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A Comparative Review of Two Methods for Estimating Seasonal Irrigation Demand

Client Consultancy Report for

Holland Beckett, Lawyers

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This was until 17 March 2009 a confidential client report prepared by DPC Ltd for the client on the client's instructions and solely for the client's use for the purpose intended. At the request 21 May 2009 of an Environment Canterbury Hearing Panel*, it has been re-classified as a public domain document and will be presented to the Hearing on 2 June 2009. Except for the changes on this page, removal of an Appendix [9.3] containing the detailed Brief of Work and references to it, re-numbering and re-dating, the report is identical to the 17 March version.
[* Hearing 14, Variation 2, Chapter 5 of the Natural Resources Regional Plan, reconvened Hearing on 2 June 2009; Chair: Dr Brent Cowie.]

EXECUTIVE SUMMARY

This report reviews and compares two methods for estimating "seasonal irrigation demand": the method used to develop the "seasonal irrigation demand standards" [SIDS] included in Schedule WQN9 [Variation 2] of Chapter 5 of the Proposed Natural Resources Regional Plan [pNRRP] and an alternative method presented to pNRRP Hearing Stage 14 by Dr John Bright of Aqualinc Research Ltd [henceforth 'Aqualinc']. The two main questions addressed are: Which method has the more robust methodology for assessing seasonal irrigation demands? Which method is more appropriate for the Rangitata Diversion Race schemes? The emphasis in the review is on: scientific defensibility; appropriateness of data and use requirements; fitness for purpose; and applicability in various resource, irrigation system and management contexts.

Both methods are based on 'conservation of water volume'. Both have used field measurements of water flows or stores: rainfall, irrigation and monitored soil moisture in the Schedule WQN9 method and lysimeter measurements of water balance components in the Aqualinc method. Both make use of climate records, although using different records and in different ways. Both aim to conform to appropriate pNRRP policies and to provide information appropriate to irrigated intensive pasture and to arable crop farming on relevant soil types in Canterbury. The two methods differ markedly in the assumptions and approximations incorporated, the computational methods employed and the seasonal irrigation demands they arrive at.

The Aqualinc method has the more robust methodology relative to scientific defensibility and the appropriateness of data and use requirements. This judgement is based on its close conformity to a fully-evaluated soil moisture budget, the relatively few assumptions required, the lack of needs for subjective adjustments, its use of best practice for unmeasured parameters such as potential evapotranspiration and its versatility in applicability in various resource, irrigation system and management contexts. In terms of fitness for the purpose of developing SIDS it can be criticised for requiring data for calibration and validation that are not widely or locally available, such as lysimeter data for arable crops. The Aqualinc method has an advantage in being readily adaptable for use providing seasonal irrigation demands for irrigation systems and management other than those prescribed for development of standards.

The Schedule WQN9 method has the positive feature of using time series of soil moisture measurements and local measurements of rainfall and irrigation spread across the Canterbury Plains on farms and soils of varying types. However, the soil moisture measurements were originally made for on-farm irrigation management purposes rather than for development of SIDS or calculating seasonal irrigation demands. Perhaps as a result, this method has the less robust procedure relative to scientific defensibility and the appropriateness of data and use requirements. This judgement is based on its lack of conformity to a fully-evaluated soil moisture budget, the quite numerous approximations, adjustments and corrections that are needed and the lack of real justification for the 'enveloping' process included. In terms of fitness for the purpose of developing SIDS it can be criticised for the lower scientific defensibility and for uncertainty about whether it is producing standards of the claimed demand probability. It has a further disadvantage in not being readily adaptable for use providing seasonal irrigation demands for irrigation systems and management other than those prescribed for development of standards.

The Aqualinc method is more appropriate for use in relation to the Rangitata Diversion Race schemes. This is because it is the more robust procedure, is readily adaptable for calculating seasonal irrigation demands for the contrasting historic [e.g. border-dyke] and recent [e.g. centre pivot] application systems and more clearly provides SIDS of known probability.

Neither of the two methods addresses significant questions related to Extraction and Reticulation Efficiencies, although some references in the existing pNRRP Chapter 5 seemingly include losses related to them.

