Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

TECHNICAL REPORT Science Group

Monitoring extent of available habitat for indigenous braided river birds in Canterbury – a 2012 baseline

Monitoring extent of available habitat for indigenous braided river birds in Canterbury – a 2012 baseline

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M Pompei
P Grove
J Cuff

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Environment Canterbury Regional Council
Kaunihera Taiao ki Waitaha

	Name	Date
Prepared by:	*Mirella Pompei, Scientist* *Philip Grove, Team Leader Science* *Jeromy Cuff, Senior Scientist*	*April 2018*
Reviewed by:	*Lesley Bolton-Richie, Senior Scientist* *Frances Schmechel, Principal Biodiversity Advisor*	*April 2018*
External review by:	*Andrew Grant, Colin O'Donnell* *Department of Conservation*	*June 2018*
Approved by:	*Tim Davie* *Chief Scientist*	*April 2019*

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200 Tuam Street
PO Box 345
Christchurch 8140
Phone (03) 365 3828
Fax (03) 365 3194

75 Church Street
PO Box 550
Timaru 7940
Phone (03) 687 7800
Fax (03) 687 7808

Website: www.ecan.govt.nz
Customer Services Phone 0800 324 636

Summary

Background: This report provides a baseline for monitoring progress towards the Canterbury Water Management Strategy (CWMS) outcome "*By 2040, increase habitat area useable by all species of braided river indigenous birds*." As a baseline, the 2012 extent of optimal and useable bird breeding habitat, and useable feeding habitat were calculated for braided rivers in Canterbury Region.

What we did: We used remote sensing software and a Geographic Information System (GIS) to identify and measure braided river bird habitats across the region. We classified 2012 satellite imagery, within defined braided riverbed study areas, into a range of ground covers. Then we evaluated braided river ground cover classes with reference to the findings from earlier research into bird habitat use. This also considered the presence and extent of braided river 'islands' which are recognised as providing optimal habitat conditions.

What we found: The analysis of the 2012 satellite imagery covered 77 Canterbury braided river sections totalling 224,550 ha in extent. Of this, 87,045 ha were categorised as being useable braided river bird nesting habitat, and 111,907 ha were categorised as useable feeding habitat. However, total regional extent of 'prime' nesting habitats, that is on islands providing a degree of protection from mammalian predators and flooding, and other 'high value' nesting habitats was considerably lower, at 983 ha and 21,405 ha respectively.

What does it mean? To measure progress toward achieving the CWMS outcome we recommend continued monitoring and reporting on the extent of not only 'useable' but also 'prime' and 'high value' bird habitats for all individual braided rivers or braided river sections identified in this study. It is important for regional-scale reporting that trends in quantity and quality of bird habitat be understood for the full range of braided river environments, from alpine headwaters and inland basins to the plains and coast; and for both large alpine and small foothill-sourced river systems.

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1 Introduction

Canterbury's braided rivers are nationally and internationally significant. Their importance is recognised in the Canterbury Water Management Strategy (Canterbury Mayoral Forum, 2010) and Canterbury Regional Policy Statement (Environment Canterbury, 2013). Both documents have chapters containing objectives, policies and targets relating to the natural character, ecosystem health and biodiversity values of braided rivers. One of the five high level outcomes set out in the Canterbury Water Management Strategy is: *By 2040, increase habitat area useable by all species of braided river indigenous birds*.

Braided rivers are habitat for over 80 indigenous bird species of which 20 species are characteristic of braided rivers and found widely on them (O'Donnell and Moore, 1983). They include four threatened species that have evolved on braided rivers and have specific adaptations for breeding and feeding there. These are the wrybill, black stilt, black-billed gull and black-fronted tern (O'Donnell, 2000). Two other threatened bird species that also occur widely, although not exclusively, on Canterbury braided rivers are banded dotterel and South Island pied oystercatcher. Most of these characteristic bird species are migratory, not spending their whole lives on braided rivers.

Braided river ecosystems and their indigenous bird fauna have been, and continue to be, influenced by human-mediated factors which are drivers in the decline of these ecosystems and the bird populations they support. These include:

1. Abstraction and creation of impoundments which change flow regimes, and in some cases, destroy preferred habitats and reduce food availability.
2. River control / flood protection works which channel, stabilise and modify habitats; and development of braided river floodplains.
3. Invasive plants, which threaten habitat integrity and displace native species.
4. Predation and disturbance by introduced mammalian predators and by native avian predators (numbers of the latter appear to be high as a result of human induced land use changes).
5. Eutrophication and other changes in water quality.
6. Recreation activities such as fishing, dog walking, use of 4WD vehicles, which disturb or kill wildlife and reduce habitat quality (O'Donnell *et al.,* 2016).

The first three factors can work, either in isolation or together, to reduce extent (i.e. quantity) of native bird habitat, particularly the preferred ground-nesting habitat for many river bird species. The latter three could be considered to impact more on quality of nesting and feeding habitat.

The flow regime of a braided river has a direct influence on its physical structure and vegetation cover, and therefore bird habitat availability. Flowing water transports sediment, shaping river channels and islands. Periodic floods are important in clearing vegetation, particularly introduced shrub weeds, and maintaining areas of bare or sparsely-vegetated substrate that are preferred nesting habitat of many river birds. Reductions in magnitude or frequency of floods can exacerbate spread of terrestrial weeds and reduce the area of sparsely-vegetated substrates available for river birds. Structural modification of riverbeds, for example by stopbank construction and gravel extraction, can also alter the extent of braided river bird habitat. Similarly, river protection plantings, spread of naturalised exotic vegetation and floodplain land developments can change natural river geomorphology, for example by reducing width of the floodplain, constraining the river within relatively stable channels and reducing the number of braids (O'Donnell *et al.,* 2016).

Exotic weeds cover areas of riverbed that were formerly bare shingle or covered in low-stature indigenous plants (e.g. *Raoulia* spp., *Muehlenbeckia axillaris, Epilobium* spp). Areas clear of emergent plants are key breeding and foraging habitats for many birds. By mapping the extent of weeds from aerial photographs it is possible to gain an idea of the area of habitat lost to indigenous plant species. Weed encroachment reaches up to 75% cover in some rivers (Wilson, 2001) which reflects the extent of habitat loss.

Braided rivers are naturally dynamic ecosystems; location and extent of their various constituent habitats, including those used by braided river birds, does change over time (Gray and Harding, 2007).

In a natural state braided river, while location of active, young and mature braidplain surfaces will shift, their total area and proportion within the braidplain remains relatively constant (Gray *et al.,* 2016). The human-mediated factors described above interact with each other and natural ecosystem drivers in complex ways, but their overall effect has been to reduce quantity and quality of habitat for birds (O'Donnell *et al.,* 2016), and other native species.

The purpose of this report is to provide a 2012 measure of extent of "useable" braided river bird habitat across the region, as a baseline for monitoring progress toward the CWMS outcome of increased area of useable bird habitat. It focuses on the habitats associated with six characteristic and relatively widespread species that utilise Canterbury braided rivers during their breeding/nesting season. These species – wrybill, banded dotterel, pied stilt, South Island pied oystercatcher, black-fronted tern and black-billed gull – are members of the 'waders' and 'gulls and terns' water bird guilds, or species grouping (O'Donnell, 2000).

2 Methods

Remote sensing software (ERDAS Imagine 2010) and a Geographic Information System (GIS) (ESRI ArcGIS) were used to identify and measure braided river bird habitats across the region. The outlines of 77 braided riverbed study areas, shown in Figures 2-1 to 2-3, were created and 2012 satellite imagery within these areas classified into a range of ground covers. A full description of the spectral analysis and regional classification methodology is provided in Appendices 1and 2. The braided riverbed study areas were not intended to define bed and margins of braided rivers for statutory or planning purposes; rather to define an 'area of interest' for purpose of identifying and monitoring extent of useable native bird habitat within braided river bed environments. Braided river study areas generally followed the braided river sections as named and described in the Environment Canterbury 'Native bird habitat' GIS layer and accompanying technical report (O'Donnell, 2000).

Braided river ground cover classes identified from spectral analysis were evaluated with reference to the findings from earlier detailed research into bird habitat use on the Ahuriri River (Robertson *et al.* 1983; Appendix 3). Habitat use analyses from this earlier study, together with expert knowledge of Department of Conservation scientists (CFJ O'Donnell and A Grant, pers comm. 2016) was drawn on to identify 'optimal' as well as 'useable' native bird habitats from the satellite imagery analysis. Braided river 'islands' and sites in proximity to water channels provide optimal habitat conditions - a degree of protection from mammalian predators and better feeding opportunities, respectively (Pickerell, 2015) – and therefore the extent of these habitats were also identified from spectral analysis.

Area (ha) of optimal and useable breeding habitat, and useable feeding habitat, were calculated for each of the 77 braided river survey areas.

