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**IN THE MATTER OF** the Resource Management Act 1991

**AND**

**IN THE MATTER OF** resource consent applications by the Lower Waitaki Mid Irrigators Group to take and use water from the Waitaki River, its tributaries or from groundwater.

## ***EVIDENCE OF IAN MCINDOE***

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### **INTRODUCTION**

#### **Background and Qualifications**

1. My full name is Ian McIndoe. I am a Soil and Water Engineer and hold the qualifications of BE (Hons) from Canterbury University and Dip Bus Stud (Finance) from Massey University. I am currently employed as Principal Engineer by Aqualinc Research Ltd, of which I am a director.
2. I have 30 years experience in water resources and irrigation related work. From 1984-90, I was the Ministry of Agriculture's water resources specialist involved in surface and groundwater allocation and management, including preparing the Ministry of Agriculture submissions on several water plans in Canterbury and other areas in New Zealand.
3. I have specialised in water allocation for irrigation and the effect of water restrictions on irrigation reliability and performance.
4. I am also an expert in irrigation design and irrigation efficiency, and have provided information and recommendations to Canterbury Regional Council covering several subjects including seasonal allocations, irrigation efficiency and irrigation reliability to help Council formulate their NRRP policies.
5. I am a board member of Irrigation New Zealand.
6. I have read the Code of Conduct for Expert Witnesses (Rule 330A, High Court Rules and Environment Court Practice Note) and agree to comply with it. I confirm that I have complied with it in the preparation of this statement of evidence.

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### **Scope of evidence**

7. I have prepared this evidence at the request of the Lower Waitaki Mid Irrigators Group, represented by Ms Jane Borthwick. This represents applicants between the Waitaki Dam and Black Point.
8. I have been asked to provide evidence on two issues:
  - Technical information to support the revised annual allocations for irrigation requested by the applicants.
  - Comment on the irrigation reliability of supply and operational characteristics of applying a 24, 48 or 72 hr moving average to Waitaki River flows.
9. In preparing this evidence, I have reviewed the following documents:
  - Canterbury Regional Council S42(a) reports prepared for the applicants.
  - Proposed alternative flow regime for the Waitaki River by David Stewart.
  - Waitaki Catchment Water Allocation Regional Plan.
  - Schedule WQN9 Revision. Review of seasonal use approach used in proposed NRRP CRC report U05/15/1.
  - Guide to calculating Annual Allocation Volume for the Waitaki Catchment January 2007
  - Quality Assurance Test of the Consents Database for the Waitaki Catchment January 2007
  - Implementation of Waitaki Catchment Water Allocation Regional Plan: current annual allocation March 07

### **ANNUAL ALLOCATIONS**

10. During the course of proceeding through the consent process, annual allocations were submitted based on a methodology known as Schedule WQN9v2, referenced in the Waitaki Plan (reference) and taken from CRC report U05/15/1.
11. It should be noted that this is a different method to that used by R Potts for determination of estimated seasonal allocations for existing irrigators (as presented to the Water Allocation Board hearings).
12. Appendix 1, Table A1 in U05/15/1 provides the proposed schedule and total seasonal demands. Figure A2-2 provides the effective irrigation seasonal rainfall exceeded 80% of the time. The difference between the two figures provides the seasonal allocation.
13. Schedule WQN9v2 has been used to determine allocation for the applications in the Lower Waitaki Valley. However, the allocations resulting from the use of the method in the Lower Waitaki have been questioned by consultants acting for the applicants for the following reasons.

