

Irrigation REPORT

CANTERBURY DETAILED IRRIGATED AREA MAPPING



PREPARED FOR
Environment Canterbury

C16010
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PREPARED BY
Peter Brown

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For more information regarding this document please contact

Dr Peter Brown
Senior Water Resource Engineer
Aqualinc Research Limited
(03) 964 6521
p.brown@aqualinc.co.nz

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Aqualinc Research Ltd

Christchurch / PO Box 20 462, Bishopdale 8543, +64 (0) 3 964 6521

Ashburton / PO Box 557, Ashburton 7740, +64 (0) 3 307 6680

Hamilton / PO Box 14 041, Enderley 3252, +64 (0) 7 858 4851

www.aqualinc.com

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EXECUTIVE SUMMARY

Accurate estimates of irrigated areas and system types are important for the regional management of both water quantity and quality. This report describes the method and results for our detailed irrigated area mapping for the 2015/16 financial year.

This report is the second in a set of two. This report documents the mapping of eight of the ten Canterbury Water Management Strategy (CWMS) zones. The first report entitled “Irrigated area mapping: Waimakariri and Orari-Opihi-Paerora” (Brown 2015a) documents the mapping of the other two CWMS zones.

A summary of the areas by zone is provided below. In total we estimate that in early 2015 the irrigated area in Canterbury was about 507,000±15,000 ha. By “irrigated area” we mean the area actually irrigated for productive gain, not the consented area. For example, if a lifestyle block has a water permit to irrigate 4 hectares, but only irrigates 0.5 hectares in practice, then their irrigated area is 0.5 ha.

Mapping accuracy continues to improve compared with mapping undertaken in 2014/15, due to a combination of recent high resolution aerial photographs, the dry 2014/15 summer which provided a high contrast in Normalized Difference Vegetation Index (NDVI) imagery, and irrigation schemes providing access to a large number of farm irrigation maps produced as part of their Farm Environmental Plan processes.

CWMS Zone	Representative year ¹	Irrigated area (ha)	Estimate range (±)
Ashburton	2013 - 2015	200,368	8,100
Banks Peninsula	2015	88	100
Christchurch - West Melton	2015	2,339	500
Hurunui - Waiau	2015	43,304	1,100
Kaikoura	2015	3,682	400
Lower Waitaki - South Coastal	2015	51,038	3,000
Orari-Opihi-Pareora	2014	56,745	3,000
Selwyn - Waihora	2015	99,427	4,200
Upper Waitaki	2015	12,384	500
Waimakariri	2014	38,093	1,900
Total (ha)		507,468	15,000
1. Representative year captured in mapping			

Disclaimer

Our mapping data includes information originally commissioned by Amuri Irrigation, Morven Glenavy Ikawai Irrigation, Ashburton Lyndhurst Irrigation, Barhill Chertsey Irrigation, and DairyNZ (Hinds nutrient zone). This was made available to Environment Canterbury to enable a consistent approach to irrigated area mapping. Users of this mapping data are advised:

- Conversion of irrigation application systems to more efficient methods is ongoing and rapid in many areas, often at a rate of over 10% per annum.
- The methods used in this mapping do not have an expectation of complete accuracy.
- It is recommended that updated information should be sought from irrigation schemes and/or individual farms before reliance is made on the information presented in these maps.

Aqualinc has extensive experience in mapping irrigated area at a farm scale. We know how irrigation systems are designed and have reviewed irrigation plans for a large number of farms in Canterbury. This knowledge has allowed us to refine and calibrate remote sensing techniques (aerial photographs, satellite multi-spectral analysis) together with Environment Canterbury's Resource Consent database, to accurately map irrigated area at a farm scale, for the whole region.

Our method of mapping irrigated area was presented to Environment Canterbury on 17 March 2014. Broadly the process involves the following steps:

1. Farm boundary extents.

Map the approximate extent of farm boundaries using land ownership and title GIS data from LINZ.

2. Irrigation systems clearly visible from photos

This step involves mapping the irrigation systems that are visible from high resolution aerial photos (0.5m pixel size or less). The system type is estimated by a range of factors including irrigation design considerations, property boundary limitations, visual sighting of travelling irrigators, and markings on the ground (e.g. wheel tracks, irrigation patterns). Where more than one set of images are available we cross-reference between imagery. This process typically identifies 80-90% of the irrigated area with a high degree of accuracy.

3. Areas with irrigation consents

In GIS we combine the farm boundaries layer with ECan consent records of irrigation consents (surface takes, groundwater takes, irrigated areas and irrigation scheme extents), and land slope. From this we identify farms and areas with water consents, and land slope less than 15°, that could potentially be irrigated.

4. Multispectral satellite analysis

We map the normalized difference vegetation index (NDVI) from Landsat imagery from January to March. We use images where there is a strong contrast between actively growing vegetation (which is likely irrigated) and dry areas.

5. Combine irrigation consents and NDVI analysis

We combine results from steps (3) and (4) to map the remaining 10-20% of the irrigated area. We manually map these areas, giving consideration to irrigation design and farm boundary limitations.

6. StatsNZ survey

We cross-reference the total irrigated area for the territorial authority with StatsNZ agricultural survey results. We give consideration to irrigation development which has occurred since the survey.

This method is particularly effective in Canterbury because: (1) the vast majority of the irrigation systems are permanent installations; (2) there is a high proportion of pivot irrigation, laterals, and RotoRainer irrigation, which can all be mapped with a high degree of confidence from aerial photos; and (3) in a dry year for most irrigated areas in Canterbury there is a reasonable NDVI contrast between irrigated and unirrigated areas.

In total we estimate that in early 2015 there was about 507,000 ha \pm 15,000 irrigated in Canterbury. Pivot and Lateral irrigation are by far the dominant systems, accounting for half the total area. RotoRainer irrigation, which were once more common than Pivot and Lateral irrigation, are now the next most common system at 16%. Borderdyke irrigation, which up until the 1990's was the dominant irrigation type in Canterbury, now only accounts for 5% of the total irrigated area (refer Figure 1).

About 80% of the irrigation in Canterbury is on the Canterbury Plains. The Ashburton District has the most irrigation with about 200,000 ha. The Selwyn District is next, with about 100,000 ha irrigated (refer Table 1 and Table 2).