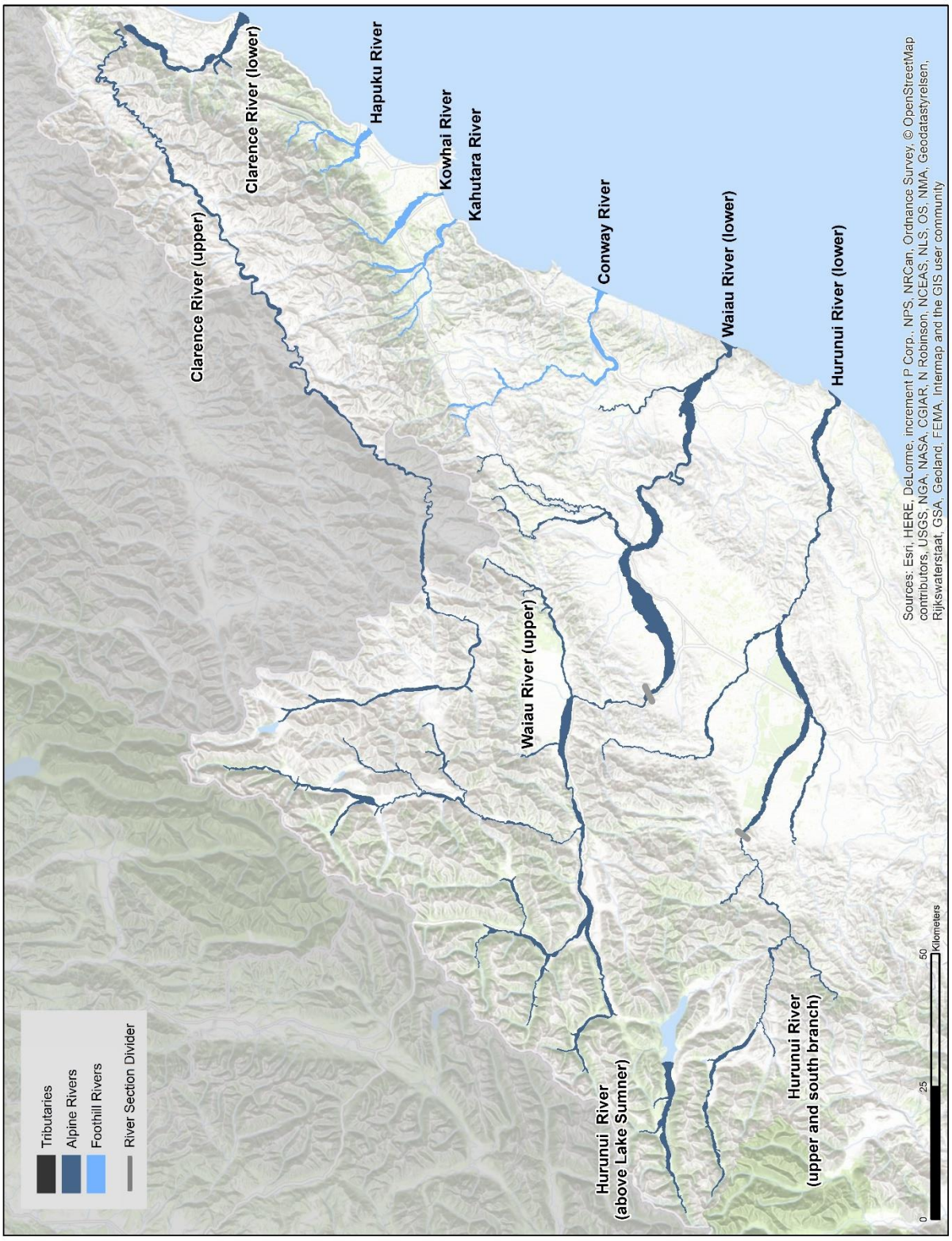

Figure 2-1: North Canterbury braided river study areas

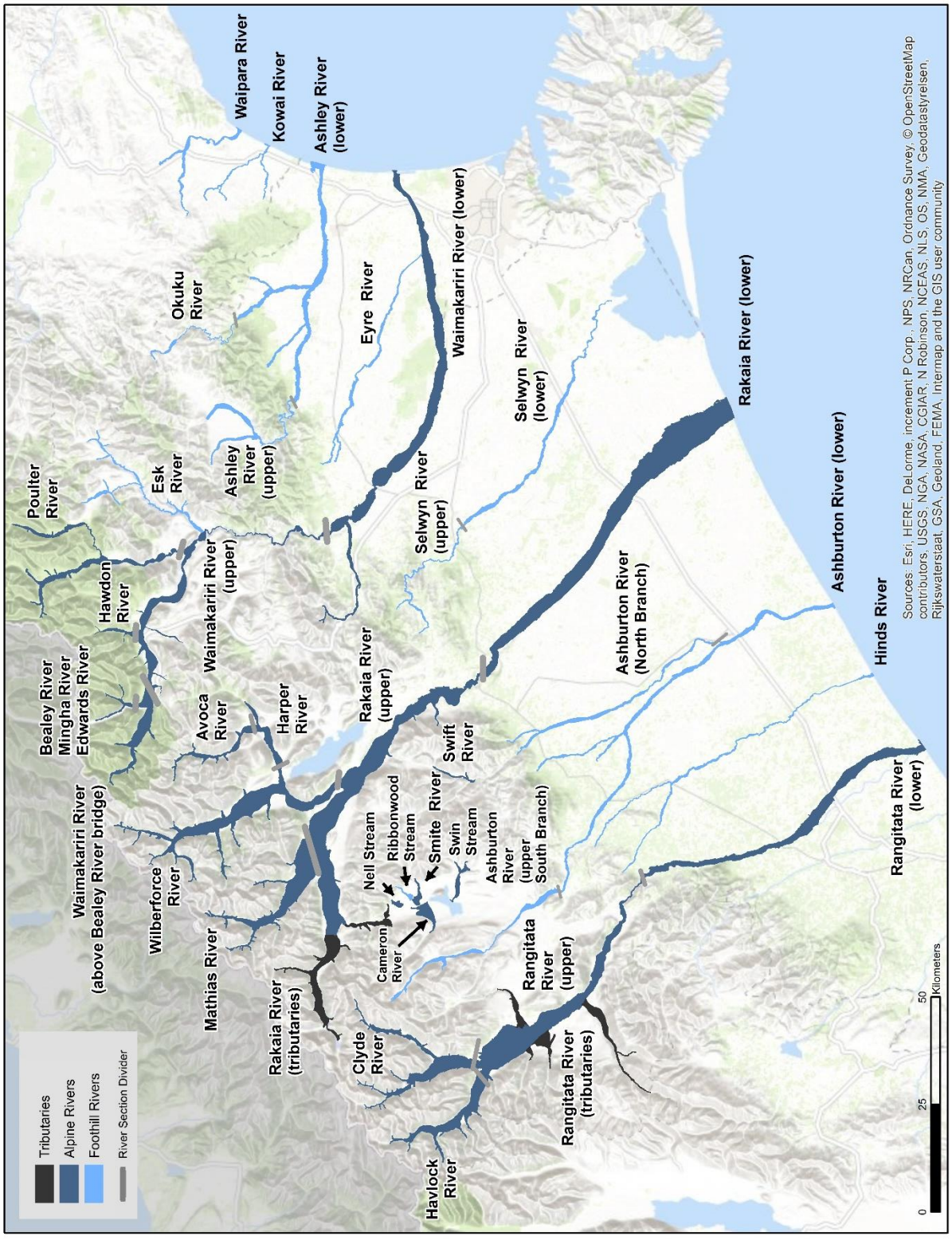

Figure 2-2: Mid Canterbury braided river bed study areas

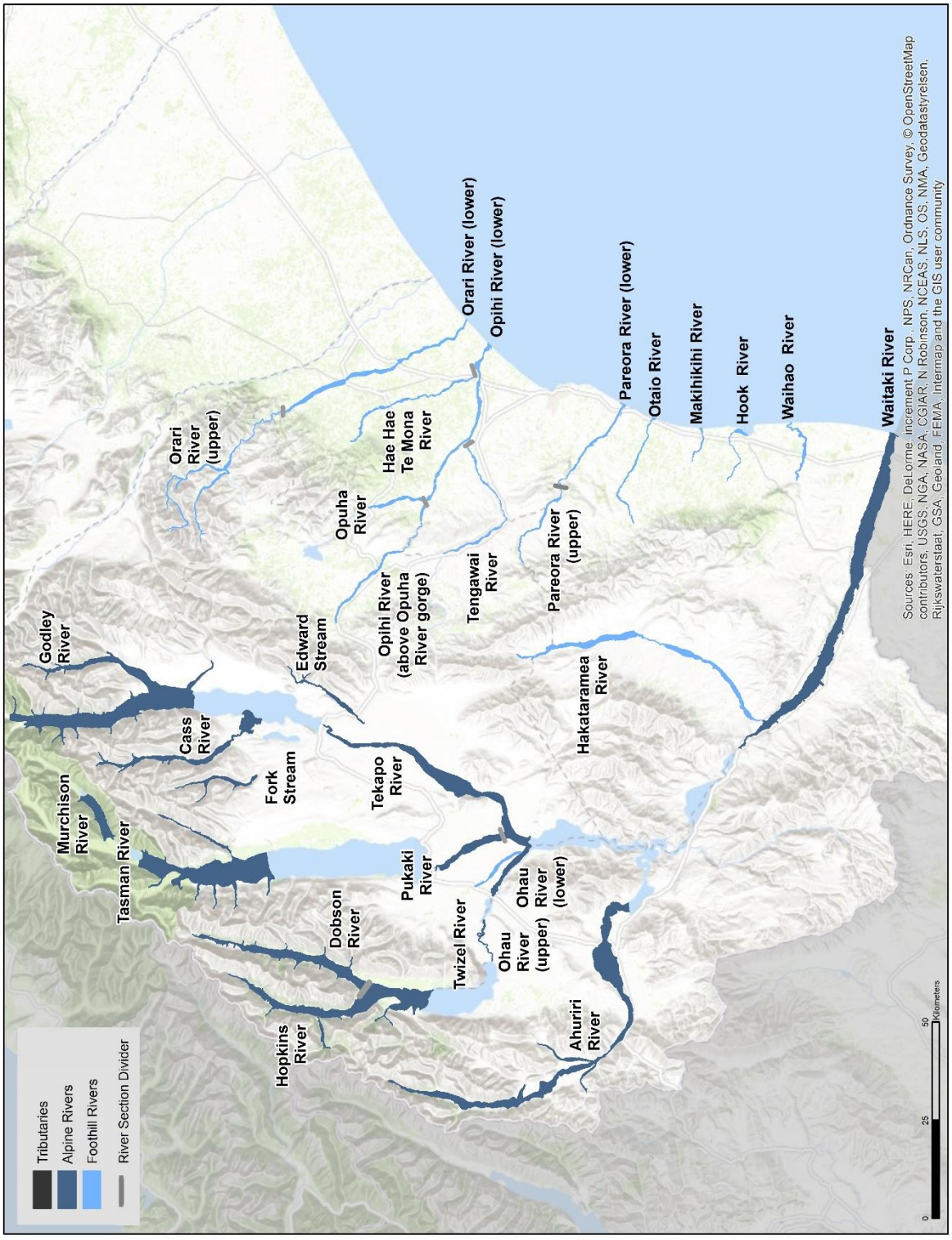

Figure 2-3: South Canterbury braided river bed study areas

3 Results

3.1 Spectral analysis classification

A list and description of the eight riverbed ground covers classified by spectral analysis of 2012 satellite imagery is shown in Table 3-1. A 'best-fit' match of these with the habitat classes described by Robertson *et al.* (1983) is shown in Table 3-2. Photograph examples of Table 3-1 ground cover classes are shown in Appendix 2.

Table 3-1: Names and descriptions for eight braided riverbed ground covers classified by spectral analysis

Cover Class	Description
Water 1 *Feeding habitat*	Deep water channel (>25 cm) and with the image pixel consisting mainly of water.
Water 2 *Feeding habitat*	Shallow water channel (<25 cm) and/or image pixel consisting of a composite of water and exposed riverbed gravels.
Raw riverbed *Nesting and feeding habitat*	Gravels and fine sediments (reworked and deposited sediments from flood events) with a fresh raw appearance (steep bank edges) and no vegetation (Figure A2-1 and Figure A2-2. Frequently inundated during freshes / small to moderate flood flows.
Older riverbed *Nesting and feeding habitat*	Smooth gravels and sediments (rounded bank edges); some signs of weathering rinds or lichens on gravels and limited establishment of low stature vegetation (Figure A2-3 and Figure A2-4). May be inundated during moderate to high flood flows.
Sparse vegetation cover *Nesting and feeding habitat*	<30% herbaceous or shrub vegetation cover with extensive exposed gravels and/or finer sediments (Figure A2-5 and figure A2-6). May be inundated during moderate to high flood flows.
Moderate vegetation cover *Nesting and feeding habitat*	30-50% herbaceous or shrub vegetation cover with exposed gravels and/or finer sediments (Figure A2-7 and figure A2-8). Inundated during high annual flood events.
High vegetation cover *Not utilised*	50-80% herbaceous or shrub vegetation cover with some exposed gravels and/or finer sediments (Figure A2-9 and Figure A2-10). May be inundated during high annual floods as well as more occasional larger flood events.
Dense vegetation cover *Not utilised*	>80% herbaceous or shrub vegetation cover with little to no exposed gravels and/or finer sediments (Figure A2-11 and Figure A2-12). Generally, not inundated during annual floods but may be during occasional larger flood events.

The bird habitat descriptions of Robertson *et al.* (1983) contain information on ground cover, vegetation structure and composition. However, the 2012 satellite imagery habitat classification is principally based on overall ground or vegetation percentage cover as viewed from above, and does not distinguish between vegetation structure and compositional groups. For water, bare gravel and sparsely vegetated riverbed habitats there is a close match between the two classifications. For moderate to dense vegetation cover there is less of a match. The 'Prostrate Vegetation / Herbfield' habitat of Robertson *et al.* (1983) was considered to best fit within the 2012 'Moderate vegetation cover' habitat class, although this class can also include other taller herbaceous and woody vegetation. 'High' and 'Dense' vegetation cover includes one or more of the following habitats described by Robertson *et al.* (1983): 'turf grassland', 'taller shrubs', 'willows', 'tussockland', 'pasture' (Table 3-2).

Table 3-2: Match of riverbed habitats described by Robertson *et al.* (1983) with 2012 satellite imagery ground cover classification

Robertson *et al.* (1983)	**2012 classification**
Water, Water and algae underwater, Water and floating surface vegetation, and Water and submerged terrestrial vegetation	Water 1 and Water 2
Bare ground	Raw riverbed and Older Riverbed
Bare ground sparse vegetation	Sparse vegetation cover
Prostrate vegetation (<10cm) herbfield, Taller shrubs (10-200cm), Willow, Flood debris	Moderate vegetation cover
Turf grassland, Taller shrubs, Willow, Tussockland	High vegetation cover
Turf grassland, Taller shrubs, Willow, Tussockland, Pasture	Dense vegetation cover

3.2 Regional classification

Regional riverbed ground cover classification results were created as maps and attribute tables, which were viewed in ArcGIS, an example is shown in Figure 3-1. Figure 3-1 displays a section of the upper Rakaia River classification results; each class can be clearly seen and is represented by a different colour, Figure 3-2 displays the ortho-photo of the same section of river.

Table 3-3 gives the total area of the eight ground cover classes within the 77 braided rivers survey areas.

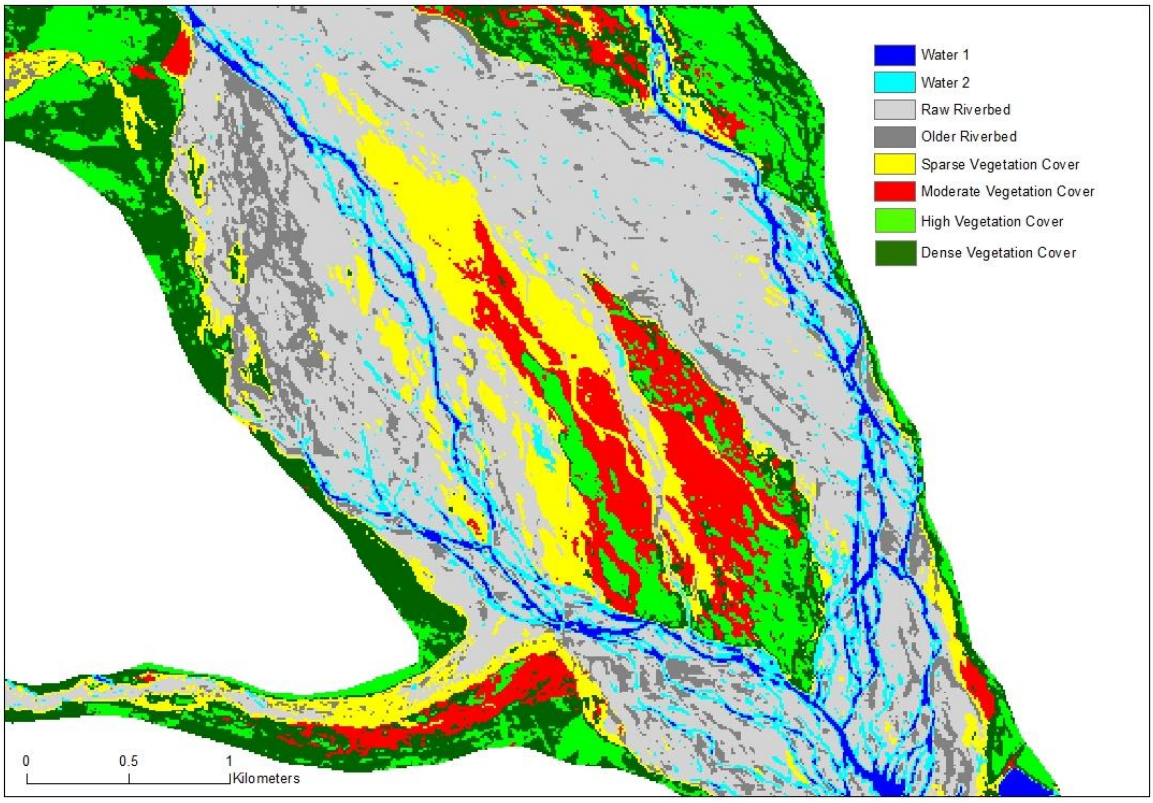

Figure 3-1: A section of the upper Rakaia River classification results

Figure 3-2: Ortho-photo of the area displayed in Figure 3-1

Table 3-3: Ground cover classification results (total ha) for 77 Canterbury Region braided river study areas (rivers listed alphabetically)

River	Water 1 Area (ha)	Water 2 Area (ha)	Raw Riverbed Area (ha)	Older Riverbed Area (ha)	Sparse Vegetation Cover Area (ha)	Moderate Vegetation Cover Area (ha)	High Vegetation Cover Area (ha)	Dense Vegetation Cover Area (ha)	Total Area (ha)
Ahuriri River	141	142	19	61	546	1,041	4,346	509	6,806
Ashburton River (North Branch)	7	91	6	7	305	25	538	558	1,538
Ashburton River (lower)	51	183	16	70	527	100	1,896	1,050	3,893
Ashburton River (upper South Branch)	0	21	31	124	189	212	629	190	1,396
Ashley River lower	186	264	5	41	481	44	2,384	941	4,346
Ashley River (upper)	27	78	8	13	173	15	622	281	1,217
Avoca River	6	62	94	117	185	122	259	215	1,060
Bealey, Mingha, Edwards Rivers	9	37	5	87	37	20	36	61	291
Cameron River	0	8	12	75	76	52	321	90	635
Cass River	66	229	426	207	555	384	711	194	2,773
Clarence River (lower)	14	422	164	220	290	109	246	294	1,757
Clarence River (upper)	380	993	61	515	583	221	293	1,190	4,237
Clyde River	11	180	98	1,729	405	387	572	288	3,670
Conway River	36	171	39	7	319	18	219	637	1,445
Dobson River	158	328	582	503	468	199	1,291	809	4,340
Edward Stream	3	1	0	12	61	168	442	28	714
Esk River	29	89	24	174	226	72	234	170	1,016
Eyre River	0	9	0	0	108	10	649	478	1,255
Fork Stream	0	4	23	85	141	47	286	61	647
Godley River	388	1,013	1,697	2,494	2,135	1,355	2,424	973	12,479
Hae Hae Te Mona River	3	8	0	2	41	17	585	201	858
Hakataramea River	10	33	0	2	62	64	2,109	352	2,631
Hapuku River	30	302	4	1	30	1	77	421	865
Harper River	12	33	42	117	121	231	297	71	923
Havlock River	4	109	112	1,455	304	303	336	215	2,839
Hawdon River	3	23	11	108	62	110	142	61	520
Hinds River	1	4	0	2	28	68	804	454	1,361
Hook River	1	2	0	0	4	3	86	134	230
Hopkins River	512	434	305	1,089	735	266	2,133	1,082	6,556
Hurunui River (above Lake Sumner)	62	78	17	39	164	24	687	254	1,325

