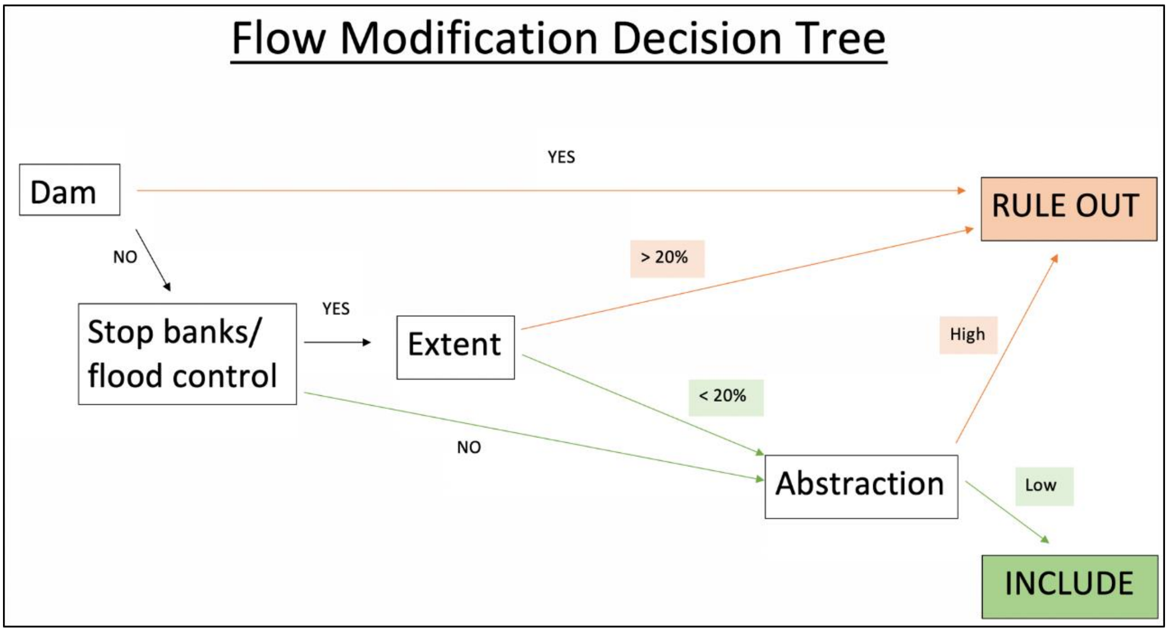

Figure 2: Flow diagram used to identify rivers with a high natural character from the rivers initially selected.

The presence of a dam within a river system resulted in the whole river failing to be included, due to the high impact on the natural system (Gray et al., 2018). Degree of flow modification was assessed based on the level of flood control methods such as groynes or stop banks that had been implemented within a given reach. This was assessed based on a percentage, where reaches with greater than 20% of the lateral habitat including the above flow modification structures were failed.

The final criteria used was the level of large-scale abstraction in each river, such as irrigation schemes or other large consents. This section identified large-scale abstraction only, as a detailed assessment of abstraction would be covered in further detail in the MCA. This assessment was dependent on the amount of abstraction, thus rivers deemed to have high levels were failed.

3.1.2 Multi-Criteria Analysis

Once the rivers most suited were identified, the MCA was created to rank these, according to their suitability for international recognition. This was achieved by identifying criteria of importance which were then scored according to expert opinion (Communities and Local Government, 2009). In this study, the MCA was applied to calculate a Holistic Assessment for Braided Rivers Index (HABRI) which was based on the three indicator categories of physical, ecological and cultural significance (see Figure 3). These were then combined, to give each river a percentage indicating their suitability for international status recognition.

