Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Science Group

Land use change on the margins of lowland Canterbury braided rivers, 2012-2019

Report No. R21/05
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May, 2023 - Some wording in this report has been amended for the purpose of clarification.

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Environment Canterbury Regional Council
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Executive summary

Background:

Braided rivers are naturally uncommon ecosystems of national and international significance. In New Zealand they have a threat status of 'endangered' and provide habitat for a diverse range of indigenous flora and fauna. The occurrence of a characteristically wide braidplain is a necessity for maintaining the natural character, ecological integrity and high biodiversity values found in these ecosystems. In 2015 Environment Canterbury published a report showing that 11,630 hectares of low plains braided river margin had been developed during the period from 1990 to 2012.

The problem:

Conversion of undeveloped and forested river margins for agriculture contributes to the loss of braided river natural character and ecological integrity through incrementally reducing the width of the undeveloped braidplain and/or physically restraining the river between artificially defined banks. Conversion of forested river margins compromises the ecological integrity of the wider braided river ecosystem through loss of habitat for native species and through loss of buffering from the effects of adjacent agricultural land management. Narrowing the width of braided river margins also reduces the natural resilience of the river to flood disturbance.

What we did:

We used satellite and aerial imagery to identify and measure the conversion of undeveloped river margin land to high producing exotic pasture or crops along the margins of Canterbury low plains braided rivers over the period 2012 to 2019.

What we found:

Loss of braided river margins has continued between 2012 to 2019, with a further 1,252 hectares, or 178 hectares per year on average, of undeveloped low plains braided river margins converted for agricultural use.

Approximately 60% of the converted land was in private ownership, 13% was designated reserve land and was 24% Unalienated Crown Land (UCL).

What does it mean?

Agricultural land use intensification along braided river margins remains a significant contributor to the decline in indigenous biodiversity values, ecosystem health and natural character of the region's braided rivers.

Consideration of climate change:

Conversion of undeveloped braided river margins for agricultural use also exacerbates climate change impacts, as agricultural land contributes to higher greenhouse gas emissions than land in its undeveloped state. Greenhouse gases, particularly methane and nitrous oxide, are associated with agricultural emissions and have 25 and 298 times more warming effect than carbon dioxide, respectively.

Whilst on their own, emissions from land developed on braided river margins could be considered small, the cumulative impact of emissions cannot be underestimated, particularly given the global commitment to the Paris Agreement.

In Canterbury, climate change projection scenarios suggest increased rainfall in alpine catchments, and subsequently, more frequent high flows in alpine-fed braided rivers. High flows in braided rivers help to clear the braidplain of weeds and increase the diversity of habitats but can also have a negative impact on the bird species that nest within the braidplain, particularly where the braidplain has been narrowed. Floods occurring during the nesting season increase the risk of nests and chicks being washed away. Wider braidplains allow more room for flood water to spread as well as reducing the risk of nests being destroyed.

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1 Introduction

In 2015 Environment Canterbury released a report showing that in Canterbury in the period between 1990 and 2012, 11,630 hectares of braided river margins on the low plains had been developed for agricultural purposes (Grove *et al*., 2015). The report showed agricultural encroachment into previously undeveloped or forested river margins had taken place along most of Canterbury's lowland braided rivers and that 40% of this development was on land administered by Department of Conservation (DOC), Environment Canterbury, District Councils, or Land Information New Zealand (LINZ), while the other 60% was private freehold land. The analysis focussed on agricultural development from a 1990 start point, determined by the availability region-wide satellite and aerial imagery, but acknowledged the substantial loss of braided river character prior to this.

This report extends the previous analysis to 2019 by using more recent satellite and aerial imagery to further monitor land use change along the lowland plains margins of Canterbury braided rivers.

1.1 Natural character and ecology of braided rivers

Braided rivers are naturally dynamic ecosystems with frequent high flow events that mobilise the abundant supply of bed material, resulting in multiple dynamic channels (O'Donnell *et al*., 2016; Williams *et al.*, 2007). Braided river channels adjust laterally across a braidplain that may be kilometres wide, mobilising the alluvial gravel bed that may be many metres deep (Gray and Harding, 2007).The frequent adjustment of channels across the braidplain supports a mosaic of habitat types of different ages (time since mobilised) and consequently of different successional stages, each with their own distinct character and providing for overall high biodiversity values (DOC, 2019; O'Donnell *et al*., 2016; Gray *et al*., 2018). Braidplains include springs, ponds, side braids, spring-fed and hill-fed tributary streams, as well as a continuum of terrestrial habitat from recently mobilised, unvegetated, bare gravels closer to the active channels to forested areas on the older, more stabilised substrates, contributing more to supporting native biodiversity than the main channel (Gray and Harding, 2007). Intact braided river ecosystems support a wide range of native species including aquatic (Gray and Harding, 2007; Gray *et al*., 2018) and terrestrial invertebrates (Patrick and Grove, 2014; DOC, 2019), fish (Gray *et al*., 2018), birds (O'Donnell, 2000; Gray *et al*., 2018), and lizards (O'Donnell *et al.,* 2016; Grove *et al*., 2015; Gray *et al*., 2018; DOC, 2019).