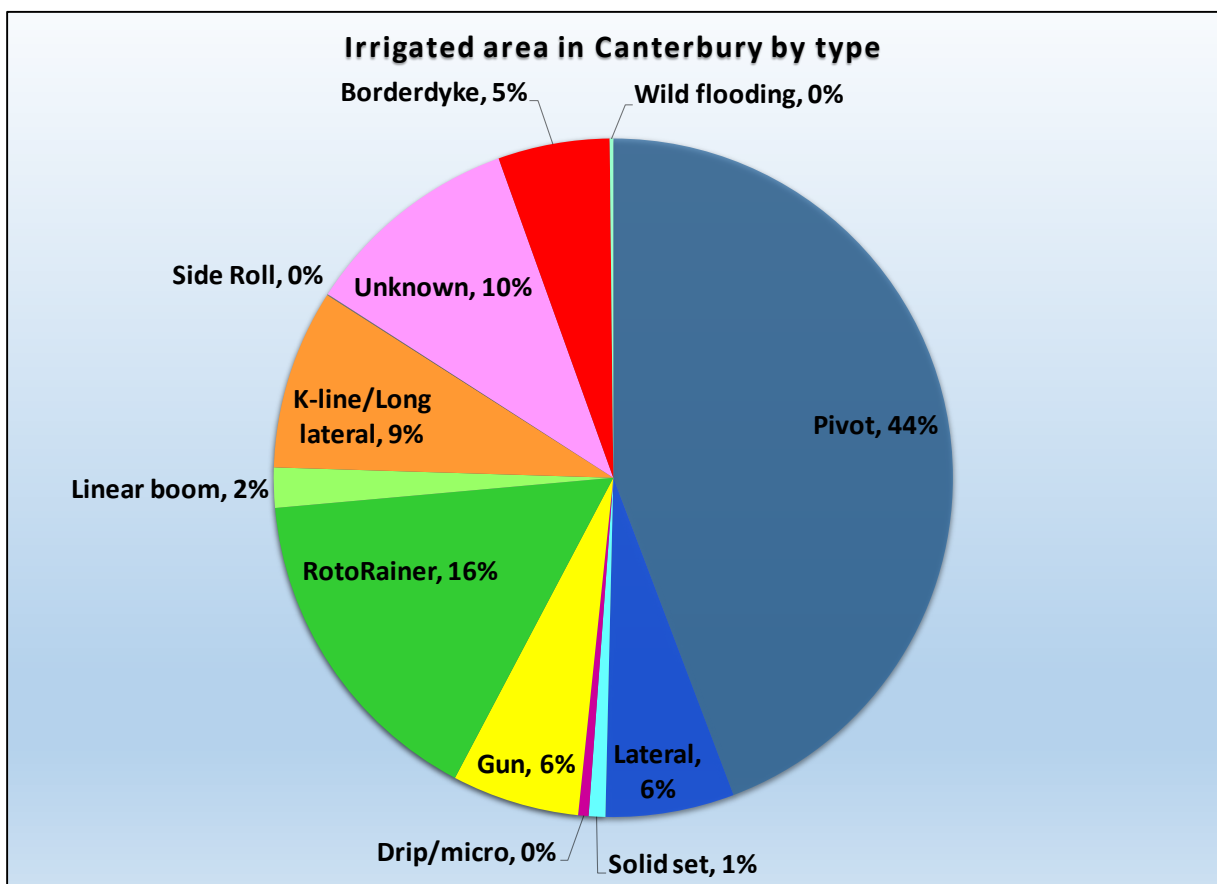


Figure 1: Irrigated area in Canterbury by type

District	Pivot	Lateral	Solid set	Drip/micro	Gun	Roto-Rainer	Linear boom	K-line/Long lateral	Side Roll	Un-known	Border-dyke	Wild flooding	Total (ha)
Typical efficiency	80-90%				50-85% ¹	50-75%			50-85%		30-60%	20-50%	
Ashburton	88,094	22,714	822	16	8,235	44,738	5,329	6,992	75	12,100	11,252		200,368
Banks Peninsula										88			88
Christchurch - West Melton	340				454	255	26	68		1,196			2,339
Hurunui - Waiau	25,251	285	1,532	1,930	3,544	1,490	134	5,160		1,547	2,432		43,304
Kaikoura	55			31	545	33		1,795		1,223			3,682
Lower Waitaki - South Coastal	11,966	1,036	559	211	2,330	1,259		19,773		4,140	9,634	129	51,038
Orari-Opihi-Pareora	26,035	2,653	28		5,179	3,208		2,785		16,772	85		56,745
Selwyn - Waihora	47,247	3,779	877	322	6,022	26,589	3,493	3,899	179	5,734	1,286		99,427
Upper Waitaki	6,926	209	123	3	896			982		574	1,930	741	12,384
Waimakariri	18,580	448	68		3,574	2,905	698	2,006		9,479	336		38,093
Total (ha)	224,492	31,124	4,009	2,513	30,779	80,477	9,680	43,460	254	52,855	26,955	870	507,468
Total (%)	44%	6%	1%	0%	6%	16%	2%	9%	0%	10%	5%	0%	100%
1. Gun irrigation is commonly used for arable crops. Irrigation efficiency for arable crops is generally higher than for pasture because of the need to avoid over watering. For pasture, Guns are typically 50-75% efficient.													

Table 1: Irrigated area by CWMS zone

District	Pivot	Lateral	Solid set	Drip/micro	Gun	Roto-Rainer	Linear boom	K-line/Long lateral	Side Roll	Un-known	Border-dyke	Wild flooding	Total (ha)	Total (%)
Typical efficiency	80-90%				50-85%	50-75%			50-85%		30-60%	20-50%		
Ashburton District	88,094	22,714	822	16	8,235	44,738	5,329	6,992	75	12,100	11,252		200,368	39%
Christchurch City	588			6	401	234	26	29		1,293			2,576	1%
Hurunui District	25,251	285	1,532	1,930	3,544	1,490	134	5,160		1,547	2,432		43,304	9%
Kaikoura District	55			31	545	33		1,795		1,223			3,682	1%
Mackenzie District	4,514				714	316		273		4,440	1,335	246	11,838	2%
Selwyn District	46,999	3,779	877	316	6,075	26,610	3,493	3,938	179	5,726	1,286		99,278	20%
Timaru District	22,440	2,653	28		4,872	2,892		1,933		11,259	85		46,162	9%
Waimakariri District	18,580	448	68		3,574	2,905	698	2,006		9,479	336		38,093	8%
Waimate District	10,150	1,036	477	103	2,178	1,259		17,379		4,190	7,336		44,108	9%
Waitaki District	7,822	209	205	112	642			3,954		1,598	2,894	623	18,059	4%
Total (ha)	224,492	31,124	4,009	2,513	30,779	80,477	9,680	43,460	254	52,855	26,955	870	507,468	100%
Total (%)	44%	6%	1%	0%	6%	16%	2%	9%	0%	10%	5%	0%	100%	

Table 2: Irrigated area by district

The CWMS has targets relative to a 2010 baseline. Two of the targets are water use efficiency improvements, and an increase in the irrigated area and/or an increase in the reliability.

We have estimated the change in irrigated area over time by comparing Statistics New Zealand (StatsNZ) agricultural survey results with Aqualinc's detailed irrigation area mapping. A regional summary is presented in Table 3 and Figure 2. From May to 2010 to January 2015 the total irrigated area in Canterbury increased from about 425,000 ha to 507,000 ha. This is a change of about 82,000 ha or 19%. During this same period surface irrigation (predominantly borderdyke) decreased from about 54,000 ha to 28,000 ha, which is a 48% reduction.

The original CWMS estimate was that there was about 500,000 ha irrigated in 2010. Our opinion is that this value was an over-estimate by about 75,000 ha. Detailed mapping estimates align reasonably closely with StatsNZ estimates, once known changes between mapping dates and StatsNZ survey dates are accounted for. CWMS 2010 estimates were primarily based on an analysis of consents, which may have over-estimated the area due to consents that were not fully developed, some consented areas being greater than the actual irrigated area, and double-counting in regions with both irrigation scheme water and private water permits.

Most of the irrigation expansion that has occurred since 2010 uses water from consents that were already in place in 2010. This illustrates the long lag time between irrigation being consented and fully developed.

Table 3: Change in irrigated area in Canterbury over time

Representative date	Area under an irrigation system (ha)			Source
	Surface irrigation	Spray irrigation	Total	
Jan 2002			287,168	StatsNZ agricultural census
Jan 2007	65,827	319,444	385,271	StatsNZ agricultural census
May 2010	53,886	371,012	424,898	Interpolated from 2007 to 2012 estimates
Jan 2012	47,896	396,881	444,777	StatsNZ agricultural census
Jan 2015	27,825	479,644	507,468	Aqualinc detailed mapping