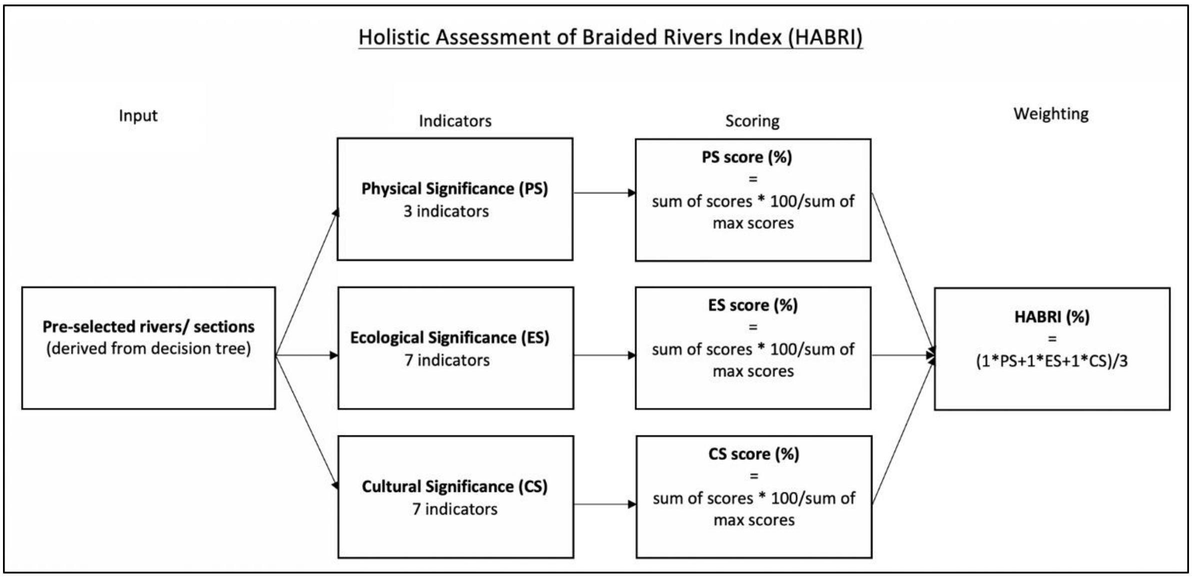

Figure 3: HABRI methodological framework used for the ranking of Canterbury's braided rivers.

3.1.3 Weighted Methodology

A weighting was included to account for different value sets. We used the method outlined in Figure 4 to weight each category.

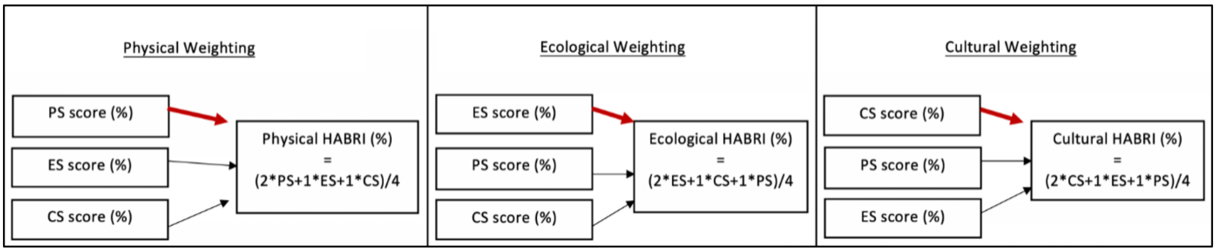

Figure 4: The weighted methodology of the analysis indicating the calculations used for the physical, ecological, and cultural weighting. In each section, the physical significance (PS), ecological significance (ES) and cultural significance (CS) were weighted differently.

3.2 Physical Analysis

Three criteria were chosen to assess the physical significance of each river. These were water quality, water quantity, and encroachment.

Water quality was assessed using four indicators. These were E. coli, total oxidised nitrogen, total phosphorus, and turbidity. Maximum acceptable values (MAV) or trigger values were obtained and used to assess the water quality data found for each river. These values are summarised in Table 2 below.

Table 2: Summary of indicators and maximum allowable values (MAV)/ trigger values used to assess water quality.

Water Quality Indicators	MAV/ trigger value
E. coli	>130 n/100m
Total oxidised nitrogen (TON)	6.9 mg/l
Total phosphorus (TP)	26 µg/l upland or 33 µg/l lowland
Turbidity	4.1 NTU upland or 5.6 NTU lowland

Data for water quality was sourced from Land Air Water Aotearoa (LAWA), however, no data was available for the Tasman, Kowai or Waimakariri rivers (see Appendix B). Water quality was then assessed and given a score value ranging from 0 to 2, using the ranking method described in Table 3.

The decision tree analysis included water extraction on a broad scale to determine its impact on the rivers natural character. To determine the scale of water abstraction from consents, the average of three active consents for each river were taken, to show an estimation of the average volume of water consented to be taken. As there are generally no areas to be irrigated in the upper reaches of Canterbury's braided rivers, the consents only apply to the lower reaches in the plains. The average consent for each river was compared with the average daily flow rate of the river to give a percentage of daily flow which was then weighted by assigning a score ranging from 0 to 2. Consent data was sourced from the Canterbury Maps Open Dataset. Flow data was sourced from Environment Canterbury, however excluded the Tasman and Kowai rivers (see Appendix B).

Encroachment was measured by comparing previous and current satellite photos to determine the size of changes in braidplain extent. Satellite imagery was sourced from Google Maps Pro (see Appendix B). Past images varied from 2004-2011, while current images could be obtained from 2019. The rivers were then ranked by assigning a score value ranging from 0 to 2.

Table 3: Indicator ranking for physical analysis.

Indicator	Criteria	Score
Water Quality	Above MAV/trigger value	0
	Between 50-100 per cent of MAV/trigger value	1
	Below 50 per cent of MAV/trigger value	2
Water Quantity	Consents for takes greater than 2%	0
	Consents for takes between 1 – 2%	1
	Consents for takes less than 1%	2
Encroachment	Loss in braidplain extent of more than 25%	0
	Loss in braidplain extent of less than 25%	1
	Gain in braidplain extent%	2

The above three indicator scores were then standardised to percentages and combined into one total percentage to represent the suitability of the physical criteria (see Figure 5).