River	Water 1 Area (ha)	Water 2 Area (ha)	Raw Riverbed Area (ha)	Older Riverbed Area (ha)	Sparse Vegetation Cover Area (ha)	Moderate Vegetation Cover Area (ha)	High Vegetation Cover Area (ha)	Dense Vegetation Cover Area (ha)	Total Area (ha)
Hurunui River (lower)	299	342	28	76	890	87	2,134	1,341	5,197
Hurunui River (upper and south branch)	77	161	23	32	262	48	479	580	1,661
Kahutara River	5	82	16	2	210	5	191	564	1,075
Kowai River	3	3	0	3	28	4	303	85	428
Kowhai River	2	75	9	0	60	2	98	600	845
Makihikihi River	1	3	1	1	10	1	34	78	128
Mathias River	57	250	1,203	386	512	279	1,642	1,332	5,661
Murchison River	38	64	53	289	325	434	217	78	1,498
Nell Stream	0	1	6	1	26	7	53	30	126
Ohau River (upper)	35	15	1	1	28	56	20	49	205
Ohau River (lower)	38	27	0	0	144	320	176	202	907
Okuku River	6	32	0	0	21	5	140	90	296
Opihi River (lower)	96	73	3	25	101	101	916	284	1,599
Opihi River (above Opuha River gorge)	0	13	0	4	104	23	535	109	789
Opuha River	3	19	0	0	30	19	289	114	475
Orari River (lower)	8	35	4	48	234	125	848	672	1,975
Orari River (upper)	3	24	7	66	228	133	682	183	1,325
Otaio River	0	9	1	1	24	4	238	184	461
Pareora River (lower)	25	26	1	1	22	7	244	175	500
Pareora River (upper)	2	4	0	0	11	4	291	83	394
Poulter River	137	233	143	343	449	182	681	594	2,762
Pukaki River	5	5	4	278	154	913	107	109	1,574
Rakaia River (lower)	955	1,271	554	3,518	862	350	5,699	3,285	16,494
Rakaia River (upper)	739	720	1,788	2,694	825	920	2,472	1,837	11,996
Rakaia River (tributaries)	28	158	230	537	321	622	790	523	3,210
Rangitata River (lower)	304	250	82	981	600	237	1,396	2,123	5,973
Rangitata River (upper)	419	608	548	2,493	867	1,122	2,494	442	8,992
Rangitata River (tributaries)	0	19	57	356	347	496	840	234	2,350
Ribbonwood Stream	0	1	3	19	15	1	14	58	109
Selwyn River (lower)	2	27	1	5	130	21	1,362	365	1,914
Selwyn River (upper)	1	15	0	0	40	7	277	196	536

River	Water 1 Area (ha)	Water 2 Area (ha)	Raw Riverbed Area (ha)	Older Riverbed Area (ha)	Sparse Vegetation Cover Area (ha)	Moderate Vegetation Cover Area (ha)	High Vegetation Cover Area (ha)	Dense Vegetation Cover Area (ha)	Total Area (ha)
Smite River	0	0	2	13	54	66	102	22	259
Swin Stream	0	0	0	39	48	62	215	35	400
Swift River	1	15	2	25	41	45	23	24	175
Tasman River	480	878	1,109	1,528	1,467	1,550	1,722	603	9,337
Tekapo River	78	119	26	165	396	2,045	2,373	569	5,771
Twizel River	2	10	0	1	28	22	199	179	440
Tengawai River	2	18	0	2	44	13	612	151	844
Waiau River (lower)	434	634	135	626	1,410	229	2,891	1,501	7,860
Waiau River (upper)	334	734	125	306	889	172	1,699	2,556	6,815
Waihao River	28	16	0	1	22	4	191	177	438
Waimakariri River (above Bealey River bridge)	32	81	114	505	340	217	425	380	2,093
Waimakariri River (lower)	327	1,266	319	2,206	1,241	320	2,457	2,272	10,409
Waimakariri River (upper)	431	306	196	1,558	554	568	406	607	4,628
Waipara River	9	36	3	6	136	20	558	185	952
Waitaki River	1,300	943	41	162	916	320	4,517	2,642	10,841
Wilberforce River	291	675	2,319	591	1,015	1,146	906	1,272	8,216

3.3 Bird habitat use

While numerous bird species utilise braided rivers, this study focuses on six characteristic and relatively widespread species which depend on Canterbury braided rivers for habitats during their breeding/nesting season. These species – wrybill, banded dotterel, pied stilt, South Island pied oystercatcher (SIPO), black-fronted tern and black-billed gull – are members of the 'waders' and 'gulls and terns' water bird guilds, or species grouping, (O'Donnell, 2000). Another notable braided river wading bird species of more restricted distribution is the kāki or black stilt. Braided rivers in the upper Waitaki valley are key habitat for this highly threatened ('Nationally Critical' – Robertson *et al.* 2017) species.

For the generalised 'waders' and 'gulls and terns' guilds (also known as 'shore birds'), Robertson *et al.* (2003) identified 'bare ground', 'bare ground with sparse vegetation' and 'water' as the main riverbed habitats utilised during the spring-summer breeding season (Appendix 3). These correspond with 'Water 1', 'Water 2', 'Raw riverbed', 'Older riverbed, and 'Sparse vegetation cover' from the satellite imagery habitat classification (Table 3-2).

'Water 1' and 'Water 2' are feeding or foraging, rather than nesting habitats. 'Water 1' (deep water) is only utilised for foraging by aerial hunting gulls and terns, while shallow 'Water 2' is also feeding habitat for waders.

Raw gravels are frequently inundated with water during freshes, so the relative extent of, 'Water 2' and 'Raw riverbed' habitats is naturally highly variable over the course of the bird breeding season. The fluctuating 'wetted margin' interface between water and raw riverbed is especially valuable feeding habitat for wading birds (O'Donnell and Moore, 1983; O'Donnell, 2000). Despite being frequently inundated, 'raw riverbed' is used as nesting habitat by braided river birds, especially wrybill and black-fronted tern.

We have calculated 'useable' nesting habitat from extent of 'Raw riverbed', 'Older riverbed', 'Sparse vegetation cover' and 'Moderate vegetation cover' categories. 'Useable' feeding habitat varies between species, but 'on-river' feeding habitats are considered to include 'Water 1', 'Water 2', 'Raw riverbed', and 'Sparse' to 'Moderate' vegetation cover. Braided river habitat used by seven characteristic species is summarised in Table 3-4, and described in more detail in Appendix 4.

Table 3-4: Summary of braided river habitat use by seven bird species over the breeding season 'Obligate' species breed only on braided river beds, 'primary' species breed largely on braided river beds but also utilise some other habitats; 'facultative' species breed in a range of habitats including braided river beds

Species **Habitat**	**Wrybill** Obligate	**Banded dotterel** Primary	**Black stilt** Primary	**Pied stilt** Facultative	**SIPO** Primary	**Black-fronted tern** Obligate	**Black-billed gull** Primary
Water 1	Not used	Not used	Not used	Not used	Not used	Feeding	Feeding
Water 2	Feeding	Feeding	Feeding	Feeding	Feeding	Feeding	Feeding
Raw riverbed	Nesting Feeding	Feeding	Feeding	Feeding	Feeding	Nesting	Nesting
Older riverbed	Nesting	Nesting Feeding	Nesting	Nesting	Nesting	Nesting	Nesting
Sparse vegetation cover	Nesting	Nesting Feeding	Nesting	Nesting	Nesting	Nesting	Not used
Moderate vegetation cover	Not used	Nesting Feeding	Not used	Not used	Nesting	Not used	Not used
High vegetation cover	Not used	Not used	Not used	Not used	Not used	Not used	Not used
Dense vegetation cover	Not used	Not used	Not used	Not used	Not used	Not used	Not used

3.4 Regional results

3.4.1 Ranking useable nesting habitat

Of the eight cover classes, four were identified as useable nesting habitat for braided river birds: raw riverbed, older riverbed, sparse vegetation cover, moderate vegetation cover. Optimal (prime) suitable nesting habitats are older riverbed and sparse vegetation cover types located on islands. As well as having suitable ground cover and good feeding opportunities, prime island habitats also provide nesting birds a degree of protection from mammalian predation and flood inundation. Second best 'high value' nesting habitats are raw riverbed together with older riverbed and sparse vegetation cover types in proximity (within ten metres) of water.

Useable nesting habitats were ranked as follows:

1. **Prime habitats.** 'Older riverbed' and 'Sparse vegetation' cover classes located on river islands (larger than 10 square metres), surrounded by at least a 10 m-wide deep water channel. Potentially utilised by all six species.
2. **High value habitats.** 'Raw riverbed' plus 'Older riverbed' and 'Sparse vegetation' cover classes located within ten metres of water, excluding island areas already identified. Potentially utilised by all six species.
3. **Medium value habitats.** Remaining areas of 'older riverbed' and 'Sparse vegetation' cover classes not already identified. Potentially utilised by all six species.
4. **Other useable habitats.** All areas of 'Moderate vegetation' cover class within the riverbed. Generally utilised by only banded dotterel and South Island pied oystercatcher.

Extent of these ranked useable nesting habitats for each of the regions braided river survey areas are shown in Tables 3-5 to 3-8 below. The river sections are grouped according to their habitat significance, as assessed by O'Donnell (2000).

Table 3-5: Area of ranked useable nesting habitats - nationally and internationally significant (O'Donnell 2000) Canterbury braided rivers. Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of prime nesting habitat (ha)	Area of high value nesting habitat (ha)	Area of medium value nesting habitat (ha)	Area of other useable nesting habitat (ha)	Total useable nesting habitat (ha)	Total river survey area (ha)	% of useable nesting habitat
Conway River	Foothill	0	136	229	18	382	1,445	26
Waiau River (upper)	Alpine	0	513	808	172	1,493	6,815	22
Waiau River (lower)	Alpine	18	542	1,611	229	2,400	7,860	31
Hurunui River (lower)	Alpine	2	306	686	87	1,081	5,197	21
Waipara River	Foothill	0	32	113	20	164	952	17
Ashley River (lower)	Foothill	0	183	344	44	571	4,346	13
Waimakariri River (upper)	Alpine	27	485	1,796	568	2,876	4,628	62
Waimakariri River (lower)	Alpine	8	870	2,887	320	4,086	10,409	39
Wilberforce River	Alpine	6	2,499	1,420	1,146	5,071	8,216	62
Rakaia River (upper)	Alpine	108	2,124	3,074	920	6,227	11,995	52
Rakaia River (lower)	Alpine	376	1,164	3,393	350	5,283	16,494	32
Ashburton River (lower)	Foothill	0	196	416	100	712	3,893	18
Rangitata River (upper)	Alpine	54	854	3,000	1,122	5,030	8,996	56
Rangitata River (lower)	Alpine	3	319	1,342	237	1,900	5,973	32
Orari River (lower)	Foothill	0	45	242	125	412	1,975	21
Opihi River (lower)	Foothill	0	58	71	101	230	1,599	14
Godley River	Alpine	8	2,248	4,070	1,355	7,681	12,479	62
Cass River	Alpine	0	484	705	384	1,573	2,773	57
Tasman River	Alpine	0	1,452	2,652	1,550	5,654	9,337	61
Edward Stream	Alpine	0	1	72	168	241	714	34
Tekapo River	Alpine	0	163	424	2,045	2,632	5,771	46
Pukaki River	Alpine	0	11	424	913	1,348	1,574	86
Dobson River	Alpine	0	716	837	199	1,753	4,340	40
Hopkins River	Alpine	55	585	1,490	266	2,396	6,556	37
Ohau River (upper)	Alpine	0	14	16	56	86	205	42
Ohau River (lower)	Alpine	0	20	124	320	464	907	51
Ahuriri River	Alpine	0	166	460	1,041	1,667	6,805	25
Waitaki River	Alpine	309	335	474	320	1,438	10,841	13

Table 3-6: Area of ranked useable nesting habitats - regionally significant (O'Donnell 2000) Canterbury braided rivers. Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of prime nesting habitat (ha)	Area of high value nesting habitat (ha)	Area of medium value nesting habitat (ha)	Area of other useable nesting habitat (ha)	Total useable nesting habitat (ha)	Total river survey area (ha)	% of useable nesting habitat
Clarence River (upper)	Alpine	1	445	713	221	1,379	4,237	33
Clarence River (lower)	Alpine	0	290	384	109	782	1,757	45
Harper River	Alpine	0	73	206	231	511	923	55
Mathias River	Alpine	0	1,282	801	279	2,362	5,661	42
Rakaia River (tributaries)	Alpine	0	348	740	623	1,711	3,210	53
Ashburton River (North Branch)	Foothill	0	98	219	25	342	1,538	22
Clyde River	Alpine	0	296	1,936	387	2,618	3,670	71
Havlock River	Alpine	0	269	1,603	303	2,175	2,839	77
Tengawai River	Foothill	0	16	30	13	59	844	7
Twizel River	Foothill	0	11	18	22	51	440	12
Pareora River (lower)	Foothill	0	11	13	7	30	500	6
Murchison River	Alpine	7	125	535	434	1,094	1,498	73
Hakataramea River	Foothill	0	23	41	64	128	2,631	5

Table 3-7: Area of ranked useable nesting habitats - locally significant (O'Donnell, 2000) Canterbury braided rivers. Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of prime nesting habitat (ha)	Area of high value nesting habitat (ha)	Area of medium value nesting habitat (ha)	Area of other useable nesting habitat (ha)	Total useable nesting habitat (ha)	Total river survey area (ha)	% of useable nesting habitat
Hurunui River (upper and south branch)	Alpine	0	110	206	48	364	1,661	22
Kowai River	Foothill	0	3	28	4	35	428	8
Poulter River	Alpine	1	315	618	182	1,117	2,762	40
Hawdon River	Alpine	0	37	145	110	291	520	56
Bealey, Mingha, Edwards Rivers	Alpine	0	48	81	20	149	291	51
Waimakariri River (above Bealey River bridge)	Alpine	0	196	763	217	1,175	2,093	56
Avoca River	Alpine	0	130	266	122	518	1,060	49
Cameron River	Alpine	0	18	146	52	216	635	34
Hinds River	Foothill	0	2	29	68	98	1,361	7
Orari River (upper)	Foothill	0	28	273	133	434	1,325	33
Hae Hae Te Mona River	Foothill	0	6	37	17	60	858	7

Table 3-8: Area of ranked useable nesting habitats on other Canterbury braided rivers not rated by O'Donnell (2000). Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of prime nesting habitat (ha)	Area of high value nesting habitat (ha)	Area of medium value nesting habitat (ha)	Area of other useable nesting habitat (ha)	Total useable nesting habitat (ha)	Total river survey area (ha)	% of useable nesting habitat
Hapuku River	Foothill	0	30	5	1	36	865	4
Kowhai River	Foothill	0	40	29	2	71	845	8
Kahutara River	Foothill	0	66	162	5	233	1,075	22
Hurunui River (above Lake Sumner)	Alpine	0	79	141	24	244	1,325	18
Okuku River	Foothill	0	12	10	5	27	296	9
Ashley River (upper)	Foothill	0	65	129	15	209	1,217	17
Eyre River	Foothill	0	14	94	10	118	1,255	9
Esk River	Foothill	0	108	316	72	496	1,016	49
Selwyn River (upper)	Foothill	0	13	27	7	47	536	9
Selwyn River (lower)	Foothill	0	27	109	21	157	1,914	8
Rangitata River (tributaries)	Alpine	0	77	683	496	1,256	2,350	53
Smite River	Foothill	0	3	66	66	135	259	52
Nell Stream	Alpine	0	7	27	7	41	126	33
Ribbonwood Stream	Foothill	0	3	33	1	37	109	34
Swift River	Foothill	0	21	69	62	152	400	87
Swin Stream	Foothill	0	1	65	45	111	175	28
Ashburton River (upper South Branch)	Foothill	0	57	287	212	556	1,396	40
Opuha River	Foothill	0	14	16	19	49	475	10
Opihi River (above Opuha River gorge)	Foothill	0	18	91	23	131	789	17
Pareora River (upper)	Foothill	0	2	9	4	15	394	4
Otaio River	Foothill	0	9	16	4	29	461	6
Makihikihi River	Foothill	0	2	9	1	12	128	10
Hook River	Foothill	0	1	3	3	7	230	3
Waihao River	Foothill	0	9	14	4	27	438	6
Fork Stream	Alpine	0	28	221	47	295	647	46

3.4.2 Useable feeding habitat

'Useable' feeding habitats vary between species. Overall, however, all the following cover classes were considered 'useable' by one or more of the six species: 'Water 1', 'Water 2', 'Raw riverbed', 'Older riverbed', 'Sparse vegetation', 'Moderate vegetation'. Note that only 'on river' feeding habitats were identified in this study. 'High vegetation' and 'Dense vegetation' cover classes are considered not to be useable nesting or feeding habitat for the six birds that are the focus of this study, although they may be habitat for other native species.