CONTENTS

"All animals are equal, but some are more equal than others." George Orwell, Animal Farm, 1984

"All models are wrong, but some are useful." George Box, Empirical Model-Building and Response Surfaces [co-author Norman Draper], 1987

1.0 Introduction

The Proposed Canterbury Natural Resources Regional Plan [pNRRP] contains a schedule [WQN9] to Chapter 5 Water Quantity providing a "method for determining the seasonal irrigation demand standard depending on land use, soil type(s) and effective irrigation season rainfall." Variation 2[1] to the pNRRP provided an amendment to this schedule. There has been criticism from a number of interested parties of both the method and the standards derived using it. An alternative method was suggested by Dr John Bright of Aqualinc to a Hearing in November 2007[2]. The Hearing Committee for the adjourned hearing has put 10 questions to Environment Canterbury officers by a Minute of 17 December 2007; 7 of these questions relate to Schedule WQN9. Question 1 is:

1. "What are the comparative strengths and weaknesses of the "Davoren" model used by ECan, versus those of the Aqualinc model? How broadly applicable are these models across the region?"

A 4-page answer to this question was provided by ECan staff and consultant Dr Tony Davoren as part of a 50-page "Response to the Minute" on 31 March 2008. Workshops of interested parties were held in June and December 2008 where further information related to the two methods was presented and further discussion took place. The current status is that ECan has[3] "continued in discussion with Aqualinc, Irrigation New Zealand and included other independent scientists in these. We need to report back to the hearing panel shortly and clarify what steps will be taken. The hearing stands adjourned on this matter."

This report has been prepared in response to a request from Holland Beckett, Lawyers, of Tauranga, acting on behalf of Rangitata Diversion Race Management Limited. The request can be summarized as:

- To undertake a comparative review of the Schedule WQ9 methodology in Variation 2 of the pNRRP and the proposed alternative Aqualinc method
- In particular:
  - (a) Which method has the more robust methodology for assessing seasonal irrigation demands?
  - (b) Which method is more appropriate for the Rangitata Diversion Race schemes?

Neither method is yet in a form which can be regarded as 'final'. The method used to develop the Seasonal Irrigation Demand Standards [SIDS] presented in Table WQN 24 is currently up to 'Version 3' in concept, although only 'Version 2' of Variation 2 to the pNRRP has any formal status. ECan officers[4] "are still working to find agreement. Aqualinc have provided a brief that they are going to work on over the next month with this aim. So there is not a final proposal from our point of view." Aqualinc is currently giving consideration to determining the 'base' and 'supplementary' seasonal volumes for all irrigable locations in Canterbury.

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[1] Adopted September 2005.

[2] Stage 14 hearing on pNRRP Section 5.5.6 – Reasonable and Efficient Use of Water and Schedules WQN8 and WQN9.

[3] From an emailed answer by Malcolm Miller of ECan on 23 January 2009 to my question about any response to the Hearing Committee minute.

[4] From an emailed answer by Malcolm Miller of ECan on 22 January 2009 to my question about what is 'currently proposed'.

Both methods are intended to provide estimates of seasonal irrigation demand which can be used to set standards to guide allocation and management of water resources. Neither method is intended to contribute new scientific understanding or to incorporate comprehensive and advanced scientific understanding of detailed atmospheric and porous media science. Indeed, some simplification and subjective choice are appropriate in setting 'standards' which, as here, provide an administrative dividing line between alternative subsequent administrative procedures – as a 'permitted' or a 'discretionary' activity. Notwithstanding that disclaimer, a method for this purpose must be reasonable, scientifically defensible and as fair as possible to all interested parties. Such a method needs to be understandable to those who must use it, require data of reasonable availability for its use and be cost-effective to use. The emphasis in this review is on:

- scientific defensibility
- appropriateness of data and use requirements
- fitness for purpose
- applicability in various resource, irrigation system and management contexts

2.0 Relevant Policies and Context

One of the 'other matters' in Part 2 of the Resource Management Act (1991) [RMA] to which "particular regard" must be given is "The efficient use and development of natural and physical resources" [S 7(b)]. Policy 3 in Chapter 9 of the Canterbury Regional Policy Statement is to "Promote efficiency in the use of water". Schedule WQN9 is intended to be one of the pNRRP measures giving effect to policies designed to address water management issues. A comprehensive evaluation of relevant issues, objectives and policies is outside the scope of this report but a brief statement of the most directly relevant will assist in evaluating the merits of the two subject methods.