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- Virtually none of the data used to determine the total seasonal demand was from the Lower Waitaki where the land proposed to be irrigated is located.
  - North-west winds coming down the Waitaki Valley can have a significant impact on irrigation requirements.
  - The rainfall contours are uncertain and small changes in location can significantly impact on the results. The assessment of effective rainfall is in itself uncertain.
  - The methodology treats irrigation demand and effective rainfall as independent parameters, when in fact they are highly dependent on each other.
  - The methodology is going through the submission process, with new research uncovering shortcomings of the methodology.
  - CRC has further modified the WQN9 schedule and is now promoting WQN9v3.
14. As a result, the consultants acting for consent applicants and the applicants themselves have had doubts about the validity of the WQN9 allocations for the Lower Waitaki area. I had also expressed concern over some of the allocations, particularly those on the heavier soils in higher rainfall areas.
15. Aqualinc was approached by the Mid River Group to use a soil water balance methodology to prepare annual allocations for the applicants and to compare the modelling results with WQN9v2 allocations to obtain more certainty about the allocation amounts.
16. This approach incorporates assumed application efficiencies of 80% and meeting demand 80% of the time (4 years out of 5), which is consistent with NRRP policy.

### **The Waitaki Plan**

17. Policy 16 of the Waitaki Catchment Water Allocation Regional Plan (the Plan) states:

*“By requiring resource consent applications for irrigation to meet a reasonable use test in relation to the instantaneous rate of abstraction and the annual volume of the proposal to take, use, dam or divert water, including:*

- a. consideration of land use and on-site physical factors such as soil water-holding capacity, climatic factors such as rainfall variability and potential evapotranspiration, and irrigation system operation and management.*
- b. consideration of an irrigation application efficiency<sup>1</sup> of at least 80 percent. Where the resource consent application is for an irrigation system with a higher application efficiency, the higher efficiency will be used.*
- c. Annual volumes based on either:*

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<sup>1</sup> Plan definition: “A measure of the amount of applied water that is stored in the crop root zone, as a proportion of the average depth of water applied to the crop”

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- i) *soil-moisture measurements, local rainfall and evapotranspiration modelling for the 1-in-5 year dry season (the year for which seasonal demand is exceeded in 20 percent of years); or*
  - ii) *the difference between peak total seasonal demand as shown in Table A1, Environment Canterbury Report U05/15 and the effective summer rainfall exceeded 80 percent of the time from an approved rainfall site.”*
18. Policy 16 therefore allows for either the CRC approach described in U05/15 to be used or soil water balance modelling to be used to determine reasonable use for irrigation.

## The Soil Water Balance Approach

19. An analysis carried out by Aqualinc of climate data in the areas covered by the proposed applications of the Lower Waitaki Mid Irrigators Group, shows that mean annual rainfall ranges from about 500 – 600 mm (Appendix A) and potential evapotranspiration ranges from 700-800 mm (Appendix B).
20. Given the close proximity and comparable annual climate totals to North Otago, I considered that the methodology of Brown and McIndoe (2003) was the most appropriate for determining seasonal allocations in the Lower Waitaki area.
21. Seasonal irrigation allocations for each applicant, using this method, are included in Appendix C. This represents applicants between the Waitaki Dam and Black Point.
22. In 2003, at the request of the Otago Regional Council, Lincoln Environmental assessed the reasonable and efficient irrigation water requirements for North Otago (Brown and McIndoe, 2003).
23. Brown and McIndoe used soil water balance modelling, which is the internationally accepted method for estimating irrigation requirements. This method is a daily accounting system of the water entering and exiting the soil within the root zone of a particular crop. This method has shown good agreement with soil moisture measurements both internationally (e.g. Allen et al. (1998)) and locally in Canterbury, (e.g. Bright (2007)).
24. The Waitaki Plan specifies one of the acceptable methods of determining irrigation seasonal allocation is soil water balance modelled with soil moisture measurement verification. The soil water balance methodology carried out by Aqualinc complies with Policy 16 (c)(i), and is therefore consistent with the Plan.
25. Furthermore, the approach of Brown and McIndoe models the effect of all of the factors mentioned in Policy 16(a), namely land use, soil water-holding capacity and spatial variability, spatial and temporal rainfall and potential evapotranspiration variability, as well as irrigation system operation and management.