Water 2 (shallow water) and raw gravel, particularly the 'wetted edge' shallow water-gravel margin, are prime 'on river' feeding habitats, especially for wading birds. However, extent and location of this wetted edge is so highly changeable that results from a 'single snapshot' satellite imagery analysis are of little relevance for long-term monitoring. For this reason, feeding habitats are not ranked; instead the listed cover classes are aggregated to provide total useable feeding habitat area (Table 3-9 to Table 3-12).

Table 3-9: Area of useable bird feeding habitat - nationally and internationally significant (O'Donnell, 2000) Canterbury braided rivers. Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of feeding habitat (ha)	Total river survey area (ha)	% of useable feeding habitat
Conway River	Foothill	589	1,445	40
Waiau River (upper)	Alpine	2,560	6,815	37
Waiau River (lower)	Alpine	3,469	7,860	44
Hurunui River (lower)	Alpine	1722	5,197	13
Waipara River	Foothill	209	952	22
Ashley River (lower)	Foothill	1021	4,346	23
Waimakariri River (upper)	Alpine	3614	4,628	78
Waimakariri River (lower)	Alpine	5,679	10,409	55
Wilberforce River	Alpine	6,037	8,216	73
Rakaia River (upper)	Alpine	7,687	11,995	64
Rakaia River (lower)	Alpine	7,510	16,494	46
Ashburton River (lower)	Foothill	947	3,893	24
Rangitata River (upper)	Alpine	6,056	8,996	67
Rangitata River (lower)	Alpine	2,454	5,973	41
Orari River (lower)	Foothill	455	1,975	23
Opihi River (lower)	Foothill	399	1,599	25
Godley River	Alpine	9,082	12,479	73
Cass River	Alpine	1,868	2,773	67
Tasman River	Alpine	7,012	9,337	75
Edward Stream	Alpine	245	714	34
Tekapo River	Alpine	2,829	5,771	49
Pukaki River	Alpine	1,358	1,574	86
Dobson River	Alpine	2,240	4,340	52
Hopkins River	Alpine	3,341	6,556	51
Ohau River (upper)	Alpine	136	205	66
Ohau River (lower)	Alpine	529	907	58
Ahuriri River	Alpine	1,951	6,805	29
Waitaki River	Alpine	3,682	10,841	34

Table 3-10: Area of useable bird feeding habitat - regionally significant (O'Donnell, 2000) Canterbury braided rivers. Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of feeding habitat (ha)	Total river survey area (ha)	% of useable feeding habitat
Clarence River (upper)	Alpine	2,754	4,237	65
Clarence River (lower)	Alpine	1,218	1,757	70
Harper River	Alpine	555	923	50
Mathias River	Alpine	2,688	5,661	47
Rakaia River (tributaries)	Alpine	1,897	3,210	59
Ashburton River (North Branch)	Foothill	104	1,538	29
Clyde River	Alpine	2809	3,670	77
Havelock River	Alpine	2,287	2,839	81
Tengawai River	Foothill	80	844	9
Twizel River	Foothill	63	440	14
Pareora River (lower)	Foothill	81	500	16
Murchison River	Alpine	1,203	1,498	80
Hakataramea River	Foothill	171	2,631	6

Table 3-11: Area of useable bird feeding habitat - locally significant (O'Donnell, 2000) Canterbury braided rivers. Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of feeding habitat (ha)	Total river survey area (ha)	% of useable feeding habitat
Hurunui River (upper and south branch)	Alpine	602	1,661	36
Kowai River	Foothill	41	428	10
Poulter River	Alpine	1,487	2,762	56
Hawdon River	Alpine	317	520	61
Bealey, Mingha, Edwards Rivers	Alpine	194	291	67
Waimakariri River (above Bealey River bridge)	Alpine	1288	2,093	62
Avoca River	Alpine	586	1,060	55
Cameron River	Alpine	224	635	35
Hinds River	Foothill	104	1,361	8
Orari River (upper)	Foothill	460	1,325	35
Hae Hae Te Moana River	Foothill	72	858	8

Table 3-12: Area of useable bird feeding habitat – Canterbury braided rivers not rated by O'Donnell (2000). Rivers are listed north to south and classified as 'alpine' or 'foothill' depending on whether sourced from the main axial ranges or eastern ranges

River	Type	Area of feeding habitat (ha)	Total river survey area (ha)	% of useable feeding habitat
Hapuku River	Foothill	368	865	43
Kowhai River	Foothill	148	845	18
Kahutara River	Foothill	319	1,075	30
Hurunui River (above Lake Sumner)	Alpine	384	1,325	29
Okuku River	Foothill	66	296	22
Ashley River (upper)	Foothill	313	1,217	26
Eyre River	Foothill	127	1,255	10
Esk River	Foothill	613	1,016	60
Selwyn River (upper)	Foothill	63	536	12
Selwyn River (lower)	Foothill	186	1,914	10
Rangitata River (tributaries)	Alpine	1275	2,350	54
Smite River	Foothill	135	259	52
Nell Stream	Foothill	42	126	33
Ribbonwood Stream	Foothill	37	109	34
Swift River	Foothill	128	400	32
Swin Stream	Foothill	150	175	86
Ashburton River (upper South Branch)	Foothill	576	1,396	41
Opuha River	Foothill	71	475	14
Opihi River (above Opuha River gorge)	Foothill	145	789	18
Pareora River(upper)	Foothill	21	394	5
Otaio River	Foothill	39	461	8
Makihikihi River	Foothill	16	128	13
Hook River	Foothill	10	230	4
Waihao River	Foothill	70	438	16
Fork Stream	Alpine	299	647	46

4 Discussion

From analysis of 2012 satellite imagery of 77 Canterbury braided river sections or study areas totalling 224,550 ha in extent, 87,045 ha are categorised as being useable braided river bird nesting habitat, and 111,907 ha are categorised as useable feeding habitat. Most (>70%) of the 'useable' habitats as calculated in this study are on river sections previously classified as Nationally and Internationally Significant habitats for indigenous birds (O'Donnell, 2000).

However, total regional extent of 'prime' nesting habitats, that is islands providing a degree of protection from mammalian predators, and 'high value' nesting habitats, which from their proximity to water are considered to provide better feeding opportunities for the greatest range of nesting bird species, is considerably lower, at 983 ha and 21,405 ha respectively. Again, the braided river sections previously classified as Nationally and Internationally Significant provided most of these 'prime' (99%) and 'high value' (77%) habitats.

While such regional aggregate figures of 'useable bird habitat' provide a useful overview and a means, for example, of monitoring and reporting progress towards stated CWMS outcomes, we advise some caution in their use at this scale. An understanding of the local context remains important as each river or stretch of river has its own distinctive hydrology and geomorphology, ecological character, bird habitat values and degree of modification. For example, the rivers with the highest proportion of 'useable' (that is bare or sparsely-to moderately vegetated) habitat identified in this study are the beds of three alpine/headwater braided river systems, the Clyde, Havelock and Murchison, but these are all classified as 'regionally' rather than 'nationally' significant bird habitats by O'Donnell (2000). And while highly-modified low plains braided rivers now have only relatively small area and proportion of 'useable' nesting habitat as found in this study, examples such as the lower Ashley (571 ha; 13%) and lower Ashburton (712 ha, 18%) are still considered to be highly (Internationally) significant habitats. Although changes in extent of useable habitat on these foothill braided rivers might appear only minor in a regional total, they can have a large impact on breeding success and therefore populations of threatened birds, especially colonial-nesting species such as black-billed gull and black-fronted tern.

We suggest that the appropriate context for measuring progress toward achieving the CWMS outcome of "*By 2040, increase habitat area useable by all species of braided river indigenous birds*" is to continue to monitor and report on extent of not only 'useable' but also 'prime' and 'high value' bird habitats for all individual braided rivers or braided river sections identified in this study. It is important for regional-scale reporting that trends in quantity and quality of bird habitat be understood for the full range of braided river environments, from alpine headwaters and inland basins to the plains and coast; and for both large alpine and small foothill-sourced river systems.

We recommend repeating this study using later rounds of satellite imagery, with ongoing regional-scale monitoring at intervals of 5-10 years. New image-analysis software with capacity to distinguish, for example, between (largely native) low-statured herbaceous vegetation cover and (frequently exotic) taller grass and shrub and cover may permit more precise calculation of 'useable' riverbed bird nesting habitat. Similarly, differentiating between grades or sizes of bare gravel substrates, especially if combined with LIDAR elevation data, could help better identify 'high value' or 'optimal' nesting habitats for various species.

As well as informing regional State of Environment reporting and CWMS outcome monitoring, results of repeat studies could assist with assessing effectiveness of management actions on particular rivers, for example, weed control and river island creation projects, and the bird habitat mitigation plan that is a condition of the Hurunui Water Project (HWP) water take consent. It would also be useful to correlate habitat monitoring data with results of river bird surveys carried out during the breeding season.

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Appendix 1: Spectral analysis

Pilot study

The upper Rakaia riverbed was used as the pilot study area for development of habitat classification using spectral analyses. This area was the subject of a contemporaneous detailed field investigation of river bed vegetation cover to help direct and monitor a large-scale weed control programme. This field survey information was available to help inform and validate the habitat classification.

A polygon of the upper Rakaia riverbed (above the gorge) was created based on a shapefile supplied by Department of Conservation. The preliminary classification used imagery derived from SPOT 5 (10 m resolution), acquired mostly in 2006-07 by The Ministry for the Environment as part of their Land Use and Carbon Analysis System (LUCAS) project. The imagery was processed to standard reflectance by Landcare Research and is shown in part in Figure A1-1.

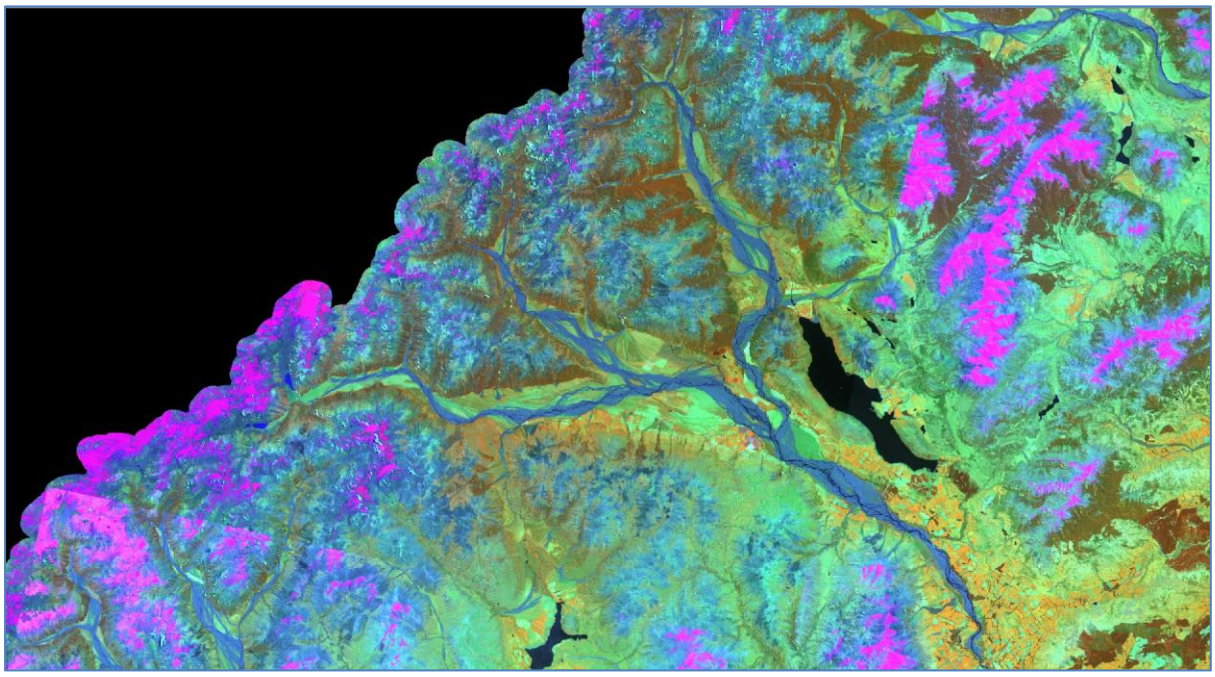


Figure A1-1: Original LUCAS imagery in the upper Rakaia Catchment

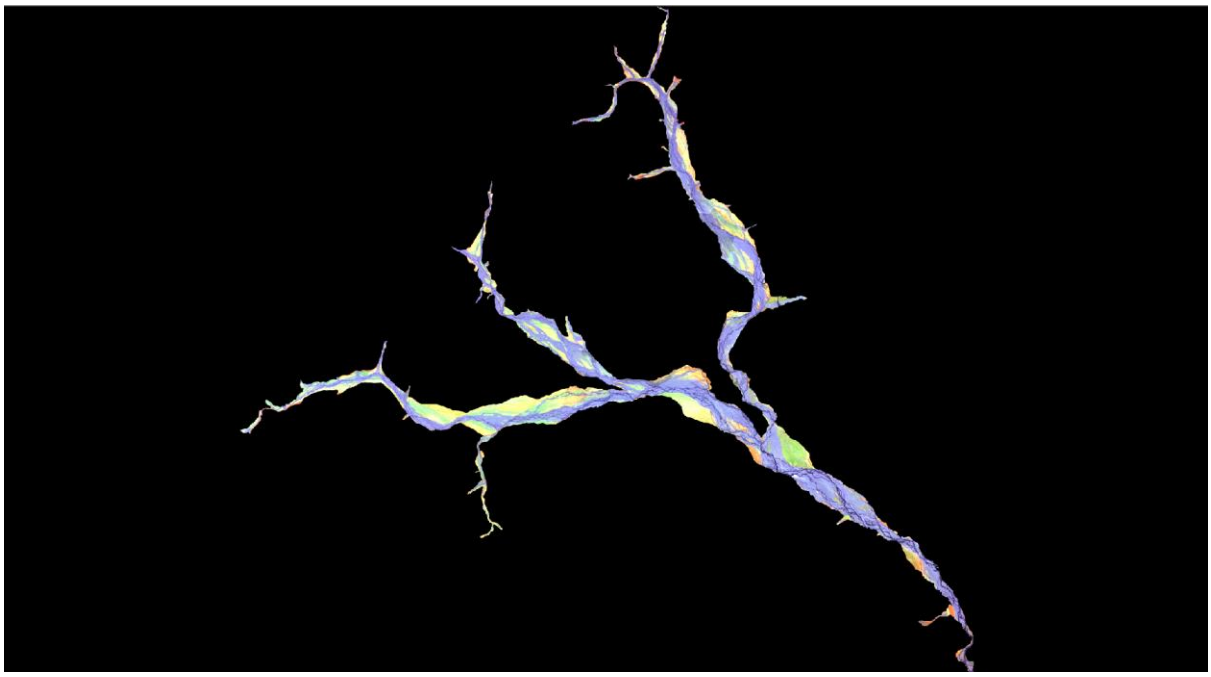


Figure A1-2: Upper Rakaia LUCAS imagery clipped to the riverbed outline

Using ERDAS Imagine software (version 10), the LUCAS imagery was clipped to the riverbed polygon (Figure A1-2). Next, an 8-class unsupervised classification was under taken. A tentative description was then made for each of the eight classes. based on satellite imagery and ortho-photos. The resulting tentative classification had two water classes and six ground cover classes ranging from no vegetation (riverbed gravels) to densely-vegetated (i.e. >80% vegetation cover).