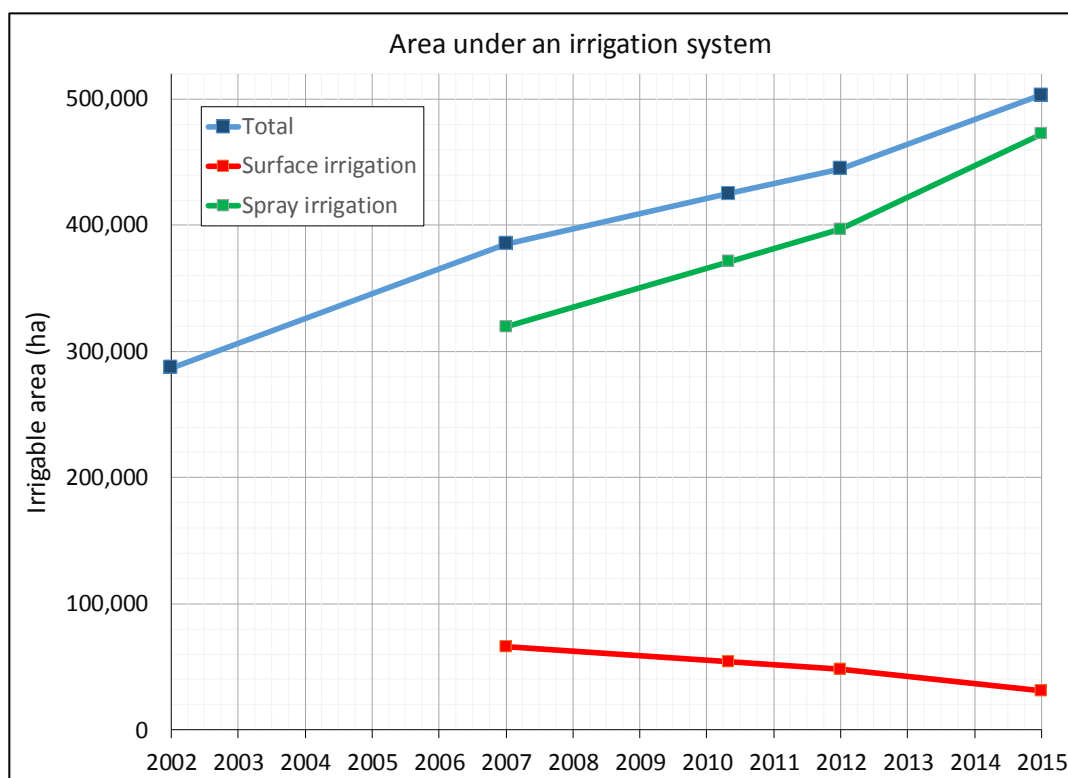


Figure 2: Change in irrigated area in Canterbury over time

A breakdown by district is provided in Table 4. The irrigated area has increased in all districts. The largest changes by area have occurred in the Ashburton District and are primarily the result of major irrigation scheme developments.

Table 5 summarises the main developments since 2010.

Table 4: Irrigated area changes from 2010 to 2015 by district

Type	Ashburton	Hurunui & Kaikoura	Timaru & Mackenzie	Waimakariri	Waimate	Waitaki (within Canterbury)	Selwyn & CHCH city	Canterbury
Aqualinc detailed mapping, Jan 2015 (ha)								
Surface	11,252	2,432	1,666	336	7,336	3,517	1,286	27,825
Spray	189,116	44,554	56,334	37,757	36,772	14,542	100,568	479,644
Total	200,368	46,986	58,000	38,093	44,108	18,059	101,855	507,468
StatsNZ interpolated, May 2010 (ha)								
Border	22,274	6,239	2,783	1,972	9,819	3,778	6,539	53,405
Spray	136,287	32,687	51,997	31,438	24,141	10,148	84,490	371,189
Total	158,627	39,329	53,594	33,737	34,178	13,173	92,260	424,898
Change relative to May 2010 (ha)								
Border	-11,022	-3,808	-1,117	-1,637	-2,483	-261	-5,253	-25,580
Spray	52,829	11,867	4,337	6,320	12,631	4,394	16,078	108,455
Total	41,741	7,656	4,406	4,356	9,930	4,886	9,595	82,570
Change relative to May 2010 (%)								
Border	-49%	-61%	-40%	-83%	-25%	-7%	-80%	-48%
Spray	39%	36%	8%	20%	52%	43%	19%	29%
Total	26%	19%	8%	13%	29%	37%	10%	19%

Table 5: Major developments from 2010 to 2015

District	Major developments
Ashburton	Borderdyke conversions, Ashburton Lyndhurst and Valetta Irrigation scheme piping, Barhill Chertsey scheme development.
Hurunui and Kaikoura	Borderdyke conversions.
Timaru and Mackenzie	Rangitata South Irrigation scheme development.
Waimakariri	NTP Eyrewell Forest developments. Borderdyke conversions.
Waimate	Borderdyke conversions, Waihao Downs Irrigation scheme development. Hakataramea Irrigation Scheme development.
Waitaki (within Canterbury)	Borderdyke conversions, Upper Waitaki developments.
Selwyn and Christchurch City	Central Plains Irrigation development and borderdyke conversions.

One of the 2015 targets for water efficiency was for 60% of water used for irrigation to be at best practice. We do not yet have district-wide estimates of what farms have 'best practice' water management, or district estimates of water use efficiency based on recorded water use. We can however provide reasonable estimates of typical on-farm irrigation efficiency based on the irrigation system type. The irrigation system type is generally the primary factor that affects efficiency, because irrigation management is constrained by the operating characteristics of the irrigation system. Table 6 summarises the irrigation systems and typical efficiencies for Canterbury. There has been a major shift since 2010 towards more efficient irrigation systems,

with large areas of borderdyke and less efficient spray irrigation being converted to efficient spray irrigation. Based on this analysis we estimate that approximately 55-60% of the area irrigated in Canterbury in 2015 achieved an application efficiency of 80% efficient or higher¹.

Table 6: Irrigated area by type and efficiency for Canterbury

System type	% by area	Typical efficiency
Pivot	44.2%	80-90%
Lateral (i.e. Linear move)	6.1%	
Solid set	0.8%	
Drip/micro	0.5%	
Gun	6.1%	50-85%
RotoRainer	15.9%	50-75%
Linear boom (e.g. TurboRain)	1.9%	
K-line/Long lateral	8.6%	
Side roll	0.0%	
Unknown (generally K-line or Gun)	10.4%	50-85%
Borderdyke	5.3%	30-60%
Wild flooding	0.2%	20-50%

¹ Includes an allowance for Gun and RotoRainer irrigation of crops generally being more efficient than irrigated pasture

4.1 Overview

This section provides further details on the available datasets and mapping accuracy for eight of the ten CWMS zones. The first report entitled “Irrigated area mapping: Waimakariri and Orari-Opihi-Paerora” (Brown 2015a) documents the mapping of the two other CWMS zones.

Accuracy is described by stating the error or uncertainty in the estimates. The percentage error at an individual paddock scale is an estimate of the maximum portion of paddocks that have been incorrectly identified as either irrigated or unirrigated. This includes ‘false positive’ and ‘false negative’ errors, and is a percentage of the total irrigated area, not the total catchment area. Errors as a percentage of the total catchment area is much lower [i.e. better]. The percentage error estimates are estimated by the mapper, and vary by system type and region, depending on a range of factors such as the clarity of aerial photographs and the contrast in NDVI imagery.

4.2 Kaikoura

An overview of the irrigated area by type for the Kaikoura CWMS zone is included in Table 7 and Figure 3. We estimate there was 3,680 ha (± 425) irrigated in 2015. Most of the irrigation is either K-line or Guns. Irrigated area estimates were presented to the Zone Committee in November 2015. They confirmed that these estimates agreed with their local knowledge. For comparison, Statistics New Zealand (StatsNZ) estimated that 2,900 ha of land in the Kaikoura District was irrigated in the 2011/12 season.

K-line irrigation and Guns provide the least distinct irrigation patterns in aerial photographs and hence the area estimates have a higher degree of error. Furthermore, the higher rainfall (compared with other irrigated parts of Canterbury) means that there is less contrast between irrigated and non-irrigated areas, even for the dry 2014/15 summer. Consequently irrigated area estimates are less accurate than other zones in Canterbury.

Table 7: Kaikoura irrigated area and type in 2015

Irrigation type	Area (ha)	% of total	Error (%)		Error (ha)	
			Individual paddock ¹	Total area ³	Individual paddock	Total area
Pivot	55	1%	4%	2%	2	1
Drip/micro	31	1%	10%	10%	3	3
Gun	545	15%	20%	10%	109	55
RotoRainer	33	1%	10%	10%	3	3
K-line/Long lateral	1,795	49%	15%	10%	269	179
Unknown ²	1,223	33%	25%	15%	306	184
Total	3,682	100%	19%	12%³	693	425

(1) The % error at an individual paddock scale is an estimate of the maximum portion of paddocks that have been incorrectly identified as either irrigated or unirrigated.
(2) Areas marked as 'unknown' system type will be predominantly Guns and K-line.
(3) The % total error is an estimate of the maximum error in the total irrigated area.