Natural vegetation on braided river margins, whether indigenous or exotic, provides a buffering function protecting the braidplain from impacts associated with adjacent land use and provides a habitat corridor for native species (Grove *et al.*, 2015). Undeveloped margins dominated by exotic vegetation also provide potential for ecological and functional restoration, whereby exotic vegetation can act as a nurse canopy facilitating the establishment of indigenous plants, either through active introduction of indigenous seed or seedlings, or through natural dispersal (Burrows *et al*., 2015; Grove *et al*., 2015).

Braided river character can also naturally vary longitudinally down their catchment, depending on lateral confinement. Rivers can be confined where they pass through alpine valleys, partly confined through foothill areas and unconfined when they reach lowland plains (Hoyle and Bind, 2018). Sometimes on the lowland plains the river has incised into older braidplain gravels, leaving the current braidplain confined between terraces. Therefore, braided river margins in lowland Canterbury include relatively stable areas on the outside edge of the current braidplain as well as, in some cases, on adjacent terraces.

1.2 Why is natural character important?

Maintaining the natural character of New Zealand's braided rivers is essential to protect the multiple biodiversity values associated with them (DOC, 2019; O'Donnell *et al*., 2016; Gray, 2018; Grove *et al*., 2015). The Canterbury Region contains approximately 64% of New Zealand's braided rivers (O'Donnell *et al*., 2016; Gray and Harding, 2007; Wilson, 2001) and these are recognised internationally and nationally as significant, both as a landscape feature and for their unique ecosystems (O'Donnell, 2000; Forest & Bird, 2016). Along with 71 other terrestrial ecosystems, braided rivers have been classified as a naturally uncommon ecosystem. Many naturally uncommon ecosystems support highly specialised and diverse species assemblages, often characterised by endemic and rare species (Wiser *et al*., 2013). Braided rivers in New Zealand have been assigned a threat status of ‘Endangered’ (Holdaway *et al*., 2012).

The threat assessment for naturally uncommon ecosystem utilised criteria based on decline in ecological function (e.g. for braided rivers, dominance of non-native invasive plants, altered disturbance regime) and decline in area. Decline in function is considered to be reversible through biological restoration, because the environmental conditions persist. Decline in area is considered permanent and reversible only through major environmental and biological restoration, making it much more difficult to achieve (Holdaway *et al*., 2012). Williams and Wiser (2004) surveyed vegetation on the Waimakariri River as part of a larger study and concluded that New Zealand’s braided rivers are “extremely invasible” with a high number of naturalised species, hence a decline in function. Agricultural encroachment represents a decline in area, so any loss of braidplain and braided river margins in favour of agricultural development poses a threat to the ecological integrity of braided river ecosystems.

1.3 Historic loss of braided river margins

The key characteristics that make braided rivers special also make them difficult to define and delineate spatially. Braidplains can be kilometres wide, while the active channel may be only a fraction of this width. Decades can pass before a river naturally re-occupies a historic patch of braidplain (Hoyle and Bind, 2018), leaving sections to move through successional stages. The Resource Management Act defines a river bed as “the space of land which the waters of the river cover at its fullest flow without overtopping its banks”. This definition does not acknowledge the constant shifting nature of a braided river within its braidplain, nor the fact that “banks” are not readily identified in these rivers. This has led to confusion as to what constitutes the bed of a braided river (Figure 1-1). Ecologically the more stabilised, higher successional areas are still part of the braided river. However, demand for productive land makes them desirable to cultivate and defend from flooding and erosion, effectively removing them from the braided river ecosystem.