Two issues identified in the pNRRP are: "5.4.4 Allocation of water within water management regimes" and "5.4.5 Reasonable and efficient use of water". These give rise to objectives: "Objective WQN4: Allocation of the available water resource" and "Objective WQN5: Efficient use of water". Objective WQN4 contains:

> "(1) The available water is allocated in ways that enables communities to maximise their social, economic and cultural wellbeing, and their health and safety.
> (2) Allocation regimes are established that identify at least one allocation block within which the reliability of supply of water does not become a factor that limits the long-term economic viability of uses that are dependent on that block of water."

Objective WQN5 states:

> "Achieve a high level of efficiency in terms of resource availability and the use of water."

Policy WQN14 is concerned with "Allocation regimes for surface and groundwater"; it refers to Schedule WQN9 in some places[5]. Policy WQN17 is reproduced here in full in Appendix 9.2. It is concerned with "Reasonable and efficient use of water". The most relevant policy item for this review is:

> "(3) Further to Policy WQN17(2) above, provide for the use of water for irrigation to be:
> (a) a permitted activity where the seasonal irrigation demand standards in Schedule WQN9 are met for seasonal irrigation use; and
> (b) a discretionary activity where the seasonal irrigation demand standards in Schedule WQN9 are not met, provided that …"

The relevant context is primary industry in Canterbury; in particular, the irrigable areas in Canterbury, amounting to some 1.3 Mha (Morgan *et al.* 2002). Changes in land use, farm management

[5] e.g. Policy WQN14 (6)(c)(i), (8) (b) (i) and the Explanation and Principal Reasons for Policy WQN14.

practices, climate and weather events in recent years have led to pressure on both surface and groundwater resources and contention over their management. There are important differences in the requirements and costs, to both ECan and resource consent applicants, between ‘permitted’ and ‘discretionary’ activities.

In this review, two methods intended to contribute to reasonable and efficient use of water are to be examined in line with the objectives and policies summarized above. ‘Efficient’ use requires that wastage be minimized i.e. water extracted for a purpose should not be ‘lost’ in ‘non-useful’ ways. ‘Reasonable’ use implies that amounts used are appropriate for the purpose and not prejudicial to the rights of other actual or potential water users. The useful purpose of irrigation is usually to preserve the health of crops [e.g. against drought] and contribute to maximizing the net return from them.

Schedule WQN9 is intended to provide[6] “the method for determining the seasonal irrigation demand standard depending on land use, soil type(s) and effective irrigation season rainfall. If the annual volume required for an activity (use of water) is within the seasonal irrigation demand standard derived using this method, the activity is provided for as a permitted activity (Rules WQN25 and WQN33). If, however, the annual volume required for an activity (use of water) is in excess of the seasonal irrigation demand standard derived using this method, the activity is provided for as a discretionary activity (Rule WQN26).”

The alternative Aqualinc method is intended to provide[7] “an alternative methodology for the estimation of Seasonal Irrigation Allocations”; it was put forward because of perceived “critical shortcomings” in the methods proposed in Schedule WQN9.

3.0 Underlying Science

3.1 Basic Science

It is important to be clear about the ‘control volume’ boundaries in space and time, relevant flows into and out of the control volume, included and excluded variables and parameters, simplifications and assumptions. Figure 1 is a simplified representation of the water flows for an irrigated land area within an irrigated farm, the plants on it, the atmosphere above it and the soil volume beneath it. No particular irrigation application type is shown or implied. There are already some flows excluded as part of the simplification: there is no upward flow from beyond the depth of crop roots; there is no sideways horizontal flow from adjacent soil volumes or atmosphere; there is no overland flow from adjacent land areas.