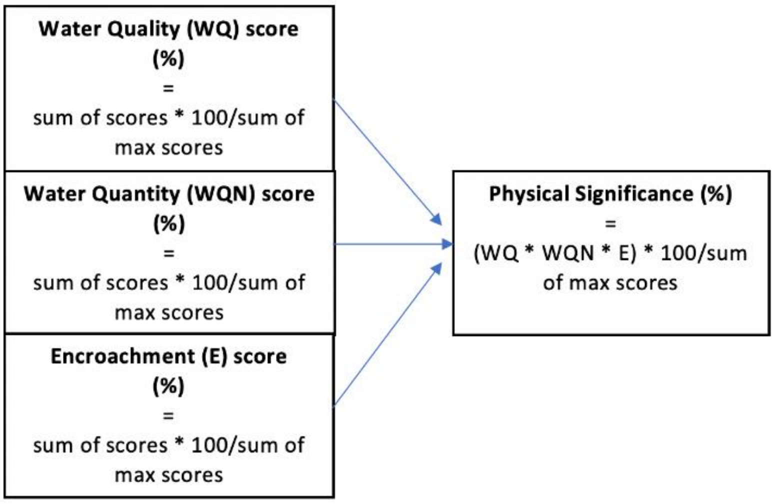

Figure 5: Visualisation of the method used to determine physical significance.

3.3 Ecological Analysis

The ecological analysis ranked each reach based on ecological significance. The final data used for this analysis was sourced from Native Birdlife: Application of the River significance assessment method to the Canterbury region by Hughey et al. (2010) which was reviewed by an expert panel (Hughley et al, 2010).

A ranking system was established using seven categories (see Table 4).

Table 4: Indicator ranking for ecological analysis.

Indicator	Info	Criteria	Score
1. Presence of nationally critical or threatened species	This was determined by the presence or absence. This category included the nationally critical black stilt and the nationally endangered black-fronted tern.	Absence	0
		Presence	1
2. Number of threatened or 'at risk' species	This category includes the bird species mentioned in category 1, as well as the wrybill, banded dotterel, New Zealand pied oystercatcher, and Caspian tern.	0 present	0
		1-2 present	1
		3-4 present	2
		5-6 present	3
3. The number of overall 'important' bird species	This included birds that are considered important species found on Canterbury rivers so were therefore counted as part of the data collected but are not necessarily in conservation danger.	0 present	0
		1-2 present	1
		3-5 present	2
		>6 present	3
4. Relative distinctiveness of habitat	This is a measure of how widely represented the habitat type and/or species assemblage for each river was throughout New Zealand.	Habitat type or species assemblage widely represented elsewhere in New Zealand	1
		Habitat type or species assemblage rarely represented elsewhere in New Zealand	2
		habitat type or species assemblage not represented in other regions in New Zealand	3
5. Measure of the total amount of habitat	The area of the riverbed was measured in hectares for each braided river.	<5000ha	1
		5000-9999 ha	2
		>10000 ha	3
6. Count of the total number of birds found at each river		<1000 individuals	1
		1000-4999 individuals	2
		>5000 individuals	3
7. Count of the number of foraging guilds at each river	This can essentially be described as the number of different types of feeding habitats. These foraging guilds included open-water divers; deep water waders; shallow water waders; dabbling waterfowl; torrent specialists; aerial hunting gulls and terns; swamp specialists; riparian wetland birds.	1-4 present	1
		5-6 present	2
		7-8 present	3

Using these categories, each river was assigned a score out of 20. This score was then turned into a percentage which was the basis of the ecological significance of each river.

3.4 Cultural Analysis

For identifying rivers with high cultural significance, two categories were used. The first part of the analysis aimed to determine historical significance to Ngāi Tahu which was determined using six indicators (see Table 5). Data was sourced from a variety of secondary sources, including Canterbury black maps and historical accounts (see Appendix C). The second category of the cultural analysis is based on ki uta ki tai, Ngāi Tahu's mountains-to-the-sea philosophy. Connectivity was analysed through visual observation using Google Earth (Appendix C).

Table 5: Indicator ranking for cultural analysis.

Category	Indicator	Criteria	Score
Historical significance	**Kaika nohoanga (settlement sites)**	Absence	0
		Presence	1
	Ara tawhito (ancient trails)	Absence	0
		Presence	1
	Mahinga Kai (places where resources including food were procured)	Absence	0
		Presence	1
	Mauka (important mountains)	Absence	0
		Presence	1
	Ikoa tawhito (place names)	Absence	0
		Presence	1
	Wai Maori (important freshwater areas)	Absence	0
		Presence	1
Connectivity	**Ki uta ki tai (mountains-to-the-sea-philosophy)**	Section of the river has been analysed	1
		Whole river with headwaters originate in the foothills	2
		Whole river with headwaters originating in the Alps	3

The overall score for a rivers cultural significance was then determined by combining the sum of a river's historical significance score and its connectivity score which was then divided by the sum of maximum possible scores (see Figure 6). This resulted in a percentage, indicating a rivers cultural significance.