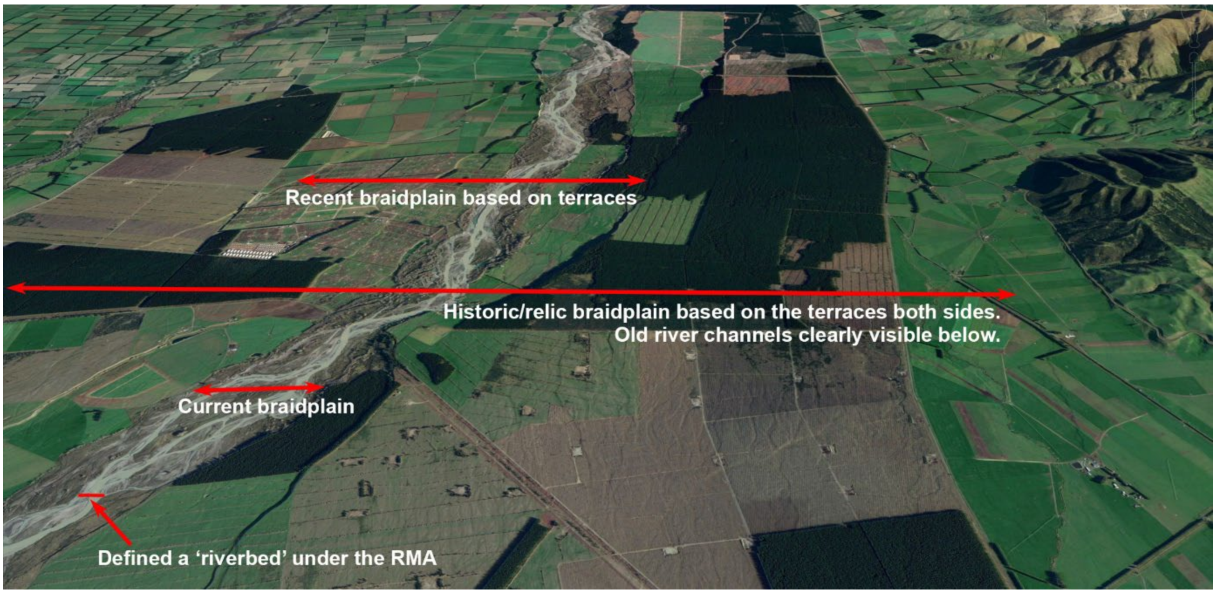

Figure 1-1: The RMA definition of riverbed compared to the current, recent, and historic braidplain. Source: Whitelaw, S. 2020

Gray *et al*. (2018) identified eight primary threats to maintaining the natural character of braided rivers in Canterbury, with land use change in the braidplain listed as one of those threats most likely to drastically alter their natural character and ecological values. Incremental physical restriction through development of river margins for agricultural purposes, often accompanied by flood control measures to protect that investment, increasingly limits the natural processes characteristic of braided rivers. Reducing the area available for a braided river to migrate laterally may channelise the river into fewer braids, or even a single channel, an issue that is recognised internationally as a threat to braided river systems (Gray *et al*., 2018). An intact braidplain contains a more resilient river ecosystem as it may reach a “dynamic stability” meaning that, despite the physical disturbance and high habitat turnover, the proportions of each habitat type remain relatively stable (Gray and Harding, 2007). Ecological resilience is an ecosystem’s ability to recover from stresses such as disturbance. Braided river ecosystems in their natural state are inherently resilient due to the diversity of habitats available and the ability of most species to move to a new patch on the mosaic. Restricting the area available to the river through flood control and land use change reduces ecosystem resilience, as reduced lateral movement of channels drives the system towards having bare gravel in early successional stages and older forested margins, but a loss of the habitat diversity provided by mid-succession surfaces. This loss of habitat diversity results in an associated loss of biodiversity values.

1.4 Purpose of this report

The purpose of this report is to document changes in land use of undeveloped or forested river low plains braided river margins since 2012. The earlier report of Grove *et al.* (2015) covered the period from 1990-2012, approximately coinciding with the passing of the Resource Management Act, until 2012, approximately coinciding with the setting of the Canterbury Water Management Strategy (CWMS) and the Canterbury Regional Policy Statement (CRPS) objectives for braided river habitats. This latest analysis period examines the interval between 2012 and 2019.

2 Methods

The methods used in this analysis follow those used in Grove *et al*. (2015) to analyse land use change in the time periods 1990-2012 The previous analysis used ESRI ArcMap 10.4 to delineate change areas, while this analysis of the period 2012-2019 period used ESRI ArcGIS Pro 2.5.

The study area generally covered the lowland plain reaches of 23 Canterbury braided rivers and did not include foothill gorges, inland basins or alpine valley floors further upstream. However, the mid-reaches of the Waiau and Hurunui Rivers where they cross the Amuri Plains were included in the study area (Figure 2-1). The study area was defined by 1990 boundaries between developed farmland and ‘undeveloped’ and forested land on the margins of 23 Canterbury braided rivers (Figure 2-1) mapped in ArcGIS Pro at a 1990 baseline scale of 1:10,000.

Polygons for each river were created using the 1990 Landsat image as a basemap, with the polygons defining the boundary between developed and undeveloped land. This boundary, referred to here as the back boundary, was refined using higher resolution (a clearer image) aerial imagery of a similar (1985–1995) vintage. Regional coverage of aerial imagery is variable, so some areas have less chance of error in the initial creation of the back boundary polygon than others. Generally, any errors are picked up as more recent imagery is examined. The back boundary was defined for the purpose of monitoring post-1990 change along river margins and does not show the legal (RMA) definition of ‘riverbed’ or geomorphological definition of ‘braidplain’.

We recorded changes in extent of ‘developed farm land’ and ‘undeveloped land’ within the study area over the period 2012-2019. Mapped change areas were limited to change that occurred from the outside of the defined river polygon in towards the active river, therefore ignoring any changes due to river avulsion and/or erosion around the edges of the river channels and active riverbed.

Change areas were identified by visual assessment of satellite imagery, aerial photographs and topographic maps. ‘Undeveloped land’ included a variety of land covers and vegetation types: rough pasture and exotic scrub and shrubland, mixed native-exotic shrubland, treeland, grassland and herbfield vegetation; and sparsely vegetated areas (Appendix 1). River margin forests include exotic willow, poplars and conifer plantations as well as naturally established exotic willow forest. Native riparian forest is not common in lowland Canterbury, but small stands are present along some rivers. ‘Developed agricultural land’ was defined as land that has been cleared of its pre-existing vegetation cover and converted to exotic pasture grasses, legumes or fodder crops.