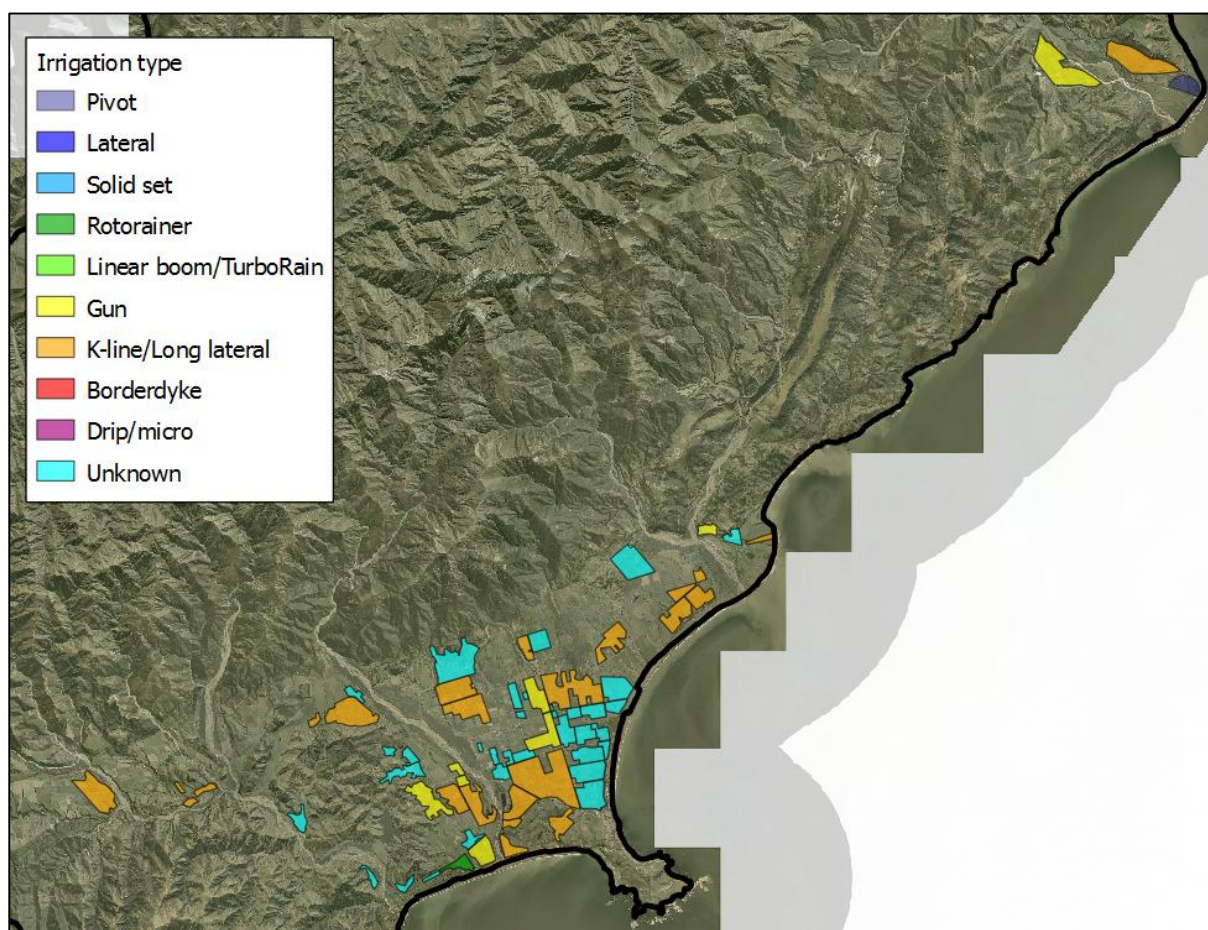


Figure 3: Kaikoura irrigated area and type in 2015

4.3 Hurunui-Waiau

An overview of the irrigated area by type for the Hurunui-Waiau CWMS zone is included in Table 8 and Figure 4. We estimate there was 43,300 ha ($\pm 1,100$) irrigated in 2015. Pivots are by far the dominant irrigation type.

The following aerial datasets were used in analysis:

- ECan 2014/15 summer imagery (0.3m pixel)
- Landsat imagery from February 2015

For the Amuri Irrigation Company scheme command area Farm Environmental Plans (FEP), prepared in 2015, were available for most farms. These FEPs included maps of the irrigated area prepared by the farmers. For these areas irrigated area mapping is particularly accurate.

The very dry summer of 2014/15 coincided with when Environment Canterbury flew an aerial survey for the district, resulting in a strong visual contrast between irrigated and unirrigated areas. For over half of the irrigated area, FEP plans prepared in 2015 were also available. Consequently irrigation accuracy for this zone is particularly good.

For comparison, StatsNZ estimated that 39,160 ha of land in the Hurunui District was irrigated in the 2011/12 season (refer Table 9). The 10% difference compared with Aqualinc's 2015 estimate will be mainly the result of new irrigation that has occurred since June 2012. The significant difference in the surface irrigation areas is due to the large number of borderdyke to spray conversions that occurred from 2012 to 2015.

Table 8: Hurunui-Waiau irrigated area and type in 2015

Irrigation type	Area (ha)	% of total	Error (%)		Error (ha)	
			Individual paddock	Total area	Individual paddock	Total area
Pivot	25,255	58%	4%	1%	1,010	253
Lateral	286	1%	4%	2%	11	6
Drip/micro	1,930	4%	8%	5%	154	96
Solid set	1,532	4%	6%	4%	92	61
Gun	3,545	8%	8%	5%	284	177
RotoRainer	1,490	3%	6%	3%	89	45
Linear boom	134	0%	6%	6%	8	8
K-line & Long lateral	5,162	12%	8%	5%	413	258
Borderdyke	2,432	6%	5%	3%	122	73
Unknown ⁽¹⁾	1,547	4%	20%	10%	309	155
Total	43,313	100%	6%	3%	2,493	1,132

(1) Areas marked as 'unknown' system type will be predominantly Guns and K-line.