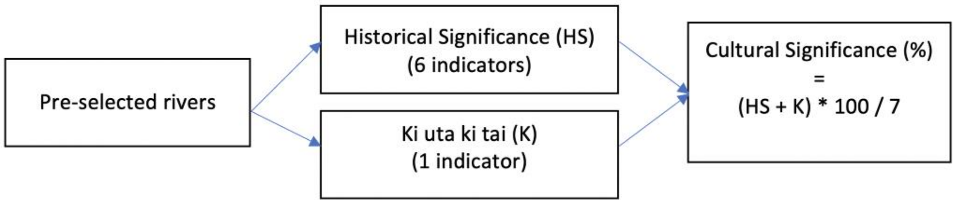

Figure 6: Visualisation of the method used to determine the cultural significance of a river.

4.Results

The tree diagram assessment narrowed down the initial 13 rivers to eight rivers/reaches. These were the Upper Ashburton, Ashley, Conway, Upper Kowai, Upper Orari, Upper Rangitata, Tasman, and Waimakariri rivers. The Rangitata was initially excluded as it did not pass the assessment, however, it was recommended by the experts that we spoke to that the upper reaches were included as it retained sufficient natural character (Gray, 2019).

4.1 Physical results

A summary of the results from the assessment of physical significance is shown in Table 6 below. Overall, the Upper Rangitata River was found to have the highest physical significance, followed closely by the Conway River, while the Upper Kowai River had the lowest physical significance.

Table 6: Summary of physical assessment results.

Awa (River)	Water Quality	Water Quantity	Encroachment	Physical Significance %
Upper Ashburton River – Hakatere	68.75	0	75	**57.92**
Ashley River-Rakahuri	100	100	25	**75**
Conway River - Piri-tūtae-putaputa	100	100	75	**91.67**
Upper Orari River	87.25	50	100	**79.17**
Upper Rangitata River	81.25	100	100	**93.75**
Waimakariri River	No Data	50	75	**62.5**

4.2 Ecological results

Table 7 shows the ecological results. The Upper Rangitata and the Waimakariri river both received a score of 18 out of 20, meaning that both rivers were given the highest ranking for ecological significance.

Table 7: Results for the ecological analysis; Where 1. presence of nationally critical or threatened species(0-1; 2. number of threated or 'at risk' species(1-3); 3. number of overall 'important' species; 4. relative distinctiveness of habitat (1-3); 5. amount of habitat (1-3); 6. the birds in numbers (1-3)7. foraging guilds (1-3) (Hughley et al, 2010).

Awa (River)	1.	2.	3.	4.	5.	6.	7.	Ecological Significance (No.)	Ecological Significance (%)
Upper Ashburton River – Hakatere	1	3	3	2	1	3	2	15	**75**
Ashley River-Rakahuri	1	2	3	2	1	2	2	13	**65**
Conway River - Piri-tūtae-putaputa	1	2	3	1	1	1	2	11	**55**
Upper Kowai River	0	1	1	1	1	1	1	6	**30**
Upper Orari River	1	2	3	1	1	1	2	11	**55**
Upper Rangitata River	1	3	3	3	3	3	2	18	**90**
Tasman River – Te Awa Whakamau	1	3	3	3	2	2	2	16	**80**
Waimakariri River	1	3	3	3	3	3	2	18	**90**

4.3 Cultural results

The rivers with the highest cultural significance to Māori were found to be the Ashley (88.89%) and the Waimakariri River (88.89%) (see Table 8).

Table 8: Results of the overall cultural significance analysis.

Awa (River)	Mahinga Kai	Ancient trails	Place names	Settlement sites	Important freshwater areas	Important mountains	**Historical Significance**	**Connectivity**	**Cultural Significance %**
Upper Ashburton River – Hakatere	1	1	1	1	1	1	**6**	**1**	**77.78**
Ashley River-Rakahuri	1	1	1	1	1	1	**6**	**2**	**88.89**
Conway River - Piri-tūtae-putaputa	1	0	1	1	0	0	**3**	**3**	**66.67**
Upper Kowai River	1	0	1	1	0	0	**3**	**1**	**44.44**
Upper Orari River	1	0	1	0	0	1	**3**	**1**	**44.44**
Upper Rangitata River	1	1	1	1	1	1	**6**	**1**	**77.78**
Tasman River – Te Awa Whakamau	1	0	1	1	1	1	**5**	**1**	**66.67**
Waimakariri River	1	1	1	1	1	0	**5**	**3**	**88.89**

4.4 Weighted and Overall Results

Tables 9, 10, and 11 describe the weighted rankings, which were calculated using the method shown in Figure 4. The Upper Rangitata scored the highest in each weighted ranking, despite its lower cultural score.

Table 9: Culturally weighted ranking for the eight Canterbury Braided Rivers.