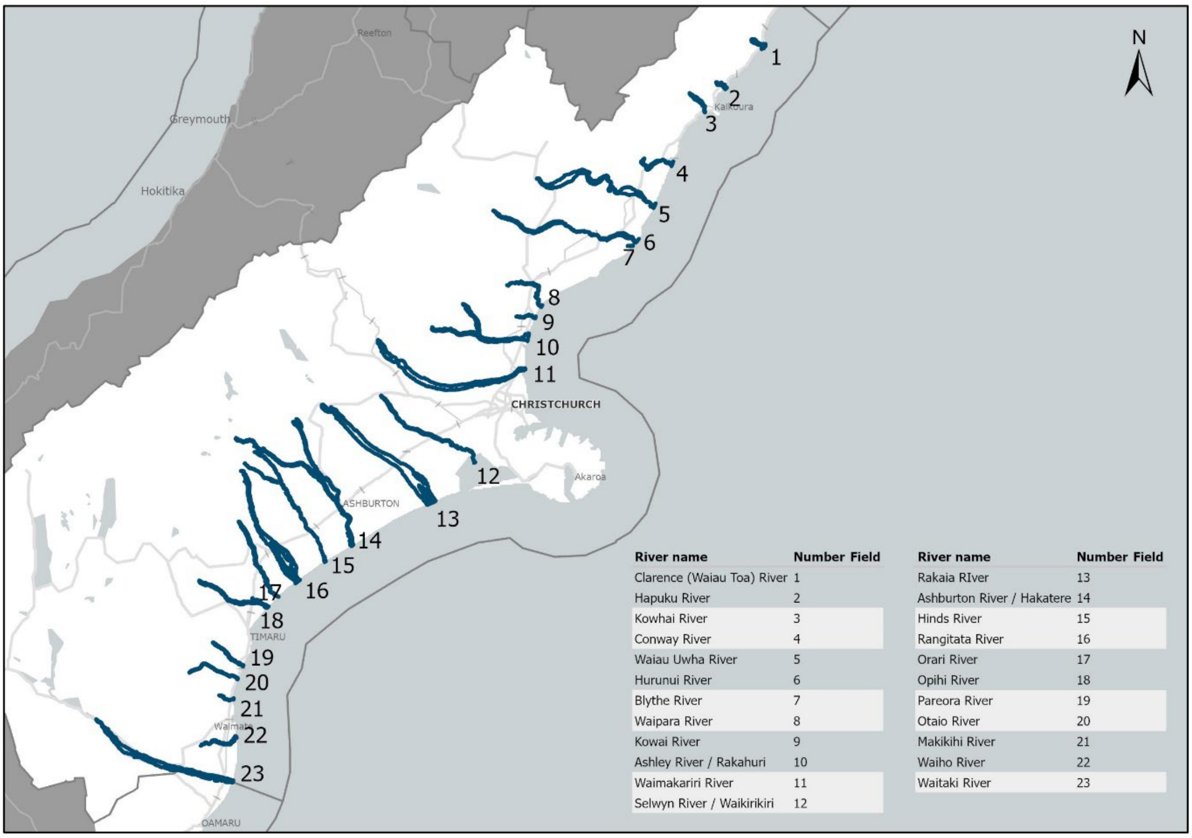

Figure 2-1: Location of lowland Canterbury braided river margins covered by this study

The satellite imagery used for this analysis were SPOT 5 2012 and Sentinel-2 2018-2019. When utilising satellite imagery, various methods of visualising the imagery are possible. We settled on true colour as this displays the imagery with a colour range similar to normal aerial imagery.