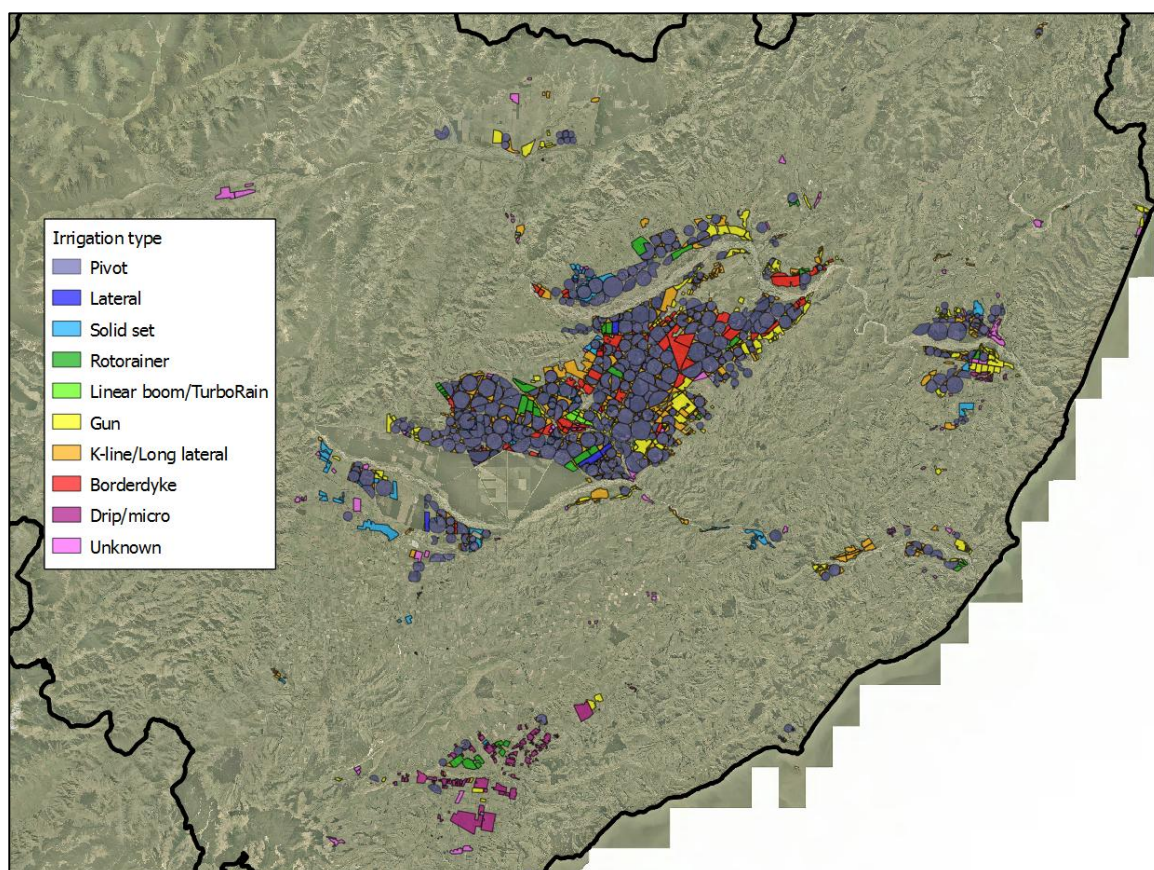


Figure 4: Hurunui-Waiau irrigated area and type in 2015

Table 9: Hurunui District StatsNZ irrigated area estimates vs. Aqualinc's estimates (ha)

Source	Surface	Spray	Drip/micro	Total
StatsNZ estimate for June 2012	4,801	32,661	1,698	39,160
Aqualinc estimate for 2015	2,432	38,951	1,930	43,304

4.4 Selwyn Waihora

An overview of the irrigated area by type for the Selwyn Waihora CWMS zone is included in Table 10 and Figure 5: Selwyn Waihora irrigated area and type in 2015. We estimate there was 99,400 ha ($\pm 4,200$) irrigated in 2015. Pivots are by far the dominant irrigation type. There has been a major shift in this zone towards more efficient irrigation over the last three years, with large areas of RotoRainer and Borderdyke irrigation being replaced with Pivot or Lateral irrigation. Pivots are particularly dominant in the Central Plains Stage 1 command area, and account for about 80% of all new irrigation systems being installed.

The following aerial datasets were used in analysis:

- Various satellite images from December 2014 to December 2015 (0.3-0.5 m pixel)
- ECan 2012/13 summer imagery (0.4 m pixel)
- Landsat imagery from March 2015 and January 2016

Environment Canterbury also flew a 0.3 m aerial survey for this zone over the 2015/16 summer. These images are due for release July or August 2016. These images could be used to refine mapping, particularly for the Central Plains Stage 1 command area, where a substantial amount of irrigation development occurred over the 2015/16 summer.

The very dry summer of 2014/15 and the dry period leading up to January 2016, resulted in a reasonable visual contrast in the satellite images between irrigated and unirrigated areas. NDVI imagery from March 2015 and January 2016 also had a reasonably strong contrast between irrigated and unirrigated areas. Consequently irrigation accuracy for this zone is reasonably good.

Table 10: Selwyn Waihora irrigated area and type in 2015

Irrigation type	Area (ha)	% of total	Error (%)		Error (ha)	
			Individual paddock	Total area	Individual paddock	Total area
Pivot	47,247	48%	4%	2%	1,890	945
Lateral	3,779	4%	4%	2%	151	76
Drip/micro	322	0%	8%	5%	26	16
Solid set	877	1%	8%	5%	70	44
Gun	6,022	6%	15%	10%	903	602
RotoRainer	26,589	27%	8%	5%	2,127	1,329
Linear boom	3,493	4%	8%	5%	279	175
K-line & Long lateral	3,899	4%	10%	7%	390	273
Side Roll	179	0%	15%	10%	27	18
Borderdyke	1,286	1%	8%	5%	103	64
Unknown	5,734	6%	20%	12%	1,147	688
Total	99,427	100%	7%	4%	7,113	4,230

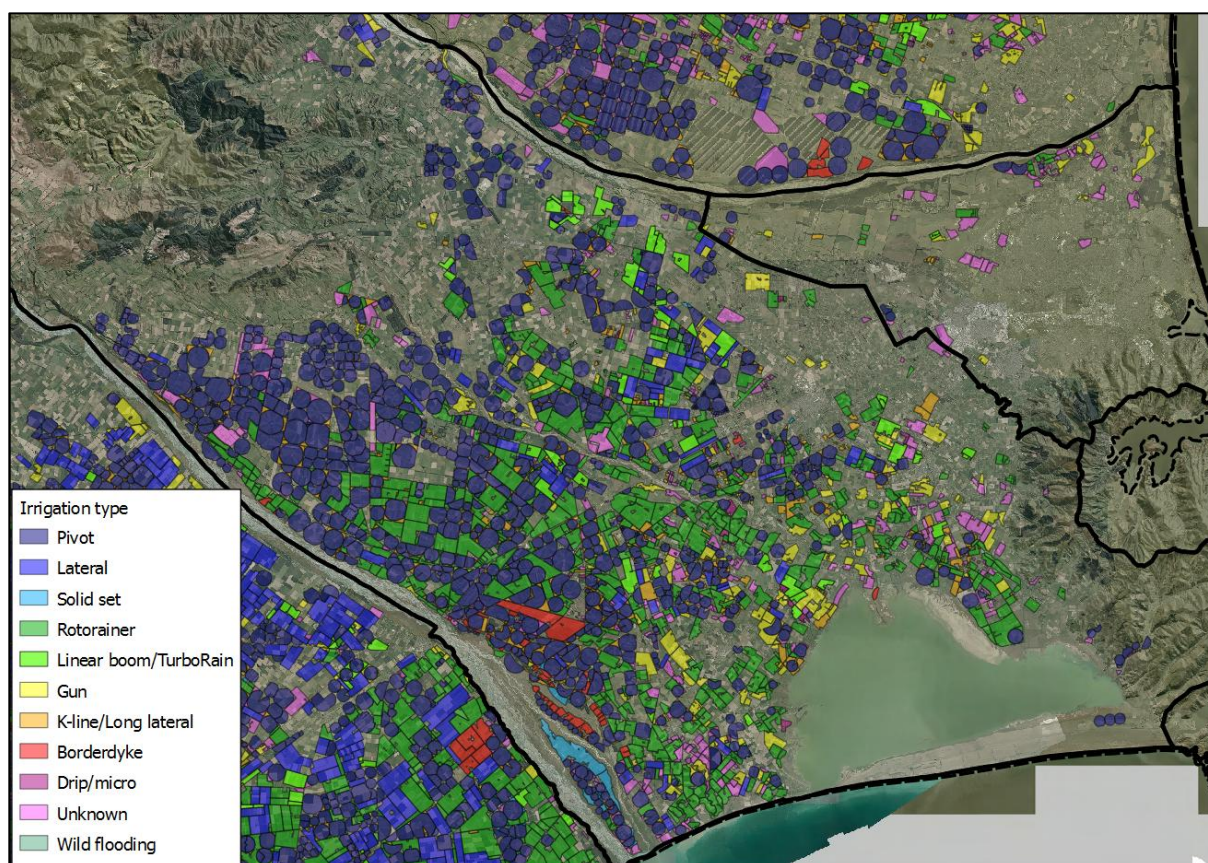


Figure 5: Selwyn Waihora irrigated area and type in 2015

For comparison, StatsNZ estimated that 87,300 ha of land in the Selwyn District was irrigated in the 2011/12 season (refer Table 11). The 14% difference compared with Aqualinc's 2015 estimate will be mainly due to new irrigation that has occurred since June 2012. A reasonable portion of the new irrigation development is associated with Central Plains Irrigation and borderdyke to spray irrigation conversions.