These steps were repeated using 2011/12 LUCAS standardised/flattened imagery when it became available in late 2012. The unsupervised 2012 classification was converted from raster to vector in ArcMap using the Raster to Polygon tool. The area (in hectares) and 'INSIDE centroid' for each polygon were calculated. The attribute data were then exported into a Microsoft Excel spreadsheet and the 10 largest polygons identified for each of the six 'terrestrial' cover classes were located for subsequent field checking (the two water classes were excluded from this field check).

The area around the centroid of the 60 'terrestrial' polygons was inspected by helicopter on 25/1/2013, from 30 m above ground level. Data collected above the centroid was:

a. vertical photo

b. spectral data using a GER 2600 Spectroradiometer.

The helicopter then moved approximately 20 m to the side of the centroid; the data collected from the side of the centroid was:

a. oblique photo

b. site description.

Results from the flight were collated to compare the actual ground cover with the tentatively described cover classes. The ground-truthing of the 60 polygons established that the tentative classification was generally a good description of the ground cover. However, in January 2013 some riverbed polygons were affected by flooding, thus the cover was different to when the SPOT imagery was acquired in 2011/12.

A preliminary 'Imagine' signature file defining the eight classes was created and checked using the Imagine Image Alarm command within the Signature Editor. The signature files must be associated with a source image file, which normally would be the source file to be classified. The initial signature file used the minimum/maximum values for each class, which resulted in a wide spread of spectral values within each class and the potential to have overlaps between classes. The overlap between the

two exposed gravel classes in the upper Rakaia is demonstrated in Figure A1-3 with this signature file, where the purple colour shows overlap between the Raw Riverbed and Older Riverbed classes. The spread within each class was reduced by restricting the spectral distributions of each class to 2 standard deviations (SD), using the Set Parallelpiped Limits in the Signature Alarm. There was very little overlap between classes with this distribution (Figure A1-4) and therefore the signature file that was created using a 2 SD spread was the one used for subsequent classification of all Canterbury's braided riverbed areas.

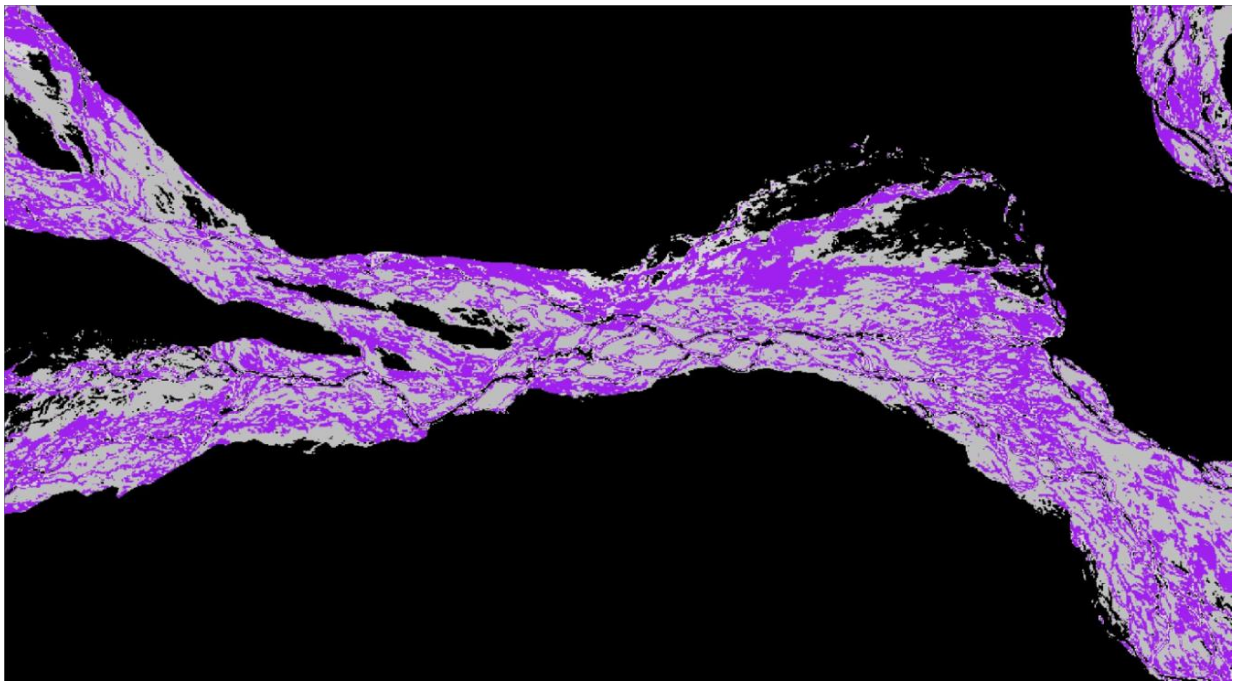


Figure A1-3: Example of overlap shown in purple between raw and older riverbeds in the upper Rakaia riverbed when using min/max spread of each class in the signature file

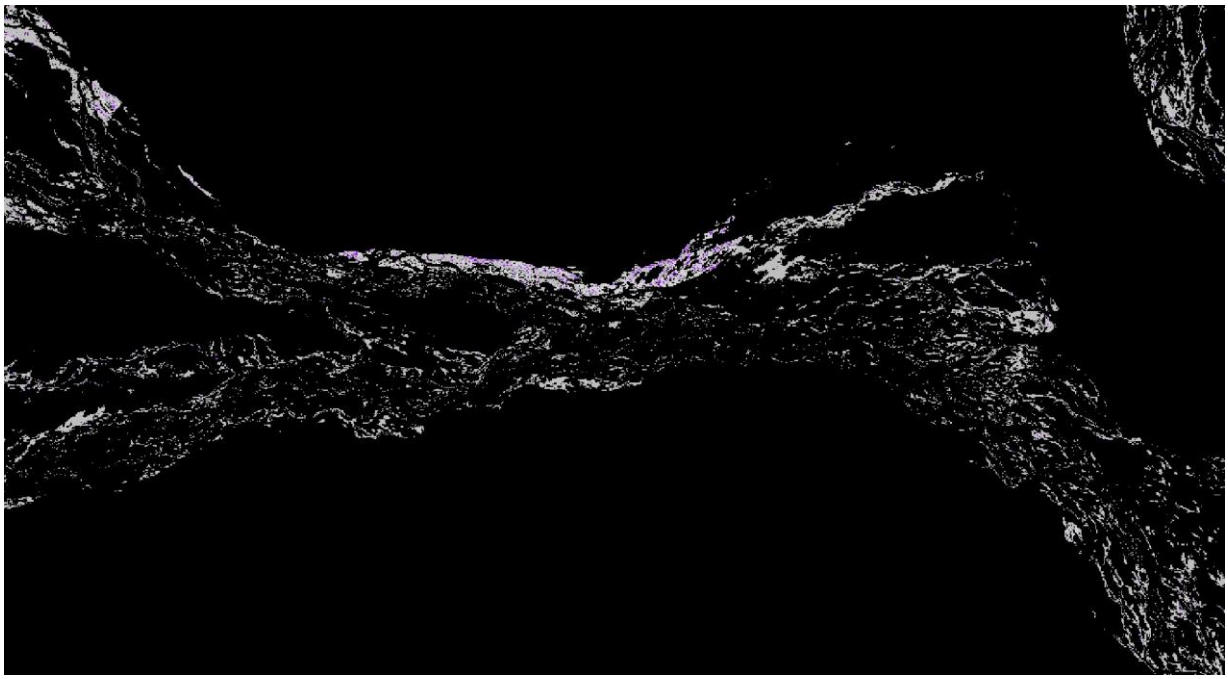


Figure A1-4: Example of overlap shown in purple between raw and older riverbeds in the upper Rakaia riverbed when using 2 SD spread of each class in the signature file

GER spectrometer

The spectrometer reflectance values obtained at each polygon centroid point are summarised in Figure A1-5 and Figure A1-6. The resolution is approximately 1.5 m (3 degree FOV, 30 m agl.). The wavelengths captured by SPOT5 and Landsat imagery are shown in these figures, thus the sensitivity of their respective bands to different cover classes can be evaluated.

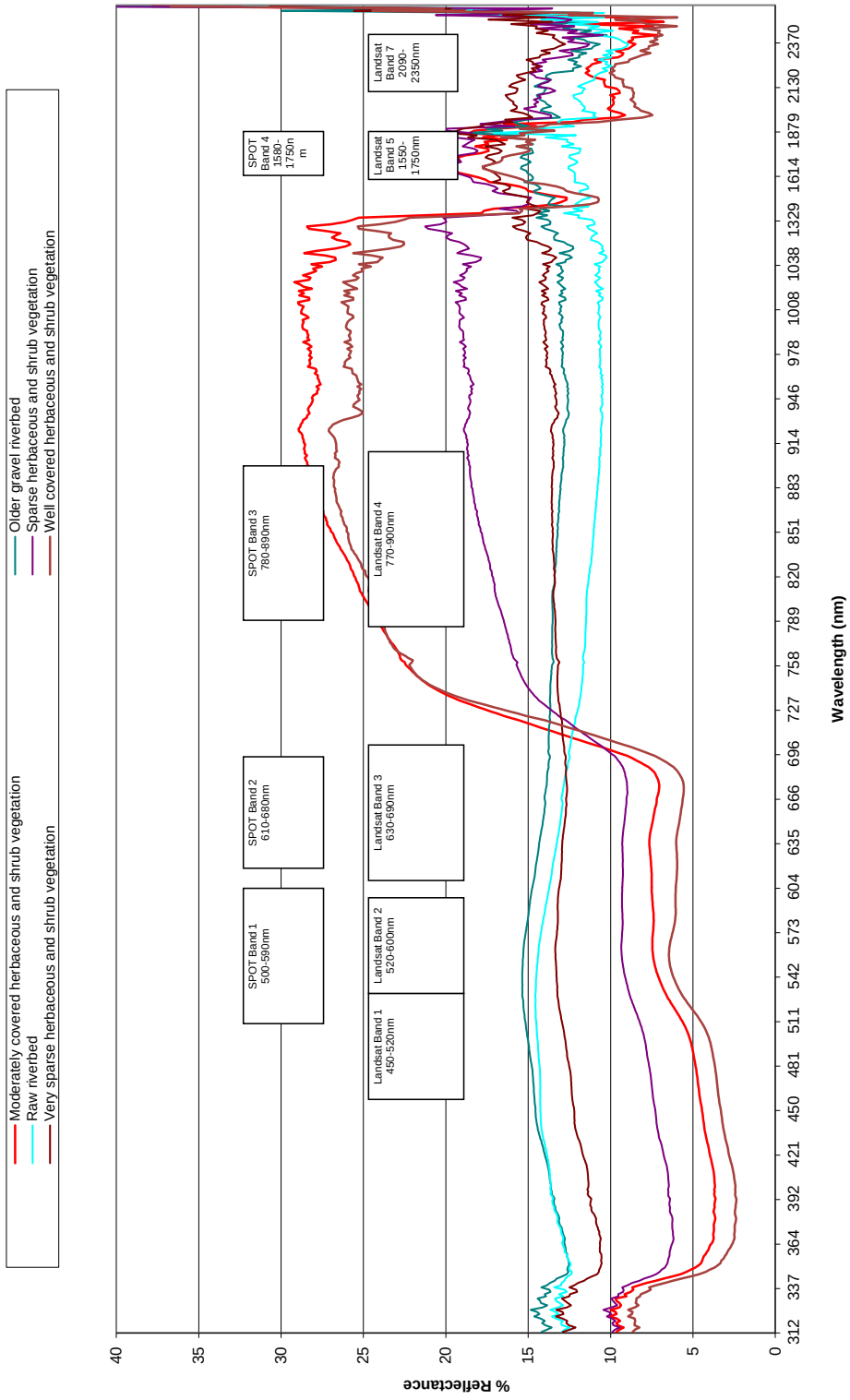


Figure A1-5: Average reflectance spectral curves for the six vegetation classes

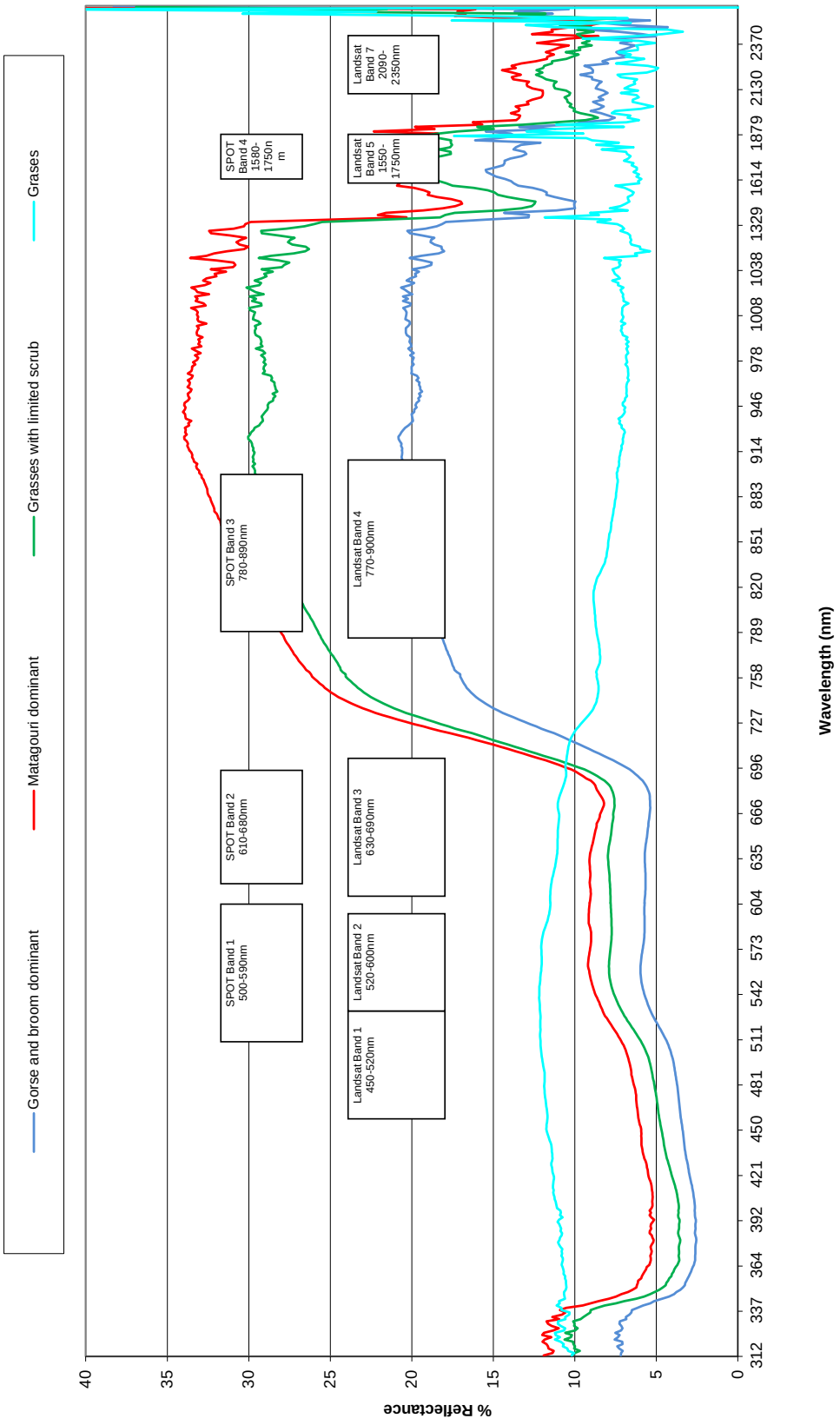


Figure A1-6: Average reflectance spectral curves for selected ground-truthed vegetation types

Regional supervised classification of river areas

The riverbed habitat classification, developed and field checked from the Upper Rakaia pilot study, was applied across the wider region as a supervised classification. Using ERDAS Imagine software (version 10) the supervised classification was performed on 77 river areas (Figure 2-1 to 2-3). The river area polygons were created in ArcGIS, by delineating river margins from aerial imagery. For the purposes of this study, the river area generally included only the current active riverbed, not historic riverbed. An area of interest (AOI) was created for each river study area using the river area polygon and raster file; canterbury_flats_2012.img. Next, using Maxlikelyhood and the signature file (created in earlier steps) a supervised classification was performed on each river's AOI, Table A1-1 displays the classification results.