Canterbury Braided River	Culturally Weighted Ranking (%)
Upper Rangitata River	85
Waimakariri River	79
Ashley River- Rakahuri	77
Conway River - Piri-tūtae-putaputa	72
Upper Ashburton River – Hakatere	68
Tasman River – Te Awa Whakamau	65
Upper Orari River	56
Upper Kowai River	39

Table 10: Physically weighted ranking for the eight Canterbury Braided Rivers.

Canterbury Braided River	Physically Weighted Ranking (%)
Upper Rangitata River	89
Conway River - Piri-tūtae-putaputa	80
Ashley River- Rakahuri	71
Waimakariri River	69
Upper Orari River	66
Tasman River – Te Awa Whakamau	61
Upper Ashburton River – Hakatere	59
Upper Kowai River	37

Table 11: Ecologically weighted ranking for the eight Canterbury Braided Rivers.

Canterbury Braided River	Ecologically Weighted Ranking (%)
Upper Rangitata River	88
Waimakariri River	79
Ashley River- Rakahuri	71
Conway River - Piri-tūtae-putaputa	69
Tasman River – Te Awa Whakamau	69
Upper Ashburton River – Hakatere	67
Upper Orari River	59
Upper Kowai River	35

The results of the overall equally weighted ranking can be seen in Figure 7. The Upper Rangitata has the highest score with 87% with the Waimakariri river coming in second with 76%.

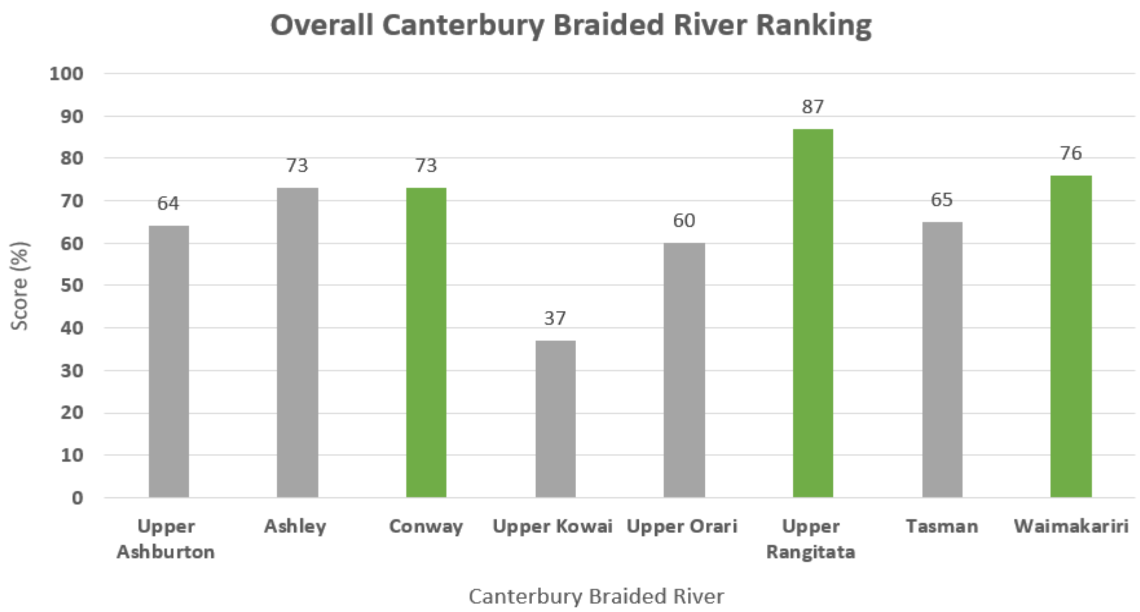

Figure 7: An overall ranking of Canterbury's braided rivers with equal weighting physical, ecological and cultural factors.

5. Discussion

5.1 Physical Discussion

These results outline the high physical quality of the Upper Rangitata and Conway rivers. It is important to note that the Rangitata river only includes the upper reach, while the Conway is the average of the upper and lower reaches. Using only the upper reaches for some rivers, and the whole extent for others is likely to have influenced the results due to a lack of consistency. Consented abstraction is not present in the upper reaches, and lower reaches are generally more affected by human pressures. The score attained by the upper reach of the Rangitata is due to the low levels of encroachment, meaning the overall lateral extent of the braidplain is likely to have a higher degree of natural character still present.

The time constraints of this study meant collecting primary data for the number of rivers to be assessed was unrealistic, however there were significant gaps in the secondary data sources used, such as the lack of water quality data for the Tasman, Kowai and Waimakariri rivers, and lack of flow data for the Tasman and Kowai. Due to this, the Tasman and Kowai rivers had to be excluded from the physical analysis as only encroachment was able to be assessed. It also would have been beneficial to assess the level of sediment transportation within each river system, however, data for this was not available (Gray, 2018).

5.2 Ecological Discussion

The results of the ecological significance analysis show that most of the braided rivers in Canterbury have moderate to high ecological significance with only a few (Conway, Upper Kowai, & Upper Orari rivers) having notably low ecological significance. While the Upper Rangitata and the Waimakariri rivers tied for the highest ecological score, it is important to note that the Tasman was the only river with a black stilt population. This is important because black stilts are the only braided river birds found within our study areas with a conservation status of nationally critical, meaning they are the most 'at-risk' birds found on Canterbury braided rivers (Robertson et al., 2016).