Table 11: Selwyn District StatsNZ irrigated area estimates vs. Aqualinc's estimates (ha)

Source	Surface	Spray	Drip/micro	Total
StatsNZ estimate for June 2012	6,913	79,237	995	87,256
Aqualinc estimate for 2015	1,286	97,676	316	99,278

4.5 Christchurch – West Melton and Banks Peninsula

An overview of the irrigated area by type for the Christchurch West Melton CWMS zone is included in Table 12. We estimate there was 2,300 ha (± 500) irrigated in 2015.

The following aerial datasets were used in analysis:

- Satellite images from November 2015 (0.5 m pixel)
- ECan 2012/13 summer imagery (0.4 m pixel)
- Landsat imagery from March 2015 and January 2016

Environment Canterbury also flew a 0.3 m aerial survey for this zone over the 2015/16 summer. These images are due for release July or August 2016. These images could be used to refine mapping.

The dry period leading up to January 2016 resulted in a reasonable visual contrast in the satellite images between irrigated and unirrigated areas. NDVI imagery from March 2015 and January 2016 also had a reasonably strong contrast between irrigated and unirrigated areas. While the dry conditions help improve mapping accuracy the Christchurch West Melton CWMS zone has a large number of lifestyle blocks. Irrigated area accuracy is low because it is difficult to accurately map lifestyle block irrigation.

For the Banks Peninsula CWMS zone we only identified about 90 ha of irrigation.

Table 12: Christchurch-West Melton irrigated area and type in 2015

Irrigation type	Area (ha)	% of total	Error (%)		Error (ha)	
			Individual paddock	Total area	Individual paddock	Total area
Pivot	340	15%	4%	2%	14	7
Gun	454	19%	20%	15%	91	68
RotoRainer	255	11%	10%	7%	26	18
Linear boom	26	1%	10%	7%	3	2
K-line & Long lateral	68	3%	40%	30%	27	20
Unknown	1,196	51%	40%	30%	479	359
Total	2,339	100%	27%	20%	638	474

For comparison, StatsNZ estimated that 5,000 ha of land in Christchurch City (including Banks Peninsula) was irrigated in the 2011/12 season (refer Table 11). The significant difference with our estimates may be as a result of how lifestyle block respondents have answered the StatsNZ survey. The consented area of irrigation is considerably more than the area mapped, because most lifestyle block owners/occupiers who have irrigation consents do not irrigate for productive gain. Also our mapping does not include any urban areas that are irrigated. District boundaries and CWMS zones do not completely align, so our total area for each is slightly different.

Table 13: CHCH City StatsNZ irrigated area estimates vs. Aqualinc's estimates (ha)

Source	Surface	Spray	Drip/micro	Total
StatsNZ estimate for June 2012	0	4,777	188	4,965
Aqualinc estimate for 2015	0	2,570	6	2,576

4.7 Ashburton

The Ashburton CWMS zone was mapped in two sections. The Hinds nutrient zone was mapped in late 2014. For this region we estimated there was 93,000 ha ($\pm 3,000$) irrigated in 2013. Further details are provided in Brown (2015b). The remainder of the Ashburton Zone was mapped in 2016, and is representative of the state of irrigation in 2015.

An overview of the irrigated area by type for the Ashburton CWMS zone is included in Table 14 and Figure 6. We estimate there was 200,400 ha ($\pm 8,100$) irrigated in 2013 to 2015. Pivots are by far the dominant irrigation type. There has been a major shift in this zone towards more efficient irrigation over the last three years, with large areas of RotoRainer and Borderdyke irrigation being replaced with Pivot or Lateral irrigation. The following aerial datasets were used in analysis:

- Satellite images from December 2014 (0.5 m pixel)
- ECan 2012/13 summer imagery (0.4 m pixel)
- Landsat imagery from March 2015

Barhill Chertsey Irrigation and Ashburton Lyndhurst Irrigation made available a large number of irrigation maps from Farm Environmental Plans prepared in 2015. For these areas irrigation mapping will be particularly accurate. The very dry summer of 2014/15 resulted in a reasonable visual contrast in the satellite images. NDVI imagery from March 2015 also had a reasonably strong contrast between irrigated and unirrigated areas. Consequently irrigation accuracy for this zone is reasonably good.

Irrigation type	Area (ha)	% of total	Error (%)		Error (ha)	
			Individual paddock	Total area	Individual paddock	Total area
Pivot	88,094	44%	4%	2%	3,524	1,762
Lateral	22,714	11%	4%	2%	909	454
Drip/micro	16	0%	8%	5%	1	1
Solid set	822	0%	8%	5%	66	41
Gun	8,235	4%	15%	10%	1,235	823
RotoRainer	44,738	22%	8%	5%	3,579	2,237
Linear boom	5,329	3%	8%	5%	426	266
K-line & Long lateral	6,992	3%	10%	7%	699	489
Side Roll	75	0%	15%	15%	11	11
Borderdyke	11,252	6%	8%	5%	900	563
Unknown	12,100	6%	20%	12%	2,420	1,452
Total	200,368	100%	7%	4%	13,771	8,100

Table 14: Ashburton irrigated area and type 2013 to 2015

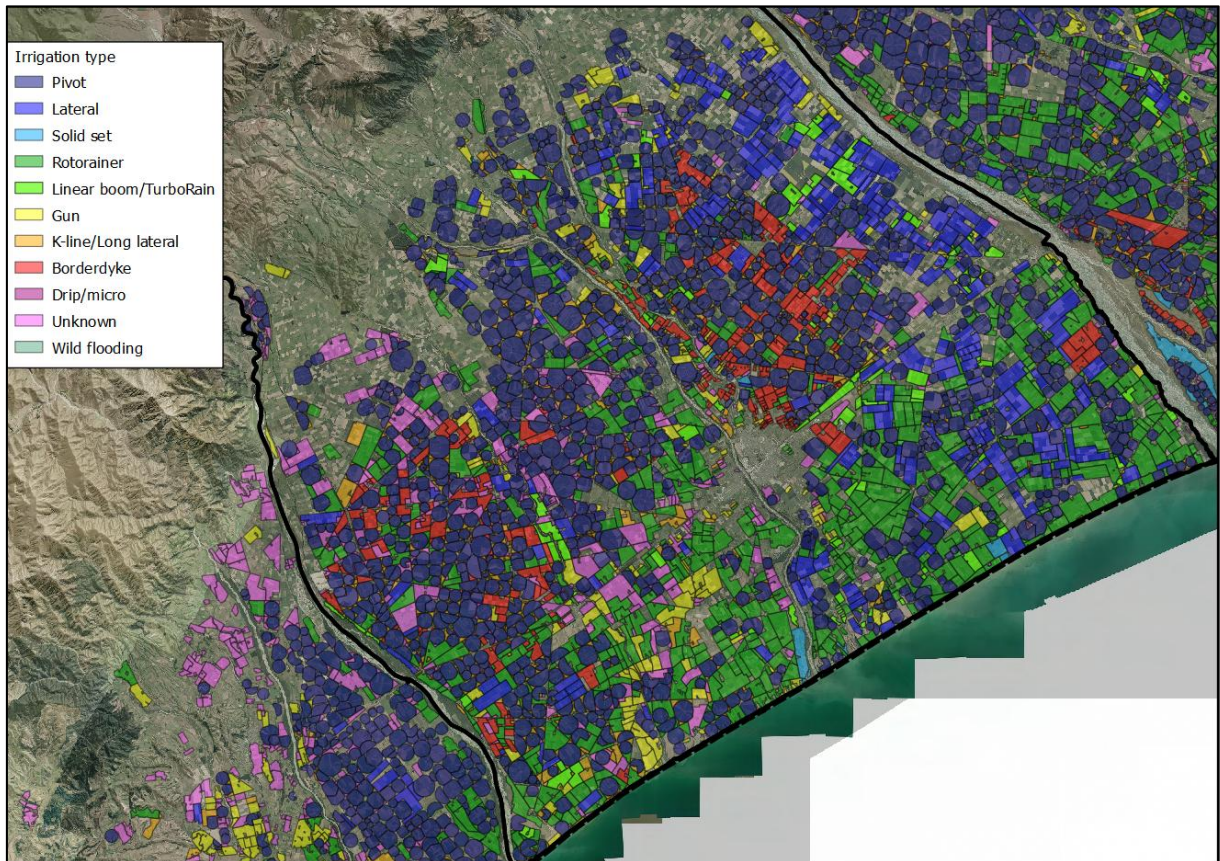


Figure 6: Ashburton irrigated area and type: 2013-15

For comparison, StatsNZ estimated that 167,900 ha of land in the Selwyn District was irrigated in the 2011/12 season (refer Table 11). The 19% difference compared with Aqualinc's 2015 estimate will be mainly due to new irrigation that has occurred since June 2012. Most of the new irrigation development is associated with borderdyke conversions, Ashburton Lyndhurst and Valetta Irrigation scheme piping, and Barhill Chertsey scheme development.