Due to gaps in the satellite imagery, caused by various phenomena including cloud cover, some calculated classified areas were less than the river area, Table A1-2 'Area difference' shows these differences. A positive area difference value indicates gaps in the imagery data (i.e. the river area was larger than the classified area) while a negative area difference value indicates the classified area was larger than the defined river area (i.e. the classified pixels extended beyond the river boundary of the shape file). These variations, while relatively small over the region, will need to be considered when rerunning the calculations to compare river habitat changes over time. The calculated classified river area was used to derive the percentage of usable feeding and nesting habitats which will enable the percentage results to be utilised in future comparisons.

Table A1-1: Area difference

River	Classified River Area (ha)	River Area (ha)	Area Difference (ha)
Ahuriri River	6,805.50	9,653.02	2,847.52
Ashburton River (lower)	3,893.26	3,893.15	-0.11
Ashburton River (North Branch)	1,537.76	1,537.98	0.22
Ashburton River (upper South Branch)	1,395.95	1,359.38	-36.57
Ashley River (lower)	4,345.76	4,281.20	-64.56
Ashley River (upper)	1,216.56	1,175.97	-40.59
Avoca River	1,059.83	1,060.17	0.34
Bealey, Mingha, Edwards Rivers	291.13	291.24	0.11
Cameron River	634.96	626.13	-8.83
Cass River	2,772.86	2,927.16	154.30
Clarence River (lower)	1,757.49	1,729.73	-27.76
Clarence River (upper)	4,236.57	4,487.21	250.64
Clyde River	3,669.78	3,669.66	-0.12
Conway River	1,445.13	1,394.10	-51.03
Dobson River	4,339.78	4,472.94	133.16
Edward Stream	714.28	695.65	-18.63
Esk River	1,016.49	1,016.55	0.06
Eyre River	1,254.68	1,207.81	-46.87
Fork Stream	647.11	747.22	100.11
Godley River	12,478.88	12,388.96	-89.92
Hae Hea Te Moana River	857.67	858.04	0.37
Hakataramea River	2,631.17	3,232.28	601.11
Hapuku River	865.24	837.16	-28.08
Harper River	923.26	923.22	-0.04
Havlock River	2,838.64	2,838.64	0.00
Hawdon River	519.61	519.70	0.09
Hinds River	1,361.09	1,283.21	-77.88
Hook River	229.78	215.69	-14.09
Hopkins River	6,556.46	6,785.11	228.65
Hurunui River (above Lake Sumner)	1,325.03	1,296.80	-28.23
Hurunui River (lower)	5,196.78	5,059.57	-137.21
Hurunui River (upper and South Branch)	1,661.05	1,572.21	-88.84
Kahutara River	1,074.55	1,035.48	-39.07
Kowai River	428.07	399.52	-28.55
Kowhai River	845.14	826.08	-19.06
Makikihi River	127.50	119.47	-8.03
Mathias River	5,660.91	5,660.66	-0.25
Murchison River	1,497.60	1,485.14	-12.46
Nell Stream	126.00	123.72	-2.28
Ohau River (lower)	907.02	907.10	0.08
Ohau River (upper)	204.52	193.16	-11.36
Okuku River	295.62	268.41	-27.21
Opihi River (above Opuha River gorge)	789.27	769.50	-19.77
Opihi River (lower)	1,599.20	1,599.33	0.13
Opuha River	474.81	463.39	-11.42
Orari River (lower)	1,974.91	1,936.00	-38.91
Orari River (upper)	1,324.76	1,272.14	-52.62
Otaio River	460.91	439.34	-21.57
Pareora River (lower)	500.01	504.26	4.25
Pareora River (upper)	394.47	376.34	-18.13
Poulter River	2,762.31	2,762.28	-0.03
Pukaki River	1,573.75	1,581.52	7.77
Rakaia River (lower)	16,493.83	16,429.90	-63.93

River	Classified River Area (ha)	River Area (ha)	Area Difference (ha)
Rakaia River (upper)	11,995.96	11,995.98	0.02
Rakaia River (upper tributaries)	3,209.79	3,209.55	-0.24
Rangitata River (lower)	5,972.52	5,913.92	-58.60
Rangitata River (upper)	8,992.01	8,996.36	4.35
Rangitata River (upper tributaries)	2,349.61	2,349.88	0.27
Ribbonwood Stream	109.09	105.45	-3.64
Selwyn River (lower)	1,913.50	1,862.06	-51.44
Selwyn River (upper)	535.93	504.41	-31.52
Smite River	258.69	252.96	-5.73
Swift River	400.28	166.39	-233.89
Swin Stream	174.85	391.41	216.56
Tasman River	9,336.72	9,278.91	-57.81
Tekapo River	5,771.04	5,771.20	0.16
Tengawai River	843.50	925.96	82.46
Twizel River	440.14	440.25	0.11
Waiau River (lower)	7,860.20	7,697.52	-162.68
Waiau River (upper)	6,815.25	6,570.51	-244.74
Waihao River	438.00	424.20	-13.80
Waimakariri River (lower)	10,408.85	10,309.82	-99.03
Waimakariri River (upper)	4,627.86	4,627.77	-0.09
Waimakariri River (above Bealey River bridge)	2,092.82	2,093.15	0.33
Waipara River	952.28	920.87	-31.41
Waitaki River	10,840.86	11,077.33	236.47
Wilberforce River	8,215.79	8,218.71	2.92

Classification validation

Checking the supervised classification results with ortho-imagery showed that the results were accurate, except for the Ashburton River (lower). Misclassified results occurred in areas where shadowed exotic vegetation was classified as areas of water (Figure A1-6). The largest of these areas were manually edited, reclassified and results tables were updated. Changes occurred in the number of pixels and sub area totals for the riverbed, however the calculated percentage results did not change. The method to correct misclassified results:

1. Click and select problem area using polygon tool
2. Paste from selected object
3. Subset and clip using aoi in viewer
4. Run tool box model maker with test_of_recoding_merge_20140903.gmd
5. Add in original image and problem area, select recode data for problem area. Update image inputs. Run Tool
6. View new image, recode as new image as result is black and white. View raster properties and column properties add columns and copy across properties from original image into new image

During the capture of the 2012 satellite imagery the Clarence and Kahutara Rivers were in flood, the images show areas of water amongst vegetated areas (Figures A1-7 and A1-8). Future comparisons of this studies data with data captured from more recent satellite imagery may show an increase in available habitats on these rivers; however, this increase may only be due to an increase in vegetation where flood waters have receded.

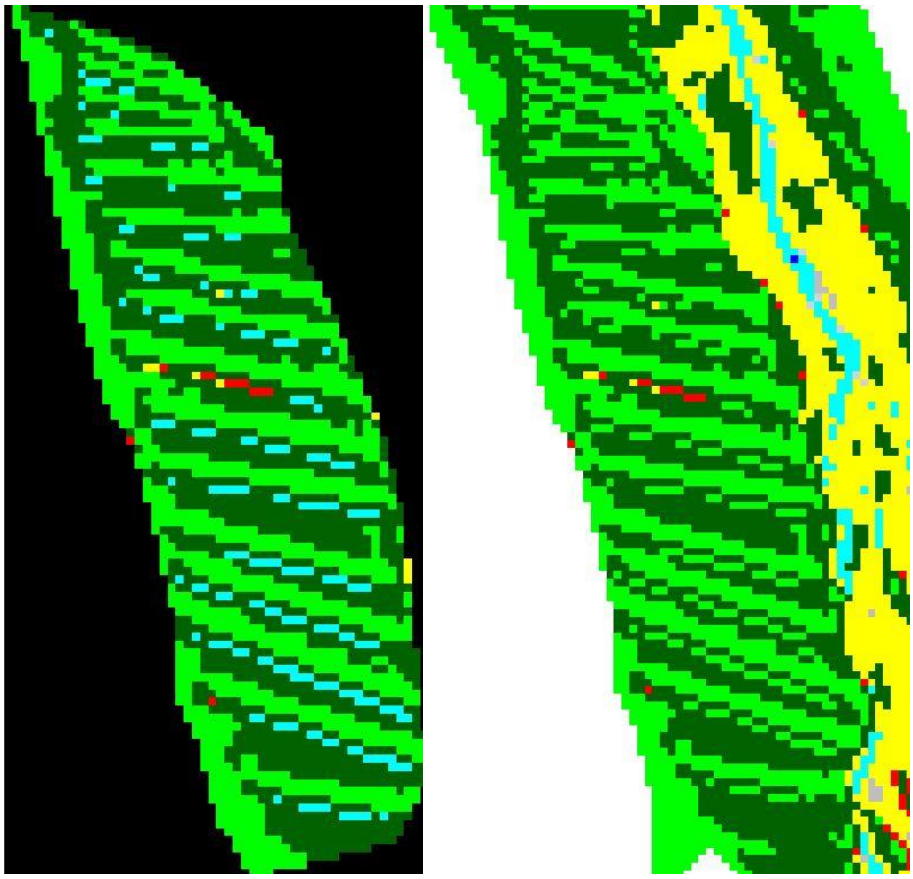


Figure A1-6: Ashburton River (lower). Left image, misclassified areas of water. Right image, corrected areas

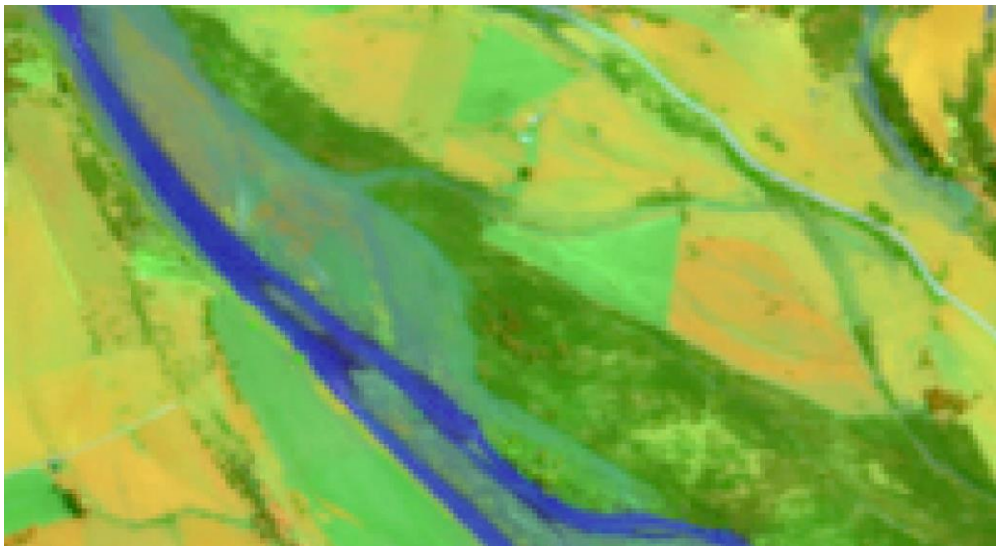


Figure A1-7: A section of the Clarence River 2012 satellite imagery results showing flooded areas

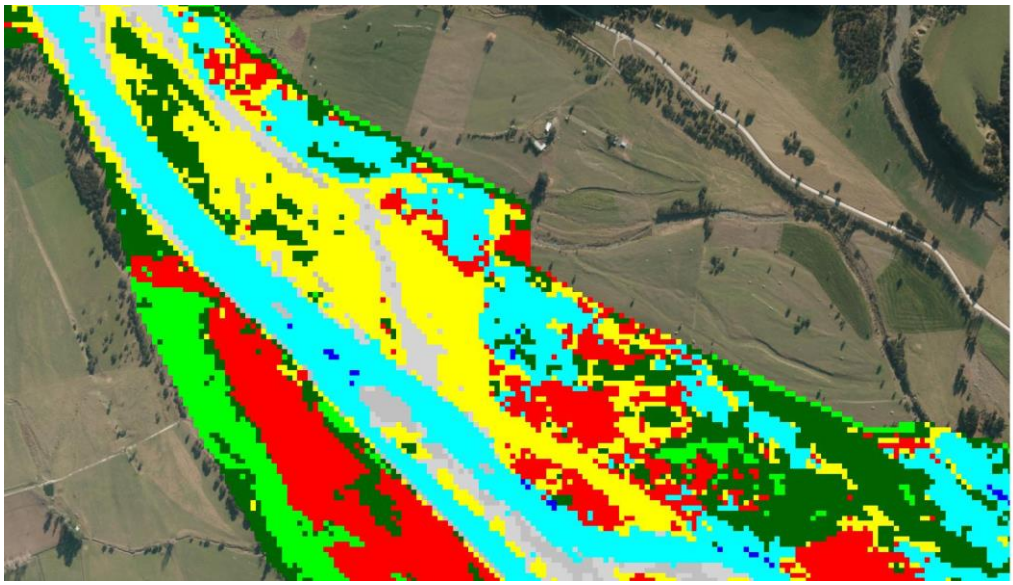


Figure A1-8: A section of the Clarence River classification results showing flooded areas

Results data analysis

The classification results were returned as raster images, which were imported in to ArcGIS for further data analysis using Model Builder, Model Builder processes available on request. Habitat areas were selected from the entire braided riverbed data, Figures A1-9 to A1-12 show the sequence of data selection for areas of optimal habitats of older gravels and sparse vegetation contained on river islands (larger than ten meters square) surrounded by at least a ten meter-wide moat (greater than 25 cm deep).