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26. The soil water balance model was run for each applicant, accounting for the differences in rainfall, evapotranspiration, and soil water holding capacity. Model input parameters are described below. Further details of the water balance model are given by Brown and McIndoe (2003) and Bright (2007).

## **Description of Model Inputs**

### ***Climate input parameters***

27. Spatial differences in mean annual rainfall and evapotranspiration are based on estimates from Tait et al. (2006) and Tait and Wood (2007), respectively. For the applicants, mean annual rainfall ranged from 500 to 650 mm (Appendix A). Potential evapotranspiration ranged from 650 to 800 mm (Appendix B).
28. Daily rainfall input data was based on historical rainfall records from Oamaru Airport (Agent 5141/5142). The mean annual rainfall (MAR) for Oamaru Airport was 509 mm, for the period June 1972 to May 2008.
29. Oamaru Airport historical rainfall data was proportionally scaled to create four time-series with mean annual rainfall of 500, 550, 600, and 650 mm, respectively. Mean annual rainfall for each applicant was rounded to the nearest 50 mm. The corresponding scaled time-series (ie. MAR = 500, 550, 600, or 650 mm) was then used as the rainfall input in the soil water balance modelling.
30. Daily potential evapotranspiration (PET) input data was based on historical climate records calculated using the Penman equation. PET records from June 1986 to Oct 2000 were obtained from Palmerston (Agent I50471) and scaled up by a factor of 1.2<sup>2</sup>. PET records from November 2000 to May 2008 were from Windsor (Agent I50087).
31. The mean annual PET for this combined time-series was 807 mm, for the period June 1986 to May 2008. This time-series was proportionally scaled to create four time-series where the mean annual PET was 650, 700, 750, and 800 mm, respectively.
32. Mean annual PET for each applicant was rounded to the nearest 50 mm. The corresponding scaled time-series (ie. Mean annual PET = 650, 700, 750, or 800 mm) was then used as the evapotranspiration input in the soil water balance modelling.

### ***Crop and soil parameters***

33. Water requirements were calculated based on intensive pasture. Crop factors for grazed pasture as a function of the time of year were directly calculated from data obtained from a lysimeter located at Dunsandel in Central Canterbury by

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<sup>2</sup> 1.2 is the average proportional difference in PET for the period of historical overlap between the Palmerston and Windsor records.

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Bright (2007). Plant available water for pasture at field capacity (PAW) estimates were obtained from the NZ Fundamental Soils Layer.

34. PAW estimates from the Fundamental Soils Layer, which generally assume a rooting depth of 900mm, were adjusted to a 600 mm rooting depth using the methodology described in Brown and McIndoe (2003) Section 2.2. This is because the main rooting depth of intensive pasture species in Lower Waitaki is expected to be 600 mm or less.
35. Where a particular applicant proposed an alternative land use, water requirements relative to intensive pasture were estimated using scale factors from Brown and McIndoe (2003) Table 9.

### ***On farm application efficiency***

36. Policy 16(b) of the Waitaki Catchment Water Allocation Regional Plan specifies annual allocations be based on a minimum irrigation application efficiency of 80%, where irrigation application efficiency is defined as the amount of applied water that is stored in the crop root zone, as a proportion of the average depth of water applied to the crop. Accordingly, this value was adopted for the modelling.
37. For well designed and managed spray systems, an application efficiency of 80% is considered reasonable. While some manufacturers claim certain systems can consistently achieve higher efficiencies, independent field testing<sup>3</sup> does not support this claim. Furthermore, most field-testing of irrigation systems neglect losses due to macro-pore flow and run-off and consequently actual efficiencies will be lower than reported.
38. 80% should be regarded as a target achievable by efficient systems where application efficiency is the primary measure of efficient irrigation. (Table 10, Brown and McIndoe (2003), Rout (2003)).