Table 15: Selwyn District StatsNZ irrigated area estimates vs. Aqualinc's estimates (ha)

Source	Surface	Spray	Drip/micro	Total
StatsNZ estimate for June 2012	18,173	149,235	912	167,890
Aqualinc estimate for 2015	11,252	189,100	16	200,368

4.8 Upper Waitaki

An overview of the irrigated area by type for the Upper Waitaki CWMS zone is included in Table 16 and Figure 7. We estimate there was 12,390 ha (± 510) irrigated in 2015. Pivots are by far the dominant irrigation type, followed by borderdyke irrigation. The following aerial datasets were used in analysis:

- ECan 2013/14 summer imagery (0.4m pixel)
- Satellite aerial imagery from October 2015 (0.5m pixel)
- Landsat imagery from March 2015

The very dry climate means there is a strong visual contrast between irrigated and unirrigated areas. Consequently irrigation area mapping accuracy is particularly good.

A comparison with StatsNZ estimates are provided in Table 17 and Table 18. The comparison is by territorial authority (i.e. district council) rather than CWMS zone. CWMS zones and district council boundaries do not align.

For the Mackenzie District there is a reasonably substantial difference between the two estimates. Some of this difference will be due to the irrigation development that occurred from 2012 to 2015. Up to 3,000 ha of the difference may be due to an over-estimate of the Ashwick Flats (near Fairlie) irrigated area, which was completed in early 2015. For Ashwick Flats where the irrigation type was marked as 'unknown' mapping was based primarily on NDVI analysis from March 2014, which lacked the contrast that was available in 2015. We recommend this area be revisited in future mapping.

For the Waitaki District (within Canterbury) the StatsNZ and Aqualinc estimates are more comparable. The difference between the two will be in part due to irrigation development that has occurred from 2012 to 2015.

Table 16: Upper Waitaki irrigated area and type in 2015

Irrigation type	Area (ha)	% of total	Error (%)		Error (ha)	
			Individual paddock	Total area	Individual paddock	Total area
Pivot	6,927	56%	4%	2%	277	139
Lateral	209	2%	4%	2%	8	4
Drip/micro	3	0%	10%	10%	0	0
Solid set	123	1%	6%	4%	7	5
Gun	897	7%	10%	6%	90	54
K-line & Long lateral	982	8%	10%	6%	98	59
Borderdyke	1,931	16%	10%	6%	193	116
Wild flood	741	6%	20%	10%	148	74
Unknown	574	5%	20%	10%	115	57
Total	12,384	100%	8%	4%	937	508

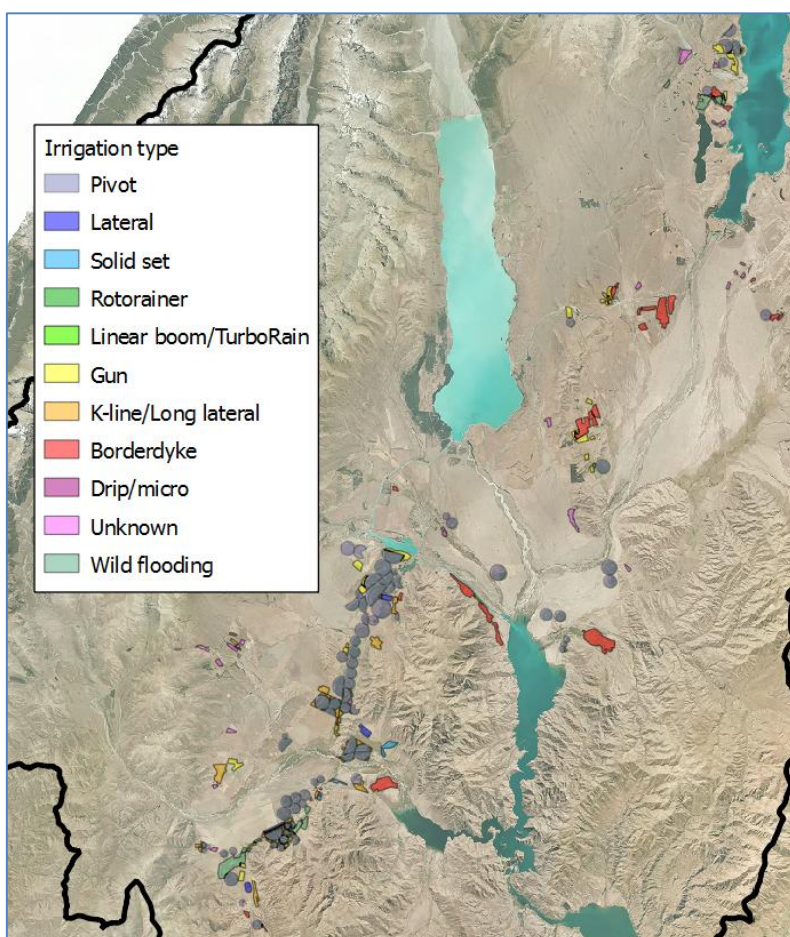


Figure 7: Upper Waitaki irrigated area and type in 2015

Table 17: Mackenzie District StatsNZ irrigated area estimates vs. Aqualinc's estimates (ha)

Source	Surface	Spray	Drip/micro	Total
StatsNZ estimate for June 2012	894	4,610	63	5,567
Aqualinc estimate for 2015	1,582	10,257	0	11,839

Table 18: Waitaki District within Canterbury StatsNZ irrigated area estimates vs. Aqualinc's estimates (ha)

Source	Surface	Spray	Drip/micro	Total
StatsNZ estimate for June 2012	3,309	11,462	121	14,892
Aqualinc estimate for 2015	3,517	14,432	112	18,061

4.9 Lower Waitaki – South Coastal Canterbury

An overview of the irrigated area by type for the Lower Waitaki – Coastal South Canterbury CWMS zone is included in Table 19 and Figure 8. We estimate there was 51,050 ha ($\pm 3,040$) irrigated in 2015. K-line irrigation is the dominant irrigation type, followed by pivot and borderdyke irrigation.

The following aerial datasets were used in analysis:

- ECan 2013/14 summer imagery (0.4m pixel)
- Satellite aerial imagery from October 2015 (0.5m pixel)
- Landsat imagery from March 2015

For the Morven Glenavy Ikawai Irrigation scheme command area detailed maps of irrigated area are available from Farm Environmental Plans and irrigation design reviews.

The particularly dry period in March 2015 provided a good NDVI contrast along the Waitaki and in the Hakataramea Valley. In the Hakataramea Valley there is a reasonable amount of deficit irrigation (i.e. applied irrigation is insufficient to meet crop water requirements), which means irrigated area estimates are less accurate. In the South Canterbury Coastal region, despite the 2015 dry year, the contrast between irrigated and non-irrigated areas was not as great compared with most other irrigated parts of Canterbury. This is due to the heavy soils, the lower potential evapotranspiration, and the high proportion of cropping. Overall for the zone irrigation area mapping accuracy was average.