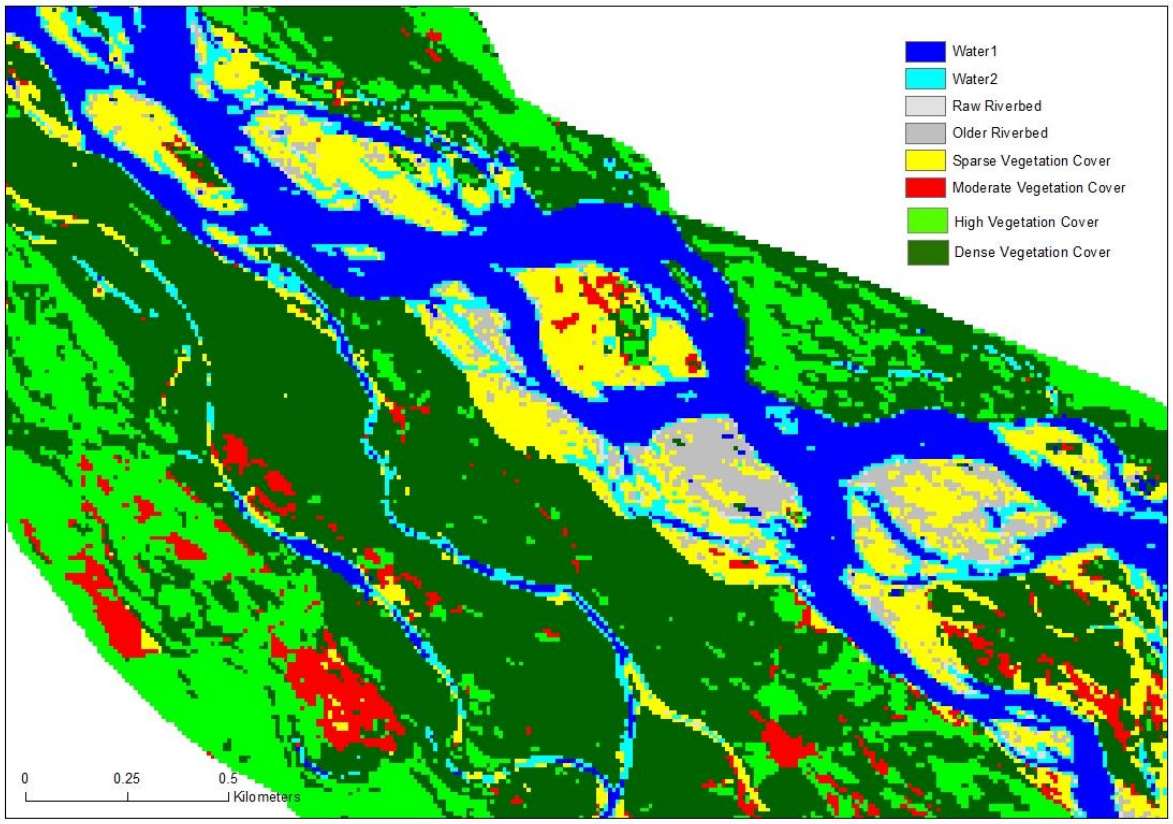


Figure A1-9: A section of the Waitaki River classification results

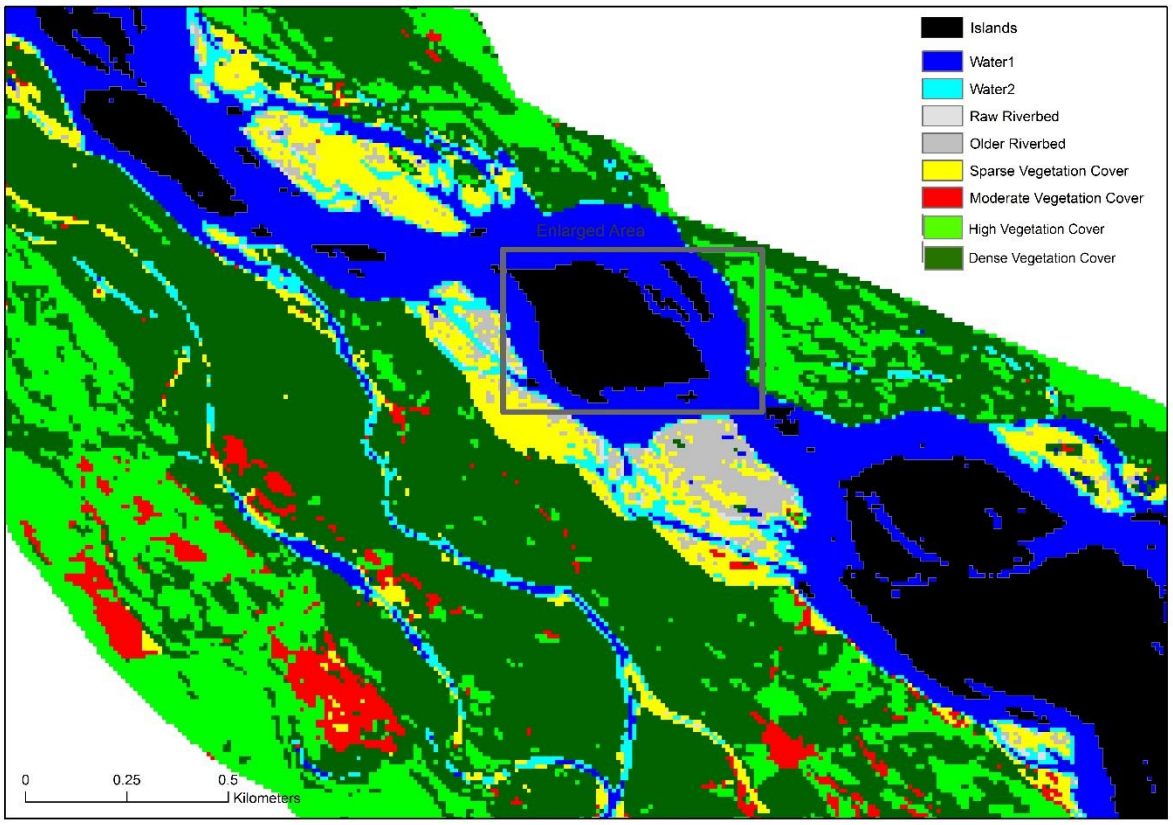


Figure A1-10: A section of the Waitaki River classification results, highlighting island areas

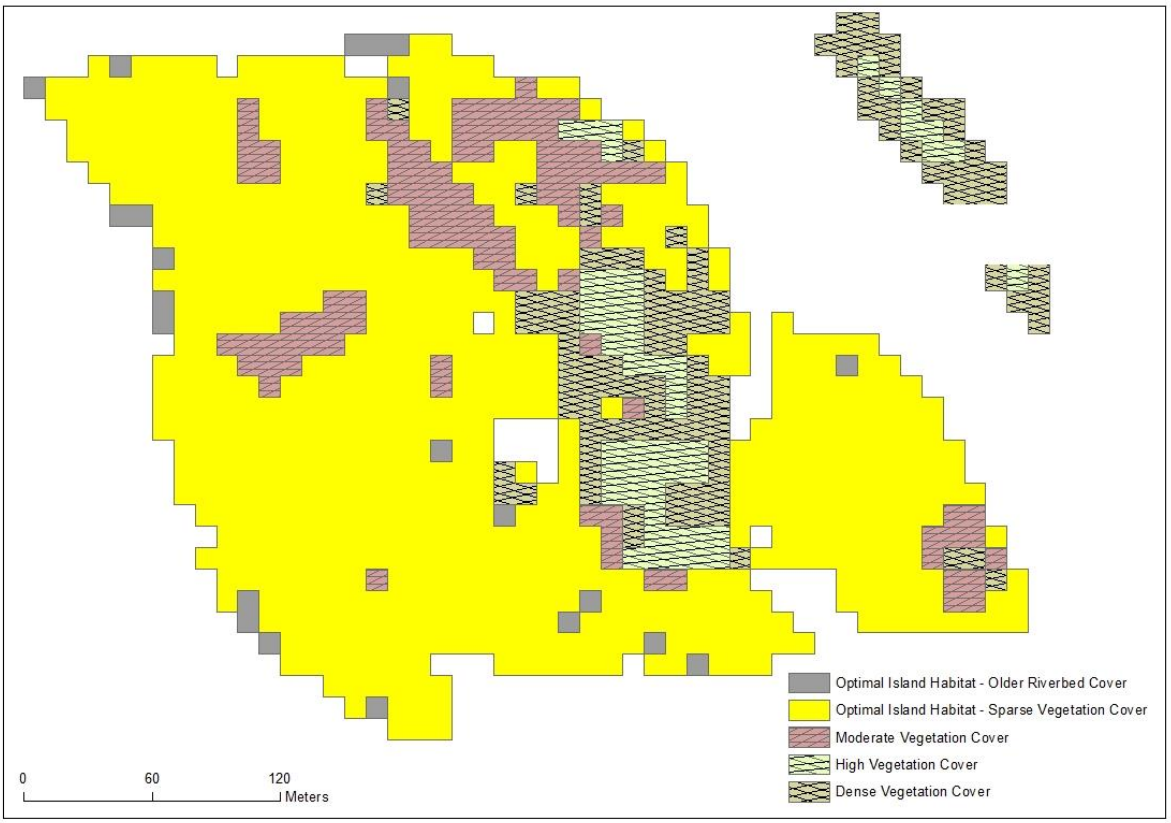


Figure A1-11: Habitats of the highlighted Waitaki River island

Figure A1-12 shows Waitaki River areas selected by buffering to select areas of optimal habitats of older riverbed and sparse vegetation, excluding island areas already selected, within ten metres of the water's edge. All results created in Model Builder were exported to Excel in table format. Analysis results and workings can be found in the financial year 2017/2018 GIS project data located at 'gisdata\project\Ecology\2017/2018\Monitoring_braided_river_birds_habitat'.

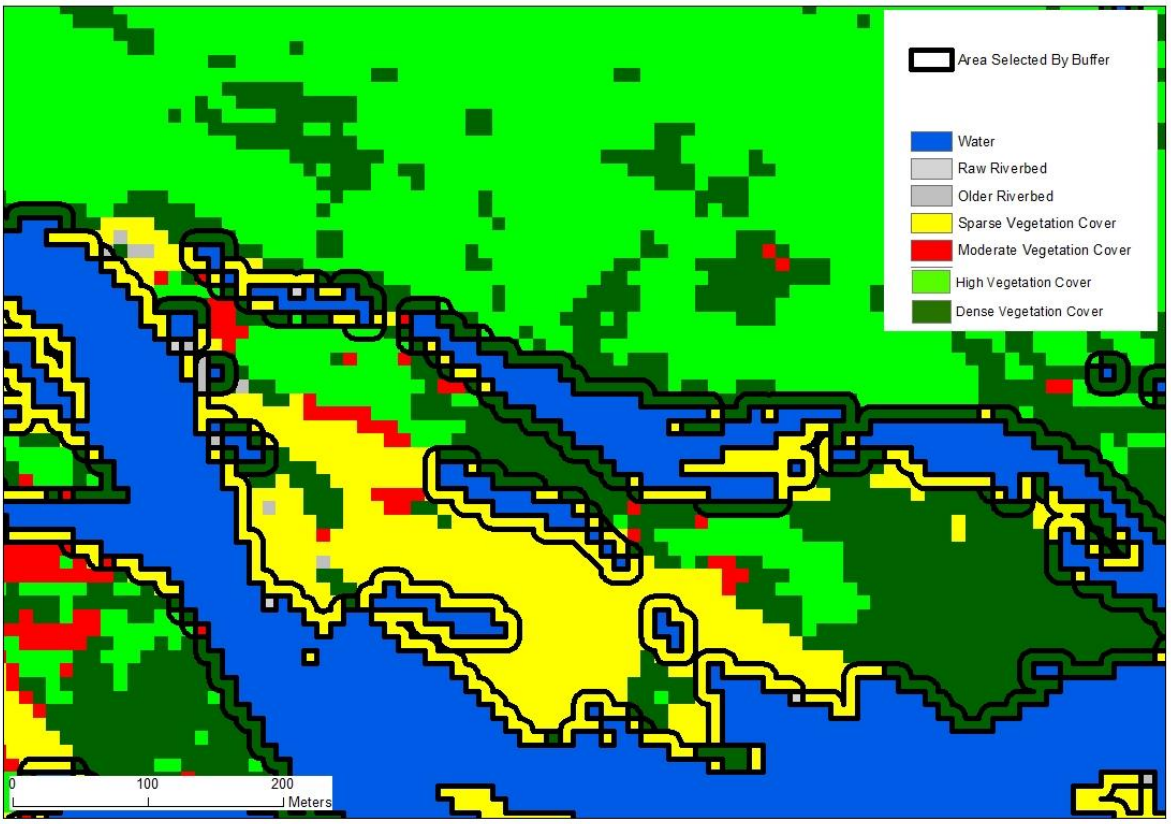


Figure A1-12: Waitaki River areas selected by buffering. Selected areas of optimal habitats of older riverbed and sparse vegetation, excluding island areas already selected, within ten meters of the water's edge