A lack of data also limited the performance of the ecological significance analysis for this project. Although braided river birds are an important part of the ecology of braided rivers, and high numbers of diverse species can indicate ecological significance, they are only one element of the ecosystem. Braided rivers are also home to aquatic and terrestrial invertebrate species, fish, lizards, lichens, mosses, and native plants and a complete ecological analysis should include these (Gray & Harding, 2007).

5.3 Cultural Discussion

The results of the cultural significance analysis indicate rivers that are highly valued by Ngāi Tahu and are therefore worth protecting from a cultural perspective. The Waimakariri and the Ashley rivers scored the highest in overall cultural significance, as both have a high number of historically significant indicators within their catchment, while at the same time, connecting the entire landscape.

While all efforts have been made to conduct the historical significance analysis as accurately as possible by reviewing an extensive amount of literature, some indicators still may be present in catchments that have not been identified. Furthermore, Townsend et al. (2004) included the current number of mahinga kai species present in his mahinga kai indicator and compared this to historical accounts. Due to a lack of data availability on mahinga kai species currently present in these rivers, this indicator had to be simplified to historical accounts only. The main constraint, however, on the cultural analysis, was the lack time to establish meaningful engagement with iwi to ensure their perspective was sully integrated. The Cultural Health Index (CHI) for streams and waterways which is a tool prepared for the Ministry for the Environment strongly suggests facilitating Māori participation in all parts of the analysis. The CHI consists of three categories of which the third is a Cultural Stream Health Measure (CSHM) including eight indicators (Tipa & Teirney, 2006). Due to our inability to make meaningful contact with the local runanga, we decided to exclude the CSHM from the analysis, as it required significant levels of input. Therefore, in future, we would recommend increasing the level of engagement with iwi, as our process unfortunately resulted in non-Māori undertaking an analysis which is based on values that underlie a Māori worldview. This meant that our research risks misinterpretation and ethnocentrism (Tipa, 2009).

5.4 Overall Discussion

This research was undertaken with the aim of finding out which of Canterbury's braided rivers would be most suited to become a Ramsar or UNESCO World Heritage Site. From the results shown above, it is clear that the Upper Rangitata is well suited to this status. The Upper Rangitata dominated throughout our research project, receiving flawless scores in certain physical, ecological and cultural categories (Figure 7). Specific attributes such as the high-water quality and quantity of the rivers, sustained braidplain and rich birdlife were some of the main reasons why the Upper Rangitata is so valuable. The Waimakariri and Conway River were in second and third place, with scores in the low-mid 70s, which is still a considerable amount lower than the Rangitata River's upper reach which scored 87%.

However, the Waimakariri and the Conway Rivers were assessed as complete rivers, whereas the Upper Rangitata was only assessed on its upper reach. This has the potential to introduce bias into the analysis. We decided to further analyse the upper reaches of the eight Canterbury braided rivers, to ensure that our results are not biased. In order to do this, we have analysed all 13 rivers included in this analysis by their upper reaches only and compared these results to the Upper Rangitata. The underlying assumption being, that if bias is present, another river would score first when considering the upper reaches only. The Upper Rangitata River still scored the highest (87%), while the Upper Ashley River scored 72% and upper Waimakariri River scored 68%, therefore supporting our overall result (Appendix D).

The weighted rankings show that the Upper Rangitata has a consistently high score across each attribute, as it scores the highest in all three weighted ranking categories (Table 9, 10 & 11). The importance of the Upper Rangitata is especially shown when culturally weighted, as it is in fourth place when considering its cultural values, however the Upper Rangitata River climbed to first place even when culturally weighted, this is a result of its rich ecological and physical attributes.

The lateral habitat of the Upper Rangitata is made up of low producing grassland, Manuka and Tussock (Appendix E). This shows the lack of human modification around the river's upper reach, as it sustains its original surroundings. Additionally, recreational areas such as bird watching, kayak access, fishing and public footpaths surrounding the Rangitata River, due to its valuable physical and ecological state (Appendix F). These results clearly suggest that, of the rivers we surveyed, the Upper Rangitata is the most suited to gain international recognition, as a Ramsar or UNESCO World Heritage site.

7. Conclusions

Our research was undertaken with the aim to identify a river that displayed exceptional physical, cultural, and ecological characteristics to be put forward for international recognition. To this end, our analysis found that the Upper Rangitata was the most suited. The Upper Rangitata scored very highly in all our criteria and survived our weighted scoring and bias assessments. While further work will be required by the Canterbury Aoraki Conservation Board to evaluate our research, we are confident that, given the constraints, we have provided a useful and robust method for evaluating Canterbury's braided rivers. Going forward, further analysis with more data, and a wider number of rivers in the initial stages would help to support the decisions of the Canterbury Aoraki Conservation Board. Future research should also aim to facilitate better Maori participation throughout the entire process in order to accurately represent this rich culture, as this was a significant shortcoming in our own research. Furthermore, the incorporation of sediment transport data in the physical and the inclusion of a Macro Invertebrate Index in the ecological analysis would be advisable.