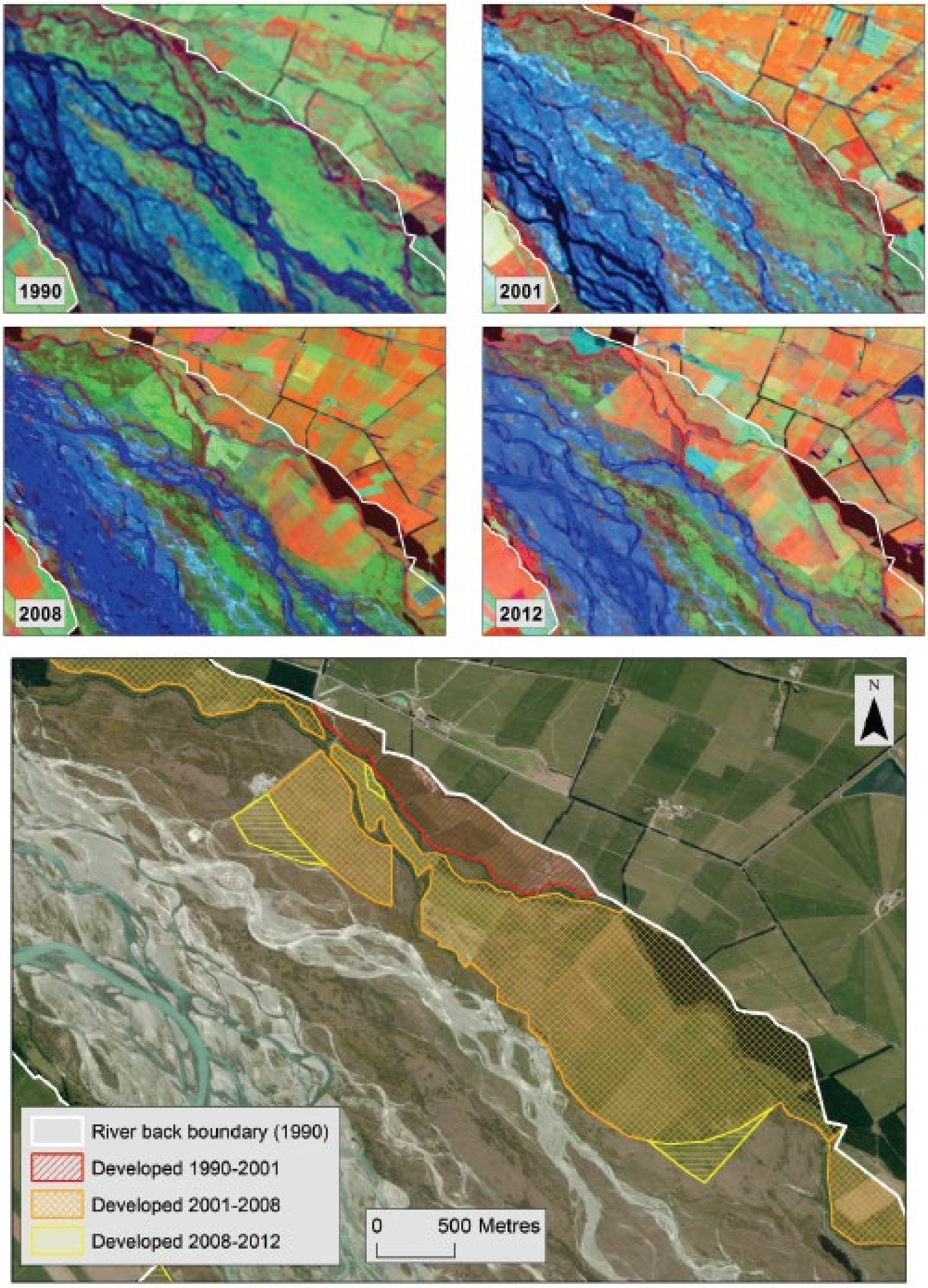

Figure 2-2: Excerpt from Grove *et al.*, 2015 showing how satellite and aerial imagery is used to identify change in land use from undeveloped to developed. Note that the white “river back boundary (1990)” line represents the 1990 baseline delineating developed and undeveloped land and does not represent the braidplain boundary

Undeveloped areas usually displayed as a consistent range of dark green colours without sudden transition to contrasting lighter colours (Figure 2-2). Areas showing change could therefore be identified by a marked change in colour from dark to light green between two sequential images. Such changes in undeveloped areas also frequently took the form of geometric shapes together with an obvious colour. For example, an undeveloped area that had been cleared and sown in pasture was clearly identifiable when the cleared area was angular and ‘paddock-shaped’. Usually, these change areas were located on the edge of the river polygon (back boundary) and were obvious when looking at images with the 1990 back boundary visible on the map.

Land use change within each river "back boundary" area was assessed by scanning up each side of the river berm while viewing 2018-2019 Sentinel-2 satellite imagery and having the 1990 back boundary visible, scanning for areas of bright green (pasture or agricultural crops) or pale yellow/brown areas (representing bare earth). Areas that displayed bright green or pale colours within the river polygon back boundary that were not captured in the previous analysis (1990–2012) were mapped and included in this period of analysis (2012–2019). These areas were then checked using one or more recent aerial images to determine the timing and accuracy of the mapped change. These higher resolution images were also used to refine the accuracy of the boundaries of the mapped development areas.

Finalised change areas were then assessed against land tenure information as shown on the Environment Canterbury GIS cadastral layer. For purposes of this analysis, land tenure was classified as:

- **Private freehold –** Privately owned land
- **Designated reserve land** - including Department of Conservation, regional and district council reserve land
- **Unalienated** – Commissioner of Crown Lands controlled, unalienated crown land (UCL) and/or designated Land Information New Zealand controlled land. For example, hydro land parcels and unformed legal road land parcels.

3 Results

In the period between 2012 and 2019, a further 1252 ha of river margin land was developed for agricultural use across the low plains reaches of 20 braided rivers, to give a regional total for the period 1990-2019 of 12,870 ha across 23 rivers (Table 3-1).