The basic scientific principle invoked by both methods is “Conservation of Volume”. This simply means that, provided water flows are appropriately accounted for, the difference between water coming in to the control volume over a specified period, and water going out, is stored in [or removed from] the control volume. The top of the control volume is the land [soil] surface. The sides are only relevant in deciding the total area, as we excluded lateral flows. Only the bottom is a slight problem. It is conventionally set at the depth of some high percentage, say 90%, of the crop roots. Even this is rarely measured at a particular site; rather it is simply estimated from published values. The corresponding volume of soil is said to be in the ‘crop root zone’. The ‘specified time period’ is ‘an irrigation season’. What this is in calendar terms, and which season by year or statistic, are choices which have to be made in the light of objectives and policies.

[6] Variation 2 Final Version 23 November 2005.
[7] Evidence of Dr John Bright to pNRRP Hearing Stage 14 on 2 November 2007.

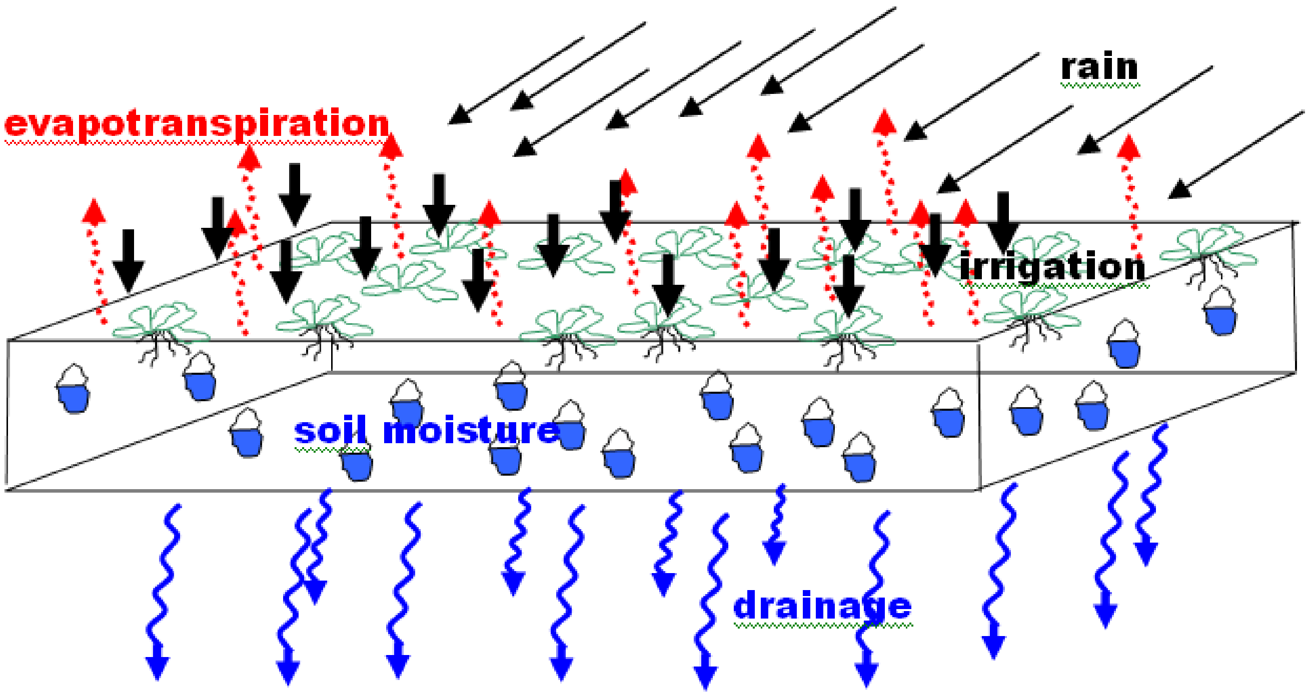

Figure 1. Simplified representation of water flows for an irrigated land area.