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10. Appendices

Appendix A. Ramsar and UNESCO Criteria

<u>The Ramsar Sites Criteria</u>	
The nine criteria for identifying Wetlands of International Importance	
Group A of the Criteria.	
Sites containing representative, rare or unique wetland types	
Criterion 1	A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.
Group B of the Criteria.	
Sites of international importance for conserving biological diversity	
Criteria based on species and ecological communities	
Criterion 2	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.
Criterion 3	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.
Criterion 4	A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.
Specific criteria based on waterbirds	
Criterion 5	A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.
Criterion 6	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.
Specific criteria based on fish	
Criterion 7	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.
Criterion 8	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.
Specific criteria based on other taxa	
Criterion 9	A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of wetland-dependent nonavian animal species.

UNESCO World Heritage Site Selection Criteria	
(i)	to represent a masterpiece of human creative genius;
(ii)	to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design;
(iii)	to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;
(iv)	to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;
(v)	to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change;
(vi)	to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this criterion should preferably be used in conjunction with other criteria);
(vii)	to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
(viii)	to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
(ix)	to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;
(x)	to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

Appendix B. Key Data Sources

Key Data Sources
New Zealand Land Cover Database: Manaaki Whenua. Retrieved from: https://www.data.govt.nz/use-data/showcase/land-cover-database/
River Environment Classification. Retrieved from: https://www.niwa.co.nz/freshwater-and-estuaries/management-tools/river-environment-classification-0
Environment Canterbury Flow Data. Retrieved from: https://www.ecan.govt.nz/data/riverflow/?loc=N
Land Air Water Aotearoa. Retrieved from: https://www.lawa.org.nz
BRaid. Retrieved from: https://braidedrivers.org

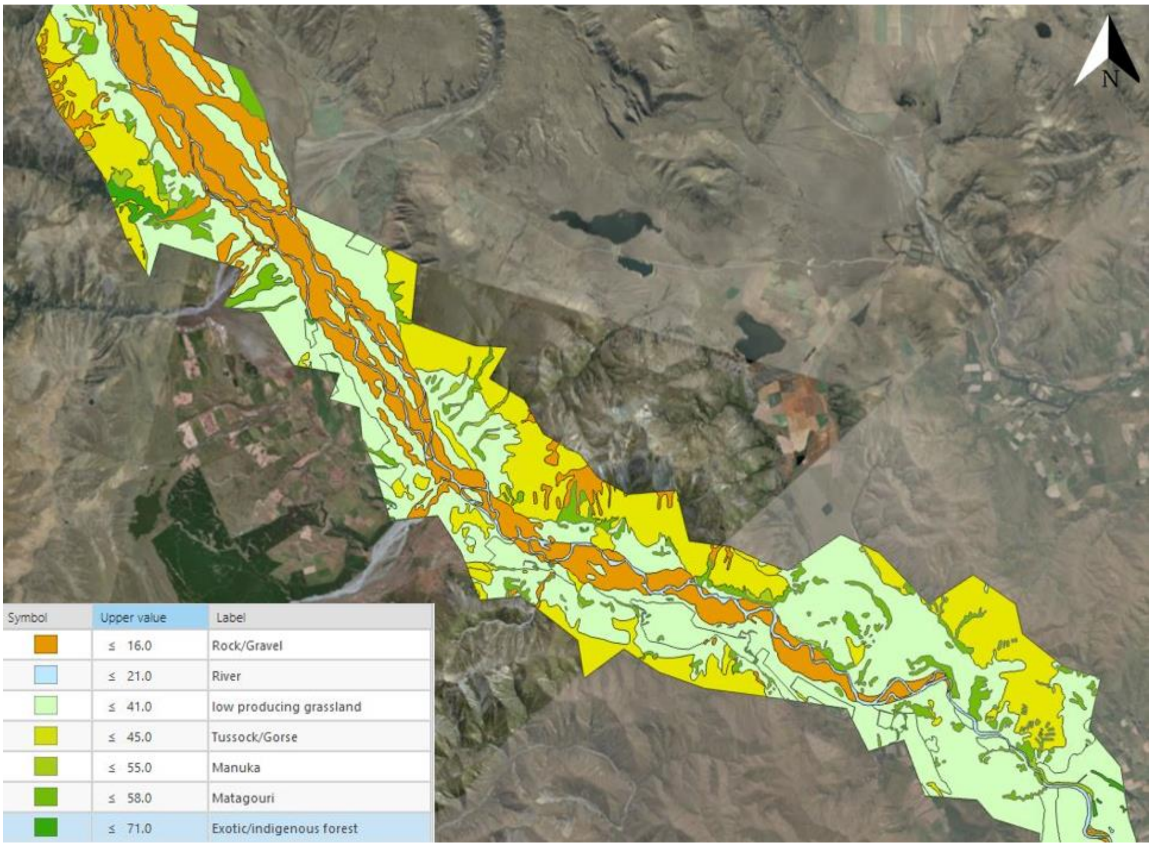
Appendix C. Data used for the cultural significance analysis.