Table 3-1: Area and percentage of braided river margin developed for agricultural purposes between 1990-2019 for all of Canterbury's low plains braided rivers

		Area (ha)				
River	**River area - 1990 baseline (ha)**	**1990-2001 (%)**	**2001-2008 (%)**	**2008-2012 (%)**	**2012-2019 (%)**	**Total change 1990 – 2019 (%)**
Ashburton River	6348	320 (5.0)	667 (10.5)	261 (4.1)	160 (2.5)	1,408 (22.2)
Ashley River	4806	146 (3.0)	178 (3.7)	19 (0.4)	68 (1.4)	411 (8.6)
Blythe River	44	0	0	0	35 (79.5)	35 (79.5)
Clarence River	761	25 (3.3)	136 (17.9)	0	8 (1.1)	169 (22.2)
Conway River	916	0	34 (3.7)	26 (2.8)	16 (1.7)	76 (8.3)
Hapuku River	400	0	14 (3.5)	0	0	14 (3.5)
Hinds River	1671	54 (3.2)	70 (4.2)	88 (5.3)	111 (6.6)	323 (19.3)
Hurunui River	3810	25 (0.7)	208 (5.5)	22 (0.6)	21 (0.6)	276 (7.2)
Kowhai River	697	2 (0.3)	0	0	0	2 (0.3)
Kowai River	212	0	10 (4.7)	0	0	10 (4.7)
Makihikihi River	172	25 (14.5)	13 (7.6)	0	16 (9.3)	54 (31.4)
Opihi River	2209	140 (6.3)	12 (0.5)	7 (0.3)	47 (2.1)	206 (9.3)
Orari River	2136	114 (5.3)	52 (2.4)	0	36 (1.7)	202 (9.5)
Otaio River	619	8 (1.3)	12 (1.9)	0	56 (9.0)	76 (12.3)
Pareora River	636	36 (5.7)	45 (7.1)	24 (3.8)	10 (1.6)	115 (18.1)
Rakaia River	16132	527 (3.3)	1641 (10.2)	137 (0.8)	59 (0.4)	2,364 (14.7)
Rangitata River	11276	1526 (13.5)	596 (5.3)	135 (1.2)	42 (0.4)	2,299 (20.4)
Selwyn River	2132	121 (5.7)	191 (9.0)	27 (1.3)	63 (2.9)	402 (18.8)
Waiau River	7964	459 (5.8)	1183 (14.9)	554.6 (7.0)	332 (4.2)	2,529 (31.8)
Waihao River	587	6 (1.1)	85 (14.4)	22 (3.7)	17 (2.8)	13 (22)
Waimakariri River	11180	561 (5.0)	89 (0.8)	69 (0.6)	14 (0.1)	733 (6.6)
Waipara River	807	0	6 (0.7)	6 (0.7)	11 (1.4)	23 (2.8)
Waitaki River	9049	410 (4.6)	326 (3.6)	148 (1.7)	130 (1.4)	1,014 (11.3)
Total across all rivers	**84564 ha**	**4,505 (5.3)**	**5,568 (6.6)**	**1,545 (1.8)**	**1,252 (1.5)**	**12,870 (15.2)**
Annual Average rate of conversion		***410***	***795***	***386***	***179***	

The Waiau River experienced the greatest change in land use area during the 2012-2019 period, with 332 ha developed (4.2% of its 1990 baseline area). The Ashburton and Waitaki river areas were the next two highest conversions by area, at 160 ha (2.5%) and 130 ha (1.4%), respectively.

For the entire 29 year period, a total of 12,870 ha of river margin land has been converted to pasture or crops with Waiau (2,529 ha), Rakaia (2,364 ha) and Rangitata (2,299 ha) rivers having the greatest area of river margin developed since 1990. These three rivers accounted for 55.8% of all river margin land developed for agriculture between 1990 and 2019.

The period between 2001 and 2008 saw the greatest area of river margin land developed, with a total of 5,568 ha (6.6% of total river area). Development during this period averaged 795 ha per year, compared to 410, 386 and 179 ha/year for the 1990 to 2001, 2008 to 2012 and 2012 to 2019 periods, respectively.

In the latest 2012-2019 monitoring interval, the braided river with the highest proportion of margin development was the lower section of the Blythe River. Along this approximately 2.5km stretch or river, almost 80% of the margin was developed between 2012 and 2019 (note that upstream of this reach the Blythe is not a braided river and was not assessed as part of this report). Land use change on the margins of the Makihikihi (9.3%), Hinds (6.6%) and Otaio (9%) Rivers also resulted in relatively high proportions being developed between 2012 and 2019. Since 1990, 31% of the Makihikihi River margin land has been developed, 19% of the Hinds and 12% of the Otaio.

Of the 1,252 ha of previously undeveloped river margin and berm land converted for agricultural use from 2012 to 2019, 64% was private freehold, 13% designated reserve land and 24% unallocated or LINZ managed land (Table 3-2). The percentage of private freehold land is similar to each of the previous three periods. The conversion of designated reserve land increased from 20% (1990-2001) to 31% (2001-2008), and decreased to 9% (2008-2012) and 13% (2012 to 2019). Conversely, unalienated land made up a greater proportion of land developed after 2008 than between 1990 and 2008.