### ***Irrigation input parameters***

39. Irrigation scheduling parameters were dependent on the soil PAW and are summarised in the following table.

PAW	Effective irrigation depth <sup>(1)</sup> (mm)	Return interval (day)	System capacity (mm/d)	Trigger soil moisture level (% of PAW)
60	24	8	3.75	60%
80	32	11	3.64	55%
100	40	14	3.57	55%
120	40	14	3.57	60%

(1) Applied water retained within the root zone, assumed to be 80% of the application depth

<sup>3</sup> Irrigation system evaluations carried out by Bloomer and Associates, and HydroServices

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40. The modelling showed that there was no significant difference between the 1 in 5 year irrigation requirements of a soil PAW of 100 mm or of 120 mm. Consequently, for applicants with a PAW greater than 120 mm, a PAW of 120 mm was assumed.

### ***Irrigation requirements***

41. Irrigation requirements for a 1 in 5 year season were calculated using the soil water balance modelling. Simulations were run from June 1986 to May 2008 (21 seasons), corresponding to the period of available PET data. The 2002/03 irrigation season (among other seasons) was found to generally correspond to the 1 in 5 season for irrigation requirements. Results for each applicant are presented in Appendix C.

### ***Conveyance and other water requirements***

42. The definition of irrigation application efficiency in the Plan refers only to water application efficiency from the irrigation unit to the plant root zone. Therefore it can be assumed that under the Plan, efficient and reasonable conveyance losses can be added to any on-farm seasonal allocation.
43. The delivery losses are most significant for community schemes with open channel conveyance (e.g. Hakataramea Valley Irrigation Ltd). Conveyance losses have not been calculated and therefore it is recommended that if these losses are significant they be added to the Appendix C allocation values.
44. In addition, water requirements for uses other than irrigation (e.g. stock and domestic needs, and frost protection) should also be added to Appendix C allocation values.

### **Comment on results**

45. Appendix C compares the soil water balance modelling with the notified annual volumes, primarily based on Schedule WQN9v2. It shows that in some cases the notified values are higher and sometimes lower than the soil water balance modelling. In most cases, the differences are relatively small.
46. As both methods are allowed according to the Waitaki Plan my recommendation is to use the higher value of the two methods to be certain that sufficient water will be available for 1 in 5 year events.
47. It must be emphasised that these values are 1 in 5 year values and will not be required in average or wetter years. Efficient irrigation practices are still required.

## **24 HOUR WAITAKI RIVER FLOWS**

48. The applicants are proposing to manage water takes from the Waitaki River on the basis of historical 24 hour moving average flows at the Kurow measurement site,

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rather than the hourly flows, as specified in the WAP. Specific evidence about the proposal is provided by Mr David Stewart.

49. In terms of managing on-farm irrigation, there are good reasons why systems need to be managed on a 24 hour basis.
50. Individual irrigation systems are nearly always designed to work at a single fixed flow rate. They are either turned on or turned off, with no provision to easily vary flows.
51. It is possible, for example, to change the flows on most spray irrigation systems by manually changing the sizes of nozzles on a system. However, that is a labour intensive, time consuming job and one that is usually only done once or twice a year, to adjust to falling groundwater levels for example, if at all. That is why irrigation systems are on (at their design flow) or off.
52. Some systems have multiple irrigation units, where there is provision to turn individual units on or off, but that requires manual intervention and involves time. Even automated systems such as horticultural irrigation systems cannot be easily changed. They need to be reprogrammed, which again takes time.
53. So, it is practical to turn on-farm irrigation systems on or off on a daily basis, but impractical to do that more than once daily and impractical to change the flow rates of systems at any time. It is certainly not practical to respond to changing flow rates on an hourly basis.
54. Farmers need to know at the beginning of a day whether they can take water or not. If for example, they ring into a hot line or check the internet, they need to be able to set irrigation up for a minimum of 24 hours. That is the process taken on rivers such as the Rakaia River.
55. A single measure of flow each day therefore, is required to be able to manage irrigation operation.