3.2 Model Representations

Figure 1 is already a 'model' of the real world – an 'iconic' model. It is readily turned into a 'symbolic' model suitable to be the basis of mathematical or computer models. An applicable mathematical model is the 'Integral Storage Equation':

$$\frac{dS}{dt} = I(t) - Q(t) \qquad \textbf{(1)}$$

$\frac{dS}{dt}$ is the time rate of change of storage; I is the inflow volume over time t, Q is the outflow volume in t. For the representation in Figure 1 and a prescribed 'season' as the time period, Equation (1) takes the form:

$$SW_{end} - SW_{start} = R + I - AET - D \qquad \textbf{(2)}$$

SW is the soil water volume at the end, and start, of the specified 'season'
R is rainfall volume added during the season
I is irrigation volume applied to the land surface
AET is the actual evapotranspiration volume departed from the land surface and crop
D is the drainage volume which has moved beyond the crop root zone.

As some drainage is associated with irrigation non-uniformity or over-watering, and some with rainfall non-uniformity or over-watering, a variant of Equation (2) has $D = D_I + D_R$. Then:

$$SW_{end} - SW_{start} = (R - D_R) + (I - D_I) - AET \qquad \textbf{(2a)}$$

$(R - D_R)$ is usually referred to as the 'effective rainfall', but sometimes $(R - D)$ is given this name.

Over an irrigation season, the difference on the LHS of Equation (2) is so much smaller than each of the terms on the RHS that it can be taken to be zero. Then the season irrigation volume:

$$\mathbf{I} = \mathbf{AET} + \mathbf{D} - \mathbf{R} \qquad \mathbf{(3)}$$

Equations (2,2a,3) are suitable symbolic models to represent the iconic model of Figure 1. Any one of them can be used to consider seasonal irrigation demand. In particular, they will be used in Sections 4.0, 5.0 and 6.0 as a basis of comparison of the two methods currently proposed. The relevance of Equation (3) to the purpose of Schedule WQN9 is summarised in this table:

I =	**AET +**	**D -**	**R**
Set a seasonal irrigation volume standard for the location and crop	Aim at maximising, to maximise plant growth opportunity	Encourage minimising, to minimise water wastage	Aim to use effectively, allowing for a chosen low rainfall year statistic

Three different ways of using Equations (2, 2a, 3) are relevant to this review:

(A) Given an appropriate model with calibrated parameters and values for each of AET, D, R [and SW for Equations (2, 2a)], I can be found. This is how such a model can be used to provide seasonal irrigation volumes for given land area, soil type and depth, crop, specified rainfall probability, specified irrigation application type and management.

(B) Given sets of values for each of I, AET, D R [and SW for Equations (2, 2a)], with specified land area, soil type and depth, crop, rainfall probability, and irrigation application type and management, specified parameters of an appropriate model can be determined.

(C) Given an appropriate model based on Equation (3), with calibrated parameters and values for three of the four variables I, AET, D and R, values for the fourth variable can be determined for given land area, soil type and depth, crop, irrigation application type and management.

The two methods reviewed differ in the ways they cater for AET and D to be taken into account in model calibration and use. As previously presented, they also make different assumptions about I and R values used for 'calibration' of model parameters. It is important to emphasise that no assumptions have been made in Sections 3.1 and 3.2 about irrigation application type, timing, other management or performance. These are very important; their effects are included in the models through the actual values of the I, AET, D and R variables used in Equations (2, 2a, 3).

3.3 Factors Influencing Model Structure and Parameters

The two methods reviewed use different variants of Equations (2, 2a, 3). Some general factors influence any choice of model structure and the model parameters. These include:

- The degree to which the model mimics reality
- Ease of use and understanding of results
- Data available to calibrate and verify the model
- Space and time availability of data for widespread use of the model
- Sensitivity of results to unavoidable errors in data
- Computational feasibility and cost