Table 3-2: Tenure of river margin areas developed adjacent to Canterbury's low plains braided rivers between 1990-2019

	Area (ha) (% of total for each monitoring period)				
Tenure	**1990-2001**	**2001-2008**	**2008-2012**	**2012-2019**	**Total 1990-2019**
Private freehold	2,892 (64%)	3,085 (56%)	997 (65%)	797 (64%)	7,771 (60%)
Designated reserve land	900 (20%)	1,746 (31%)	146 (9%)	158 (13%)	2,950 (23%)
Unalienated Crown Land	715 (16%)	741 (13%)	406 (26%)	297 (24%)	2,159 (17%)

4 Discussion

"*Factors that alter the natural character of these rivers will inevitably impact upon ecological functions and populations of indigenous species*" (Gray *et al.,* 2018).

4.1 Continued loss of braided river margins

The current analysis shows that development of braided river margins has continued. Grove *et al.* (2015) found that the rate of conversion from undeveloped river margin to farmland began to slow after 2008. This subsequent analysis has shown a similar pattern, with development of river margin continuing, but at a lower rate than in the previous periods analysed. Although attempts to prevent further reduction in the area of braided rivers, particularly the alpine-fed rivers (Clarence, Waiau, Hurunui, Waimakariri, Rakaia, Rangitata and Waitaki rivers), have been implemented through the Canterbury Land and Water Regional Plan and the Canterbury Water Management Strategy, these measures have not been entirely successful in the prevention of further development of braided river margins. The rivers where most land has been converted between 2012 and 2019 were the Waiau, Ashburton, Waitaki and Hinds Rivers. The Hinds River is a small foothill-fed river and the development of river margin has been greatest between 2012 and 2019 compared to the earlier analyses.

Similarly, between 2012 and 2019, the Blythe River lost 35 hectares of river margin and whilst this is a small area relative to other larger braided rivers, this constitutes nearly an eighty percent loss of its river margin. These results show that it is not only the alpine-fed rivers being affected.

4.2 Loss of natural character and ecological integrity

Braided river ecosystems were assessed as having a threat status of endangered due to the high proportion of naturalised species reducing ecosystem function (Holdaway *et al*., 2012). As mentioned earlier, decline in function can be reversed with restoration efforts. However, since 2012, at least 1,252 hectares of river margin, including areas of braidplain has been removed from Canterbury's braided river ecosystems. This represents a decline in area, something that is much more difficult to remediate and therefore has a more permanent impact on braided river ecosystem integrity. Canterbury's braided rivers occupy approximately 164,000 ha, made up of 103,000 ha of active riverbed (areas of unstable gravels and flowing channels) and 61,000 ha of recent braidplain (flat land either side of the active riverbed) (O'Donnell *et al*., 2016). The loss of lowland braidplain area since 2012 equates to 2% of the total recent braidplain. Since 1990, the area converted to agriculture represents 20% of the total recent braidplain area. This loss is in addition to the many thousands of hectares converted and protected from flooding through formal flood protection measures prior to 1990.

Along with loss of area, a key threat to the ecology and natural character of braided rivers is stabilisation of the channels (O'Donnell *et al*., 2016; DOC, 2019; Gray *et al*., 2018; Pompeii *et al*., 2019; Grove *et al*., 2015). The natural dynamics of braided rivers are supported by frequent floods, a plentiful supply of bed material and the ability for the river to adjust laterally. Agricultural development of river margins, along with invasive woody weeds, and engineered flood protection work impede the natural adjustment processes that allow a river to migrate across its braidplain. The flow regime can be altered by dams or large scale water abstraction for irrigation or drinking water, and the supply of bed material can be reduced by gravel extraction or cut off by dams. Narrowing the braidplain corrals flow into fewer, deeper channels, reducing the number and size of small side braids. This loss of natural character results in a reduction of ecological integrity and resilience, and the ability to support the range of habitats and species characteristic of braided river ecosystems (Gray *et al.,* 2018; Grove *et al*., 2015).

4.3 Loss of habitat

Braided river margins often include tributary streams and wetlands, along with their associated biodiversity values. Retaining these margins as undeveloped "wilderness" provides an important buffering function, protecting these wetlands and streams, as well as the wider braided river ecosystem, from the effects of adjacent land use. Despite the fact that many undeveloped and forested river margins are dominated by exotic vegetation, these areas still have high biodiversity values, as both native and exotic vegetation can offer habitat for native species (e.g. Tocher *et al*., 2015). Exotic vegetation in the river margins can provide habitat for native species including birds such as pūkeko, marsh crake and Australasian bittern (O'Donnell, 2000), several species of lizard (O'Donnell *et al*., 2016; Grove *et al*., 2015), and bats (O'Donnell *et al*., 2016). The few areas of native vegetation remaining often include species that are classified as rare and threatened such as *Meuhlenbeckia ephedroides* (threatened - nationally critical), *Discaria toumatou* (at risk-declining) and *Raoulia monroi* (threatened - nationally critical): as such, development of braided river margins removes habitat for native species, reduces buffering function and inhibits habitat connectivity.

The value of the smaller, foothill-fed braided rivers should not be ignored as they can also provide important habitat opportunities (O'Donnell and Moore, 1983; O'Donnell, 2000), partially because they are subject to quite different flow and flood regimes than alpine fed rivers (O'Donnell and Moore, 1983).