Signed \_\_\_\_\_ Ian McIndoe

August 2008

## **References**

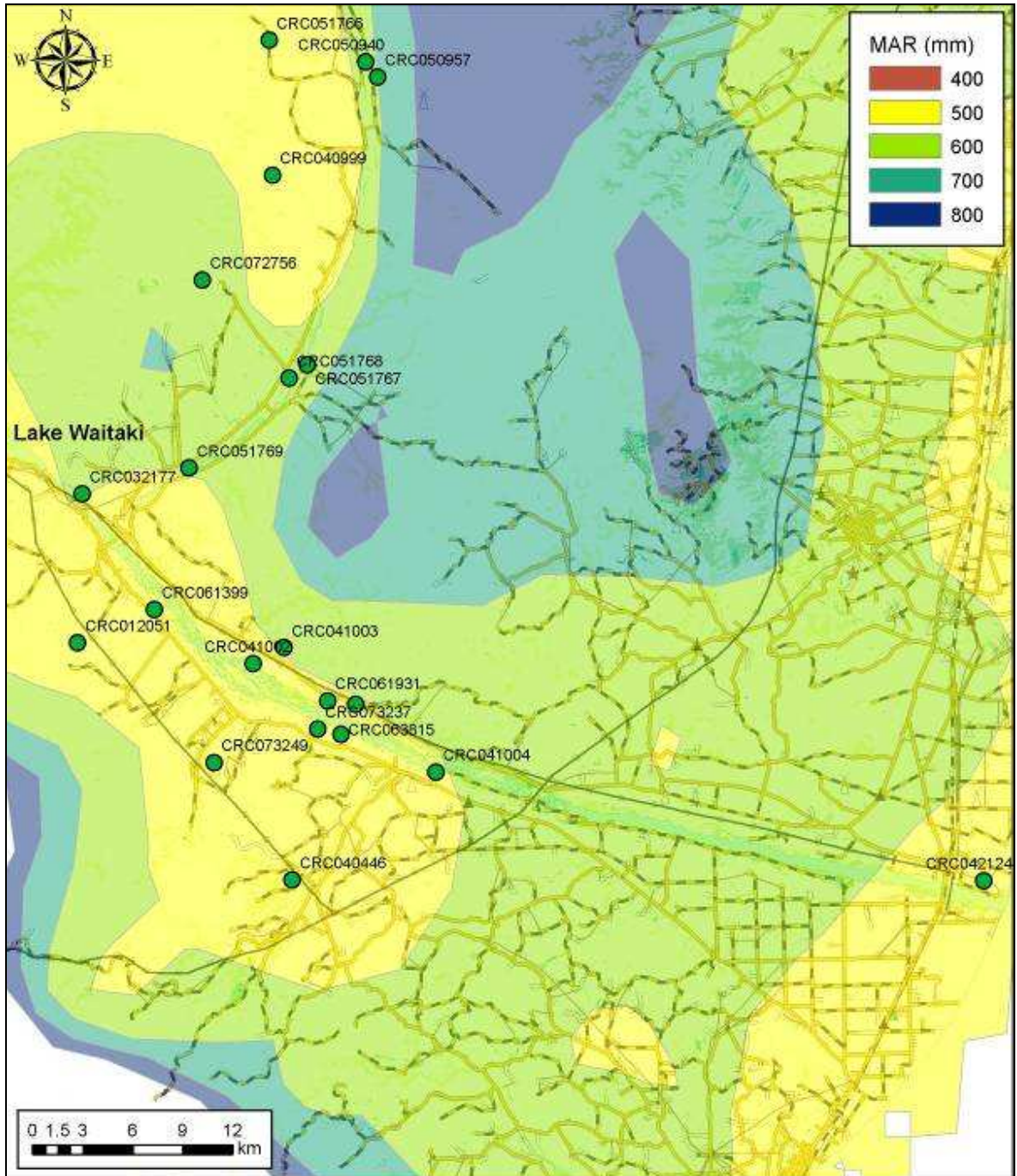
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