Awa (River)	***Upper Ashburton River – Hakatere***	***Ashley- Rakahuri***	***Conway - Piri-tūtae-putaputa***	***Upper Kowai River***	***Upper Orari River***	***Upper Rangitata River***	***Tasman – Te Awa Whakamau***	***Waimakariri River***
Mahinga kai	*1: Yes (Jolly et al., 2013).*	*1: Yes (Ngāi Tahu, 2019).*	*1: Yes (Ngāi Tahu, 2019).*	*1: Yes (Jolly et al., 2013).*	*1: Yes (Ngāi Tahu, 2019).*	*1: Yes (Ngāi Tahu, 2019).*	*1: Yes (Ngāi Tahu, 2019).*	*1: Yes (Tau et. al, 1990; Ecan, 2014)*
Ara tawhito (ancient trails)	*1: Pass to the West Coast (Ngāi Tahu, 2019).*	*1: Travel route across the plains (Ecan, 2014).*	*0: N/A*	*0: N/A*	*0: N/A*	*1: Pass to the West Coast (Beattie, 1945; Tipa & Associates, 2015).*	*0: N/A*	*1: Pass to the West Coast (Ngāi Tahu, 2019).*
Ingoa Tawhito (Place names)	*1: Hakatere (swift waters) (Beattie, 1945).*	*1: Rakahuri (the sky turned around) (Waimakariri District Council (WDC), 2018).*	*1: Piri-tūtae-putaputa (name of an important battle) (Ngāi Tahu, 2019).*	*1: Kowai (likely to be Ko Wai meaning rivers or water) (New Zealand Government, 2019).*	*1: Oraro (lively) (Timaru District Council (TDC), 2019).*	*1: Rangitata (close sky or day of lowering clouds) (Taylor, 2001).*	*1: Te Awa Whakamau (Awa means river, Whakamau unknown) (Ngāi Tahu, 2019).*	*1: Waimakriri (cold water) (Encyclopedia Britannica, 2019).*
Kaika Nohoanga (settlement sites)	*1: Ōtūroto (Lake Heron) (Ngāi Tahu, 2019).*	*1: Kaiapoi Pā (Ecan, 2014).*	*1: Pariwhakatau (Ngāi Tahu, 1991).*	*1: Nohoanga (Jolly et al., 2013).*	*0: N/A*	*1: Several (Tipa & Associates, 2015).*	*1: Pukaki (Ngāi Tahu, 2019).*	*1: Several (ECan, 2014).*
Wai Māori (important freshwater areas)	*1: Ōtūwharekai (Ashburton Lakes) (Te Runanga o Ngāi Tahu [Ngāi Tahu], 2019).*	*1: Surrounding wetlands (Jolly et. al, 2013)*	*0: N/A*	*0: N/A*	*0: N/A*	*1: Ealing Springs, McKinnon Stream, Spring fed streams around Erewhon and Mesopotamia (Tipa & Associates, 2015).*	*1: Lake Pukaki (Ngāi Tahu, 2019).*	*1: Te Hāpua Waikawa (Lake Lyndon), Ōpōrea (Lake Pearson), Howdon and Sarah (Tau et. al, 1990).*
Mauka (important Mountains)	*1: Kiekie/ Mount Somers (Ngāi Tahu, 2019).*	*1: Pūteawhatiia (Ngāi Tahu, 2019).*	*0: N/A*	*0: N/A*	*1: Tarahaoa (Mount Peel), Huatekerekere (Little Mount Peel (Ngāi Tahu, 2019).*	*1: Mahaanui (Mount Harper) (Beattie, 1945). Tarahaoa (Mount Peel), Huatekerekere (Little Mount Peel (Ngāi Tahu, 2019).*	*1: Aoraki/ Mount Cook (Ngāi Tahu, 2019).*	*0: N/A*
Ki uta ki tai (mountains-to-the-sea philosophy)	*1: Section of river (determined by the decision tree analysis)*	*2: Whole river (originates in foothills)* (Google Earth Pro)	*3: Whole river (originates in the Southern Alps)* (Google Earth Pro)	*1: Section of river (determined by the decision tree analysis)*	*1: Section of river (determined by the decision tree analysis)*	*1: Section of river (determined by the decision tree analysis)*	*1: Section of river* (Google Earth Pro)	*3: Whole river (originates in the Southern Alps)* (Google Earth Pro)

Appendix D: Upper Canterbury Braided River Bias Analysis

Awa (River)	**Ranking of the upper reaches (%)**
Upper Rangitata River	87
Upper Ashley- Rakahuri	72
Upper Waimakariri	68

Appendix E: Upper Rangitata Landcover Classification Projection



Appendix F: Upper Rangitata Access ways