Alpine-fed and foothill-fed rivers tend to flood at different times of the year. Alpine rivers typically have more stable flows during winter and flood during spring when snow melt combines with orographic rain, whereas foothill-sourced rivers typically flood in winter when southerly weather fronts are more common (O'Donnell and Moore, 1983; Gray and Harding, 2007). Birds adapted to nesting on braided rivers have a breeding season from approximately August through to February, coinciding with spring floods in the alpine-fed rivers when nests and chicks can be washed away. Under natural conditions, wide braidplains allow flood waters a wide area to spread into, reducing the risk to nests and chicks. However, where flood flows are restricted as a result of flood protection measures, flood events can present a high risk to breeding success.

Climate change projection scenarios in Canterbury suggest more frequent high flows in alpine-fed braided rivers which will add further risks to bird species that nest within the braidplain. More frequent flood events during the spring/summer seasons reduces the chance of a successful breeding season if nests or chicks are washed away multiple times.

Alpine-fed and foothill-fed rivers offer slightly different habitat features and complement each other, providing choice in breeding sites in the landscape (O'Donnell and Moore, 1983). In years with multiple large flood events, breeding efforts in alpine-fed rivers can be severely impacted, while birds breeding on foothill-fed rivers may experience better breeding success by avoiding the large alpine-fed flood events. However, smaller rivers present fewer breeding opportunities due to their small size, and as shown by this analysis, are also affected by land use change on their margins.

4.4 Protection of braided river values

Protection of braided river values requires a consistent management approach across their entire length and width. With responsibility for managing braided rivers split between the Canterbury Regional Council who have responsibility for the active channel, and the 10 Territorial Authorities who each have responsibility for the rest of the braidplain within their district, managing the braided river ecosystem in an integrated manner is difficult. Nonetheless, an integrated management approach is important in order to minimise risks to the natural character and ecological integrity of braided rivers.

4.5 Conclusion

Demand for farmland continues to put pressure on braided river ecosystems. Any ongoing loss of braided river margin due to agricultural encroachment, along with loss of ecological function due to increasing pressure of exotic species has the potential to push braided river ecosystems to the point where they may become critically endangered. Conversion of publicly owned land has continued to make up a substantial proportion of encroachment, with approximately one third of all developed land being in public ownership

In addition, the ongoing loss of undeveloped and forested river margin to agriculture shows that we are not yet meeting the outcomes intended under policy 10.3.2 of the Canterbury Regional Policy Statement to preserve the natural character of river and lake beds and their margins …, nor Target 2 of the

Canterbury Water Management Strategy to maintain the braided character of all Canterbury's braided rivers.

Meeting policy outcomes and management targets is imperative to ensure that risks to the biodiversity, natural character and ecological function of braided river ecosystems are minimised.

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Appendix 1: Definition of terms

Braidplain	The braidplain is the area or width of alluvial plain covered by active braided river channels both currently and historically.
Braided river	A river with high sediment load having numerous channels which repeatedly branch and re-join, forming a pattern of low islands and shallow bars.
Canopy	The layer or layers of uppermost plant crowns in vegetation, i.e. that foliage which faces upwards to the sky and would be seen in ‘bird’s eye’ view.
Floodplain	Alluvial land adjacent to a river which continues to be affected by flood overflows from the river.
Forest	A vegetation structural class having >80% canopy cover of trees and shrubs, with tree cover exceeding that of shrubs. Trees (including tree ferns) are those having a trunk ≥10 cm dbh (diameter at breast height); cf. treeland.
Grassland	A vegetation structural class having canopy cover of grasses 20–100%, exceeding that of any other growth form or bare ground. Tussock grasses belong in tussockland.
Gravel	Fragments of rock 2–60 mm in diameter.
Habitat	The environment occupied by an organism or community.
Herbfield	A vegetation structural class having cover of herbs 20–100%, exceeding that of any other growth form or bare ground. The herb growth form includes all herbaceous and low-growing semi-woody plants that are not separated as tussocks, ferns, reeds, rushes, sedges, grasses, cushion plants, turf, mosses, or lichens.
Pool	A small body of still water; also a slow-flowing and relatively deep reach of a stream or river.
Riparian	Situated along the immediate margin of a river or stream.
Rough pasture	Grassland comprised of exotic grass species, largely self-sown, that has little or no fertiliser inputs and is either ungrazed or lightly grazed.
Scrub	A vegetation structural class having canopy cover of shrubs and trees >80%, with shrub cover exceeding that of trees. Shrubs are woody plants with stems <10 cm dbh (diameter at breast height).
Shrubland	A vegetation structural class having canopy cover of shrubs 20–80%, exceeding that of any other growth form.
Sparsely vegetated	<20% vegetation canopy cover.
Spring	A stream emerging to the surface from underground, as a single point source of groundwater discharge.

Treeland	A vegetation structural class having 20–80% canopy cover of trees, tree cover exceeding that of any other growth form, but tree canopy discontinuous above lower non-woody vegetation; cf. forest.
Unalienated Crown Land	Crown land that has not been transferred to another.

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