Within the Waihao Irrigation Scheme command area some of the irrigation mapped is proposed, but was not installed in 2015. For this area irrigated estimates are largely based on irrigation plans submitted to Morven Glenavy Irrigation Scheme for approval. The Waihao Irrigation Scheme is due to be commissioned sometime in 2016.

A comparison with StatsNZ estimates is provided in Table 20. CWMS and district council boundaries do not align, and the comparison is by territorial authority boundaries. The difference between the two estimates is probably mostly due to the recently commissioned Hakataramea Irrigation Scheme (approximately 1,000 ha new irrigation), and the soon-to-be commissioned Waihao Irrigation Scheme (approximately 3,000 ha new irrigation).

Table 19: Lower Waitaki – Coastal South Canterbury irrigated area and type in 2015

Irrigation type	Area (ha)	% of total	Error (%)		Error (ha)	
			Individual paddock	Total area	Individual paddock	Total area
Pivot	11,968	23%	4%	2%	479	239
Lateral	1,036	2%	4%	2%	41	21
Drip/micro	212	0%	8%	5%	17	11
Solid set	559	1%	8%	5%	45	28
Gun	2,330	5%	10%	7%	233	163
RotoRainer	1,259	2%	8%	5%	101	63
K-line & Long lateral	19,777	39%	10%	7%	1,978	1,384
Borderdyke	9,635	19%	8%	5%	771	482
Wild flood	129	0%	20%	20%	26	26
Unknown	4,140	8%	25%	15%	1,035	621
Total	51,045	100%	9%	6%	4,725	3,038

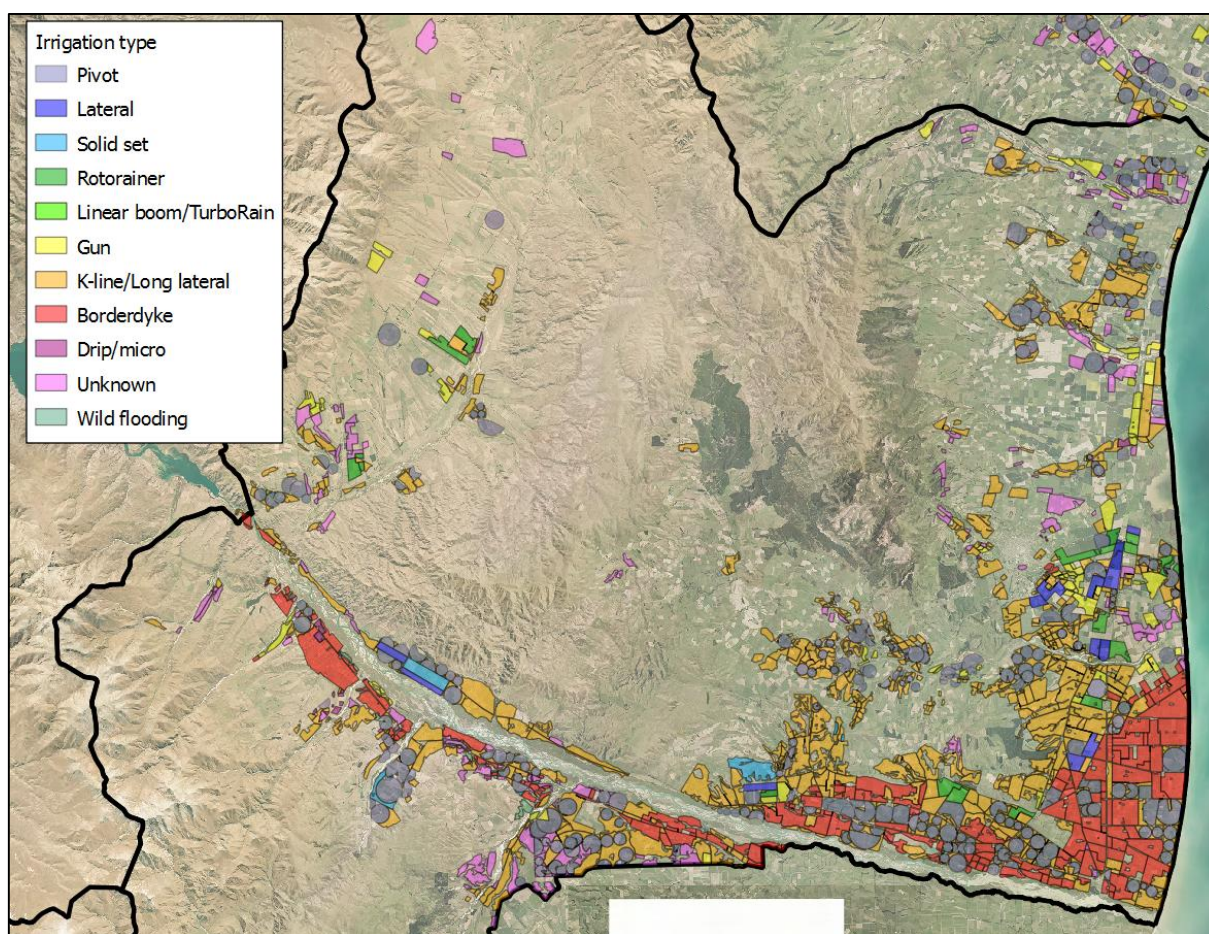


Figure 8: Lower Waitaki – Coastal South Canterbury irrigated area and type in 2015

Table 20: Waimate District StatsNZ irrigated area estimates vs. Aqualinc's estimates (ha)

Source	Surface	Spray	Drip/micro	Total
StatsNZ estimate for June 2012	9,916	26,729	67	36,712
Aqualinc estimate for 2015	7,337	36,675	103	44,115

GIS data is supplied as an ESRI shapefile, and QGIS SQLite and QML style files. The files are named “canterbury_irr_area_vYYYY_MM_DD”, where ‘YYYY_MM_DD’ is the date stamp. Details on the fields supplied with the data are included in Table 21. When the data is updated, old mapping estimates should not be deleted, but rather the status changed to ‘historic’. This will allow changes in the irrigated area over time to be tracked.

Table 22 provides further details on the irrigation type, including typical application efficiency for pasture irrigation.

Table 21: GIS fields

Field in GIS	Description
type	Irrigation type (refer Table 22)
length_m	Pivot length/radius. N/A for other irrigation system type. Includes corner arms and end guns where applicable. Not calculated for all pivots.
notes	Notes from the GIS mapper
area_ha	Area in hectares
confidence	Confidence of estimate. Not recorded for most areas.
district	Territorial authority district. Used for comparisons with StatsNZ estimates
cwms_zone	Canterbury Water Management Strategy zone
year_irr	Year that mapping best represents
yearmapped	Year that mapping was completed
status	Current = most recent estimate. Historic = historic estimate. Used to track changes when irrigated areas are updated.

Table 22: Irrigation type and efficiency

Name in GIS file	Other common names	Typical efficiency for pasture
Pivot		80-90%
Lateral	Linear move, Linear	80-90%
Drip/micro		80-90%
Solid set	Fixed grid	80-90%
Gun	Big Gun	50-75%
RotoRainer	Rotary Boom	50-75%
Linear boom	TurboRain	50-75%
K-line & Long lateral	Hand move, sprinklers, laterals	50-75%
Borderdyke		30-60%
Wild flood	Contour irrigation	20-50%
Unknown	Generally K-line or Gun	50-75%

- Brown, P. (2015a) “Irrigated area mapping: Waimakariri and Orari-Opihi-Paerora”. Report prepared for Environment Canterbury by Aqualinc Research Ltd. Report No. C15043/1. March 2015.
- Brown, P. (2015b). “Statement of primary evidence of Peter Brown for Fonterra Co-operative Group Ltd and DairyNZ Ltd”. Evidence prepared for the Proposed Variation 2 of the Proposed Land and Water Regional Plan – Section 13 Ashburton. 15 May 2015.

Appendix A: Irrigated area maps