3.4 A Note on Application Efficiency

Efficiency of water use is referred to in the RMA (1991), the Regional Policy Statement and the pNRRP, as summarised in Section 2.0. Chapter 5 of the pNRRP refers to "application efficiency" in Policy WQN17 and the following "Explanation and Principal Reasons", in notes following Table WQN24 of Schedule WQN9 and in other places. It is defined in the "Definition of Terms for Chapters 4 to 8 Only" at the end of the revised Chapter 5: "**Irrigation application efficiency** is a measure of the amount of applied water that is stored in the crop root zone, as a proportion of the average depth of the water applied to the crop." Application efficiency assumes some importance in this review as it is enshrined in Policy WQN17 (2) (b) with a specified numerical value of 80%:

> "assume that there is an irrigation application efficiency of at least 80% even if the actual system being used has a lower application efficiency. Where the water permit application is for an irrigation system with a higher application efficiency, the higher figure will be used."

The method used to calculate "Total Seasonal Demand" in Schedule WQN9 has an "application efficiency" of 80% built in to it. The alternative Aqualinc method for deriving "Total Seasonal Demand" calculates "actual" "application efficiency" and provides it as an output. Comment will be made in Sections 4 to 6 related to application efficiency, so it is important to be clear what it indicates.

Any water volumetric efficiency less than 100% indicates that some water has been 'lost' from the purpose intended. Many 'efficiencies' have been previously defined in the context of irrigation. A report prepared for ECan in 2002 on "Efficient and Reasonable Use of Water for Irrigation" (McIndoe 2002) refers to "in excess of thirty definitions of various measures of irrigation efficiency, including several definitions of application efficiency, depending on the area of interest." The report recommended use of:

$$\text{Irrigation System Efficiency} = \frac{\text{Water applied that is stored in crop root zone}}{\text{Total amount of water delivered to the farm}}$$

$$\text{Application Efficiency} = \frac{\text{Water applied that is stored in crop root zone}}{\text{Average depth of water applied to crop}}$$

A consistent set of volumetric efficiencies which allows for losses at various levels of any irrigation system can be based on[8] the set developed by Painter and Carran (1978):

$$\text{Extraction Efficiency} = \frac{\text{volume delivered to the reticulation system}}{\text{volume extracted from the supply}}$$

$$\text{Reticulation Efficiency} = \frac{\text{volume delivered to the application devices}}{\text{volume delivered to the reticulation system}}$$

$$\text{Application Efficiency} = \frac{\text{volume delivered to the application surface}}{\text{volume delivered to the application devices}}$$

$$\text{Distribution Pattern Efficiency} = \frac{\text{volume retained in the crop root zone}}{\text{volume delivered to the application surface}}$$

[8] The Distribution Pattern Efficiency definition here differs slightly, but significantly, from the 1978 article by using "retained in" the crop root zone, instead of "delivered to". It might be better called "Root Zone Retention Efficiency".

Because these cover losses in all irrigation systems, sequentially from the supply to the water retained in the crop root zone, they may be multiplied together and their product is:

$$Irrigation\ System\ Efficiency = \frac{volume\ retained\ in\ the\ crop\ root\ zone}{volume\ extracted\ from\ the\ supply} \qquad \textbf{(4)}$$

This 'Irrigation System Efficiency' is equivalent to that above from McIndoe (2002), **with one important proviso:** the volume temporarily "stored" in the crop root zone is not necessarily the same as the volume "retained" in the crop root zone long enough for the crop to make use of it.

If under-watering [deficit irrigation] is such that 'field capacity' is not reached anywhere, even with quite non-uniform distribution, then Distribution Pattern Efficiency is 100%. But if irrigation over-watering occurs anywhere, even with 100% Distribution Pattern Efficiency, or if sufficient rainfall occurs when soil moisture is near 'field capacity', some of the water **delivered to** the crop root zone is lost from it without becoming **available to** the crop and the "Distribution Pattern Efficiency" is less than 100%.