Appendix 2: Riverbed ground cover classification photo examples

Figure A2-1: Example of raw riverbed class – vertical view

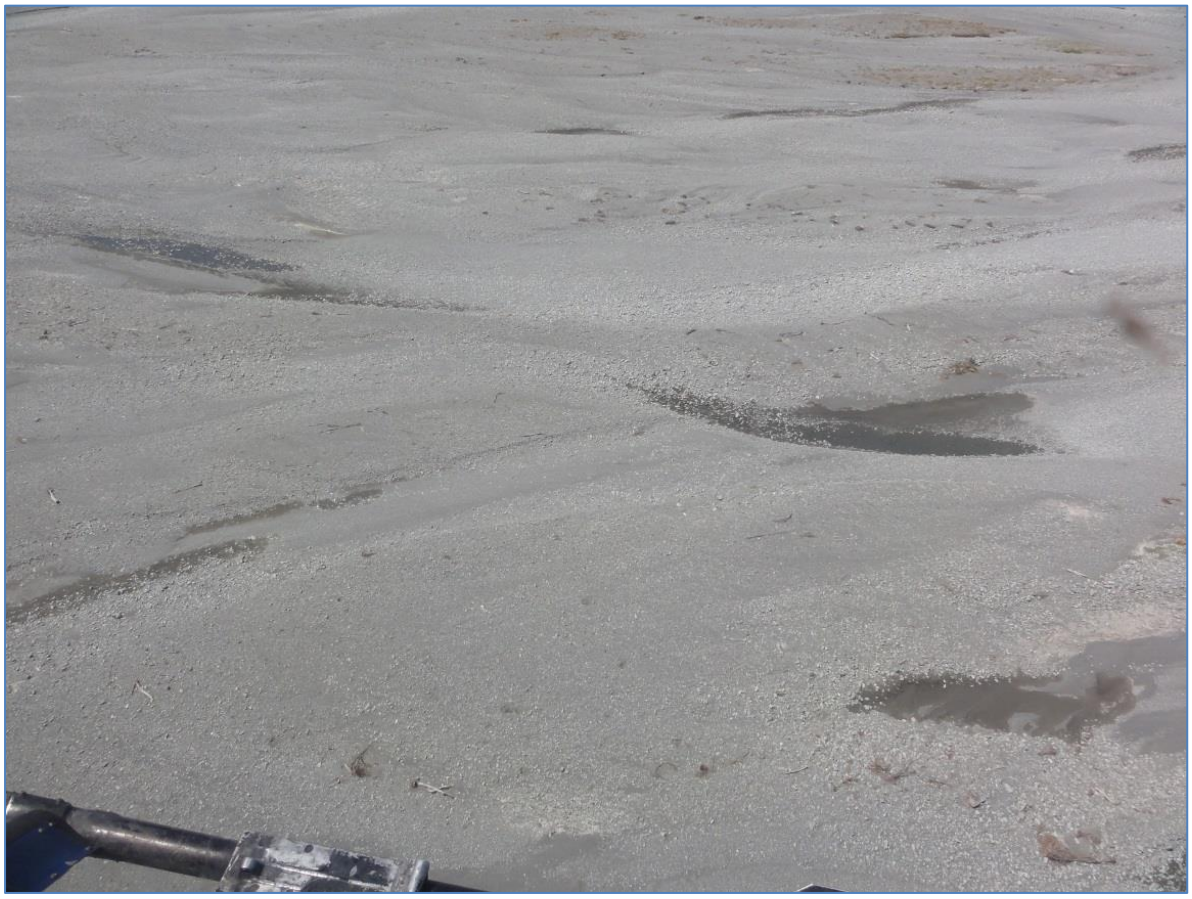


Figure A2-2: Example of raw riverbed class – oblique view

Figure A2-3: Example of older riverbed class – vertical view

Figure A2-4: Example of older riverbed class – oblique view

Figure A2-5: Example of sparse vegetation cover - vertical view

Figure A2-6: Example of sparse vegetation cover - oblique view

Figure A2-7: Example of moderate vegetation cover - vertical view

Figure A2-8: Example of moderate vegetation cover - oblique view

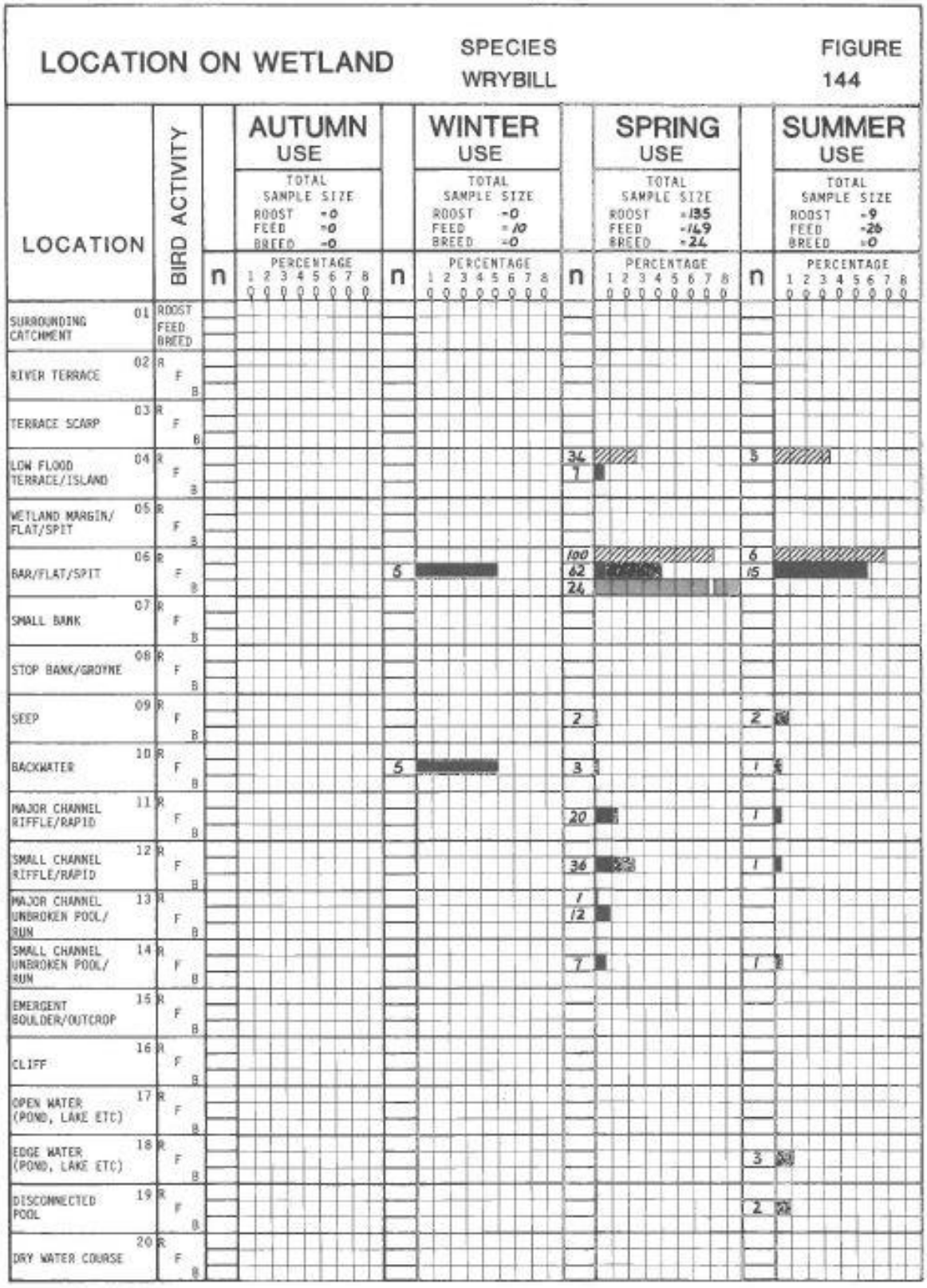
Figure A2-9: Example of high vegetation cover - vertical view

Figure A2-10: Example of high vegetation cover - oblique view

Figure A2-11: Example of dense vegetation cover - vertical view

Figure A2-12: Example of dense vegetation cover - oblique view

Appendix 3: Example of habitat use data from Robertson *et al.* (1983), used to calculate proportions of observations per habitat type


LOCATION ON WETLAND
SPECIES
WRYBILL
FIGURE
144
LOCATION
BIRD ACTIVITY
AUTUMN USE
TOTAL SAMPLE SIZE
ROOST =0
FEED =0
BREED =0
WINTER USE
TOTAL SAMPLE SIZE
ROOST =0
FEED =10
BREED =0
SPRING USE
TOTAL SAMPLE SIZE
ROOST =135
FEED =149
BREED =24
SUMMER USE
TOTAL SAMPLE SIZE
ROOST =9
FEED =26
BREED =0
n
PERCENTAGE
1 2 3 4 5 6 7 8
0 0 0 0 0 0 0 0
01 SURROUNDING CATCHMENT
ROOST
FEED
BREED
02 RIVER TERRACE
03 TERRACE SCARP
04 LOW FLOOD TERRACE/ISLAND
34
1
5
05 WETLAND MARGIN/ FLAT/SPIT
06 BAR/FLAT/SPIT
5
100
62
24
6
15
07 SMALL BANK
08 STOP BANK/GROYNE
09 SEEP
2
2
10 BACKWATER
5
3
1
11 MAJOR CHANNEL RIFFLE/RAPID
20
1
12 SMALL CHANNEL RIFFLE/RAPID
36
1
13 MAJOR CHANNEL UNBROKEN POOL/ RUN
1
12
14 SMALL CHANNEL UNBROKEN POOL/ RUN
7
1
15 EMERGENT BOULDER/OUTCROP
16 CLIFF
17 OPEN WATER (POND, LAKE ETC)
18 EDGE WATER (POND, LAKE ETC)
3
19 DISCONNECTED POOL
2
20 DRY WATER COURSE
R
F
B

Appendix 4: Braided river habitat class use by six characteristic bird species

Wrybill *Anarhynchus frontalis* Threat ranking: Nationally Vulnerable

Of the six focus species, the wrybill has the most specialised adaptation to riverbed breeding, that is, it breeds *only* on braided rivers (Robertson et al. 2003; Heather and Robertson 2000). The main breeding rivers are all in Canterbury: the upper Waitaki tributaries, Rangitata, Rakaia and Waimakariri; with lower numbers of breeding birds also recorded on the Ashburton, Ashley, Hurunui and Waiau rivers (as well as the Makarora and Matukituki rivers in Otago). After breeding, most birds fly north to the large tidal harbours and estuaries of the northern North Island; a few overwinter in the Nelson-Golden Bay area.

Their return from northern estuaries starts in early August and eggs are laid from late August to January, with many adults laying a second clutch particularly if the first is lost to flooding or predation. Wrybill pairs form and defend territorial nesting and feeding areas. Usual nesting sites are islands of bare gravel, or a shingle bank near water at a high point without vegetation. During the breeding season, diet of adults and chicks is mainly aquatic insects: mayfly, caddisfly, stonefly larvae as well as bugs and beetles. Fledglings and failed breeders start leaving the braided rivers in late November, with the main northward movement of birds in late December – early January (Heather and Robertson 2000).

Under the 2012 satellite imagery classification, we assess useable nesting habitat of wrybill as 'raw riverbed', 'older riverbed' and (sometimes) 'sparse vegetation cover'; main feeding habitat is 'Water 2' and 'Raw riverbed'.

Banded dotterel *Charadrius bicinctus* Threat ranking: Nationally Vulnerable

The banded dotterel is another characteristic riverbed user, although it is also found nesting on other bare/sparsely-vegetated or low-statured vegetation habitats such as beaches, lake margins and inland outwash plains. Nevertheless, across their range, banded dotterel are most numerous on braided river beds during the breeding season, probably because these offer the best and most proximate combination of suitable nesting and productive feeding habitats. The main breeding population stronghold is Canterbury. After breeding, birds migrate either to northern New Zealand or Australia in February-March (Robertson et al 1983; Heather and Robertson 2000).

Banded dotterels start returning to Canterbury breeding sites in August-September. Banded dotterel are also territorial with breeding pairs defending their nesting areas. When nesting in riverbeds, nests are located mainly on higher elevation locations than those chosen by wrybill, but bare ground, sparse vegetation or low herb vegetation cover are still preferred. Eggs are laid September-December. After hatching, chicks soon leave the nest and feed independently. Breeding season diet of adults and chicks includes a variety of terrestrial and aquatic invertebrates, supplemented by occasional berries of prostrate plants (Heather and Robertson 2000).

From the 2012 satellite imagery classification, we assess useable riverbed nesting habitat of banded dotterel as 'older riverbed', 'sparse vegetation cover' and 'moderate vegetation cover'; while riverbed feeding habitats include the afore-mentioned as well as 'water 2' and 'raw riverbed'.

Pied stilt *Himantopus himantopus* Threat ranking: Not Threatened

Pied stilt are a facultative braided river species that can and do utilise a range of other habitats for nesting and feeding, including freshwater wetlands, lake/lagoon margins and estuaries. However, they are relatively common and widespread on braided rivers during the nesting season. Birds on Canterbury riverbeds move to coastal areas in December-February. Some then move on to northern North Island harbours while others remain in Canterbury coastal areas over the late summer-autumn period. Pied stilts return to their breeding grounds between June and October, where they breed in loose colonies.

Within braided riverbeds, 'older riverbed' and 'sparse vegetation cover' habitats are preferred for nesting, with 'water 2' and 'raw riverbed' their main feeding habitat during breeding season. Diet on

riverbeds is mainly larvae of mayflies, caddisflies, stoneflies and midges, plus adult waterboatmen and molluscs (Heather and Robertson 2003).

In their report on Ahuriri River birds, Robertson et al. (1983) devoted considerable attention to the habitat requirements of Critically Endangered black stilt *Himantopus novaeseelandiae* compared to those of *H. himantopus*. They concluded that the black stilt was more of a braided river specialist than pied stilt, particularly during the spring breeding season. However, as black stilt do not currently breed outside of the upper Waitaki catchment, they were not considered for purposes of the wider region-wide analysis.

South Island pied oystercatcher *Haemotopus ostralegus* Threat ranking: At Risk - Declining

South Island pied oystercatcher, like banded dotterel, breed in a variety of habitats but particularly favour braided riverbeds. Canterbury riverbed birds shift to estuaries and coastal lagoons after breeding. From late December to early March, most then migrate to estuaries and sandy beaches of the North Island and northern South Island, but many also remain on South Island and Stewart Island estuaries through to the winter. Birds start returning to their Canterbury breeding grounds from early June, but most breeding birds return in late July to early August.

Breeding pairs usually reclaim and defend the same territory year after year. On riverbeds they show a marked preference for nesting on bare or sparsely vegetated sites, often choosing slightly raised areas of bare sand near a piece of driftwood or prominent stone (Robertson et al 1983; Heather and Robertson 2003). Diet during the breeding season for riverbed nesting birds includes both aquatic and terrestrial insect larvae, small fish and earthworms. Riverbed-nesting pairs and chicks utilise shallow water and wet sand/silt feeding habitat close to the nest site, with adults also flying to nearby terrestrial habitats (e.g. ploughed paddocks) to gather food.

From the 2012 satellite imagery classification, we assess useable riverbed nesting habitat of pied oystercatcher as ‘older riverbed’, ‘sparse vegetation cover’ and ‘moderate vegetation cover’; with those plus ‘water 2’, and ‘raw riverbed’ the main feeding habitats.

Black-fronted tern *Sterna albostriata* Threat ranking: Nationally Endangered

Black-fronted terns breed on shingle riverbed and riverbanks of Canterbury rivers (as well as on Motueka River, Buller River, and rivers in Marlborough, Otago and Southland). In late summer and autumn they disperse north, occasionally reaching Northland, and south to water off Stewart Island. However, outside the breeding season, most birds feed at sea within 10 km of the east South Island coast and the Cook Strait area. Autumn and winter flocks of 100-300 birds are regularly seen at Farewell Spit, Lake Grasmere, Kaikoura Peninsula, Hurunui, Ashley, Ashburton and Opihi river mouths, and at Aramoana.

Black-fronted terns begin to return to their breeding grounds in August-September. They nest in small, ‘loose’ colonies of up to 50 pairs, some on riverbeds near the coast, but most well inland. The nests are scrapes in the shingle and spaced well apart within the colony. Favoured nesting sites are shingle bars in mid-channel (i.e. braided river ‘islands’) with a bare or sparsely-vegetated cobble substrate. Nests are often located on higher ridges or shingle bars that are still close to flowing channels. Eggs are usually laid from October to late November, but sometimes into January. While breeding, they feed in flocks over rivers and nearby farm land returning to the nest to feed their young. Over rivers they feed aerially, either contact-dipping to take emergent aquatic insects (mayflies and stoneflies) and diving for small fish (Robertson et al 1983; Heather and Robertson 2003).

We assess useable riverbed nesting habitat of black-fronted tern as ‘raw riverbed’, ‘older riverbed’ and ‘sparse vegetation cover’; with ‘water 1’ and ‘water 2’ their riverbed feeding habitats (other feeding habitats being outside our braided riverbed study area).

Black-billed gull *Larus bulleri* Threat ranking: Nationally Critical

Black-billed gulls breed in large colonies, mainly on braided riverbeds of the South Island from Marlborough to Southland, but also on sandspits, boulderbanks or shellbanks along the coast. In autumn birds leave their inland breeding areas and move towards the coast where they spend the winter months. They are moderately mobile over this period, with many South Island birds moving to the North Island and Stewart Island in the winter.

On Canterbury braided rivers, birds return in September to the general area of their previous nesting colony, but with changes in riverbed patterns and vegetation, will rarely use the same site for more than a few years. Once a site has been chosen, breeding pairs build nests and start laying, from late September to December. Later clutches are generally replacements after a colony has been destroyed by floods or predators, or deserted if food supplies dwindle in the early stages of the nesting cycle. Nesting colonies are large and densely packed, frequently numbering in excess of 1000 pairs. Colonies are located on bare open shingle margins or islands in braided riverbeds. Braided river mouth lagoons or hapua are often favoured locations, combining suitable colony nesting sites with good food supply.

Incubation is for 20-24 days. The chicks are capable of walking within 24 hours of hatching, but remain dependent on their parents for food. After all eggs have hatched the family abandons the nest and moves around within the colony, though both parents continue to brood, feed and guard the young. As chicks grow, they tend to congregate in loose creches guarded by a few adults, while the other parent birds search for food.

Inland-breeding black-billed gulls usually feed in flocks on unpredictable, but temporarily rich food supplies such as terrestrial invertebrates exposed by ploughing or brought to the surface by irrigation or rains, and shoals of small fish. They are adept at hawking above flowing water for emergent aquatic invertebrates. Rivermouth-breeding black-billed gulls also have the marine environment as a foraging option (Heather and Robertson 2003). For inland colonies, there is a general shift over the course of the breeding season, from feeding in or over aquatic river habitats in early spring, to other ‘off river’ terrestrial and aquatic habitats (e.g. lakes, ponds) in late spring-summer (Robertson et al. 1983).

We assess useable riverbed nesting habitat for black-billed gulls as ‘raw riverbed’ and ‘older riverbed’; with ‘water 1’ and ‘water 2’ providing feeding habitat (other feeding habitats being outside the study area).

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