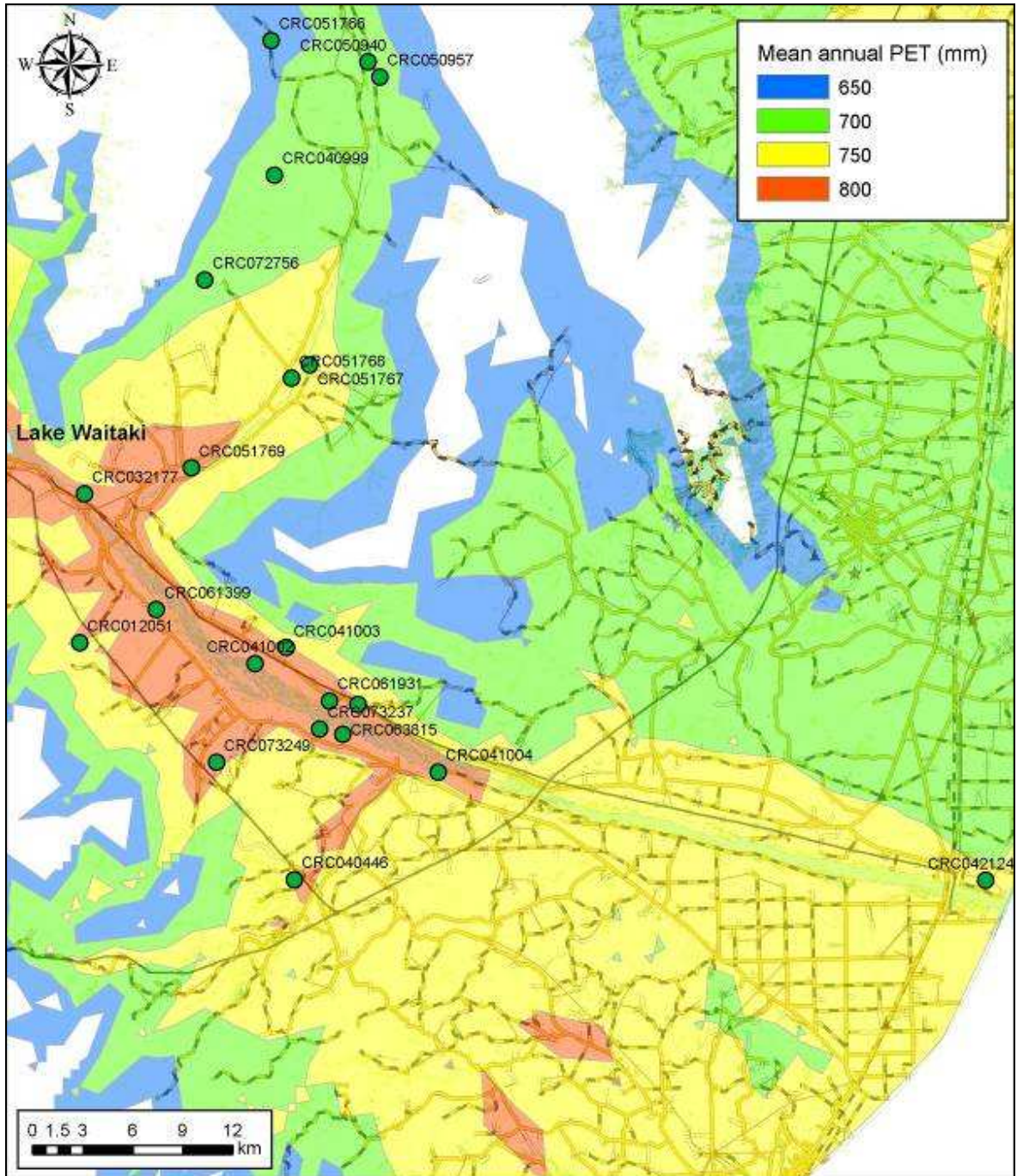
## Appendix A: Mean Annual Rainfall



Mean annual rainfall as estimated by Tail et al. (2006).

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## Appendix B: Mean Annual Potential Evapotranspiration



*Mean annual potential evapotranspiration as estimated by Tail et al. (2006)*

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Appendix C Seasonal Allocation using soil water balance budgeting												
Consent	Applicant	Crop type	Irrigation type	Other water uses <sup>(1)</sup>	Daily take (m <sup>3</sup> /d)	Area (ha)	Mean annual		Allocation		Notified annual volume	
							Rainfall (mm) <sup>(2)</sup>	PET (mm) <sup>(3)</sup>	mm/yr	m <sup>3</sup> /yr	mm/yr	m <sup>3</sup> /yr
<a href="#">CRC0517</a> <a href="#">67</a>	RPNZ Properties Ltd	Intensive pasture	Spray	None	2,592	48	609	739	552	265,000	525	252000
<a href="#">CRC0517</a> <a href="#">68</a>	RPNZ Properties Ltd	Intensive pasture	Spray	None	2,246	40	590	754	570	228,000	530	212000
<a href="#">CRC0517</a> <a href="#">69</a>	RPNZ Properties Ltd	Intensive pasture	Spray	None	1,728	40	556	775	654	261,600	540	216000
<a href="#">CRC0509</a> <a href="#">40 &amp;</a> <a href="#">CRC0509</a> <a href="#">57</a>	RG & ZL Pringle	Intensive pasture	Spray	None	4,666	120	667	690	440	528,000	510	612000
<a href="#">CRC0619</a> <a href="#">19</a>	Clarkesfield Holdings Ltd	Intensive pasture	Spray	None	3,413	188	542	783	229	562,500	560	1053920
<a href="#">CRC0619</a> <a href="#">31</a>	Clarkesfield Holdings Ltd	Intensive pasture	Spray	None	475	12	540	795	600	70,800	560	66080
<a href="#">CRC0638</a> <a href="#">15</a>	ER Rutherford	Intensive pasture	Spray	None	6,998	125	525	783	590	737,500	565	706250
<a href="#">CRC0410</a> <a href="#">04</a>	Maerewhenua Dist. Wat. Res. Co. Ltd	Intensive pasture	Spray	None	40,435	936	555	773	570	5,335,200	627	5868270
<a href="#">CRC0732</a> <a href="#">37</a>	Torach Farms Limited	Intensive pasture	Spray?	None	8,640	250	540	758	524	1,310,000	490	1225000
<a href="#">CRC0321</a>	Hakataramea Valley Irrigation Inc	Intensive pasture	Spray	None	86,400	1,857	578	784	590	10,956,300	600	11142000



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- (4) Plant available water for pasture at field capacity (PAW). PAW estimates, unless noted otherwise, are from the NZ Fundamental Soil's Layer (NZFSL) (Landcare Research). PAW estimates, which generally assume a rooting depth of 900mm, have been adjusted to a 600mm rooting depth using the methodology described in Brown and McIndoe (2003) Section 2.2, since the main rooting zone of intensive pasture species are generally 600mm or less.
- (5) Where system capacity is less than the requirements for intensive pasture (Brown and McIndoe 2003, Table 1 - adjusted to 80% irrigation efficiency) recommended seasonal allocation has been proportionally reduced.
- (6) 1 in 5 year irrigation requirements from soil water balance modelling, assuming an application efficiency of 80%.
- (7) Seasonal requirements for horticulture assumed to be 85% of intensive pasture (refer Brown and McIndoe 2003, Table 9).
- (8) Source: Estimated from surrounding soils, in the absence of a NZFSL estimate.
- (9) Source: Environment Canterbury's GIS detailed soil's layer.

Brown, P. and McIndoe, I. (2003). "Irrigation requirements for North Otago": Report No. 4461/1. Prepared for Otago Regional Council by Lincoln Environmental. October 2003.