The "Application Efficiency" from McIndoe (2002) is equivalent to the "Distribution Pattern Efficiency" in my list above, with the same important proviso that "stored" means "retained". As stated, it does not include any loss of water which is delivered to the application devices but does not reach the application surface, as allowed for in my "Application Efficiency". The "Irrigation Application Efficiency" defined in the "Definition of Terms" of pNRRP Chapter 5 is equivalent to the product of the last two efficiencies of my set above i.e. Application x Distribution Pattern Efficiency, with the proviso that the wording is amended to "the amount of applied water **retained in** the crop root zone as a proportion of the average depth of water applied to the crop", instead 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". With this same proviso, the wording used following Policy WQN17 for "Irrigation Application Efficiency" would be equivalent to the "Irrigation System Efficiency" of McIndoe (2002) and my definition here in Equation (4). This is not just a matter of semantics; there is risk of misunderstanding and miscalculation apparent in Chapter 5 and in the methods reviewed here, as will be discussed in Section 6.

4.0 Schedule WQN9 Method

4.1 The Method Itself

Variation 2 provides a four-step[9] procedure:

1. find the total seasonal demand from the right hand column of Table WQN24 for the particular land use and soil type(s) (PAW class);
2. determine effective irrigation season rainfall for the location using the map of it, Figure WQN12;
3. deduct this rainfall amount from the total seasonal demand amount to give the irrigation requirement in millimetres depth – this provides the seasonal irrigation demand standard for the intended land use;
4. [implied in the schedule; added here] compare this seasonal irrigation demand standard with the water depth equivalent to the volume applied for.

[9] The schedule procedure has 5 steps; the last 2 steps convert mean depth to volume. The 4th step in my list is implied in the schedule. I have made minor grammatical corrections to the Variation 2 presentation.

The procedure is straightforward and corresponds to a use of Equation (3) in the form (C) in Step 3:

I =	**(AET + D) -**	**R**
Seasonal irrigation volume standard for the location and crop [assumed "application efficiency" 80%]	Seasonal volume demand from Table WQN24 for the land use and soil type	Effective irrigation season rainfall from Figure WQN12

4.2 Derived Seasonal Irrigation Volume Standards

Values in Table WQN24 used in Step 1 were derived (Davoren and Scott 2005) from 1998/1999 irrigation season field measurements for soil types and crop/pasture distributed across the Canterbury Plains. Measurements of rainfall, irrigation and soil moisture were used to determine effective rainfall, effective irrigation and "freely available water, FAW", and to determine soil moisture at the beginning and end of the monitoring period. Computation equivalent to using Equation (2a) was used to calculate total seasonal AET.

$$SW_{end} - SW_{start} = (R - D_R) + (I - D_I) - AET \qquad \textbf{(2a)}$$

$$AET = (R - D_R) + (I - D_I) - (SW_{end} - SW_{start}) \qquad \textbf{(2b)}$$

An adjustment was made to AET to correct for monitoring period being different from a nominal 'season' of 1 October to 30 April by including any additional effective rainfall and irrigation outside this period. Effective irrigation was adjusted to "allow for a uniform irrigation application efficiency of 80%". This was done by adjusting the effective irrigation or rainfall so that approximately the same crop daily water use was maintained after an irrigation or rainfall event as had been the case before it. The effective irrigation summed for the season was then divided by 0.8 to obtain gross irrigation[10].

These totals of seasonal AET were taken to be the "Total Seasonal Demand" "adjusted" for pasture and "weighted and adjusted" for crops. The weighting used farm data with related soil moisture data to represent "typical mixes of arable crops". Profile available water, PAW, was estimated by multiplicative and additive factors applied to FAW for three conditions of soil stoniness and depth.

Total seasonal demands were estimated for the soil moisture monitoring sites using a simple water budget model (Scott 2004) equivalent to Equation 2(b), site weather measurements 1972-2003 and an assumed irrigation management[11]. Corrections increasing 1998/1999 demand values by between 5% and 37% were required to estimate 80%ile [only 1 year in 5 greater] high demand values at the monitoring sites.

Computed values of Total Seasonal Demand (AET + D) are shown plotted against PAW in Figure 2 [Figure 4.1 from Davoren and Scott (2005)]. The accompanying text is: "The total adjusted seasonal demand data for intensive pasture and the total weighted adjusted arable demand was separated into three categories of PAW – less than 75mm, from 75-110mm and greater than 110mm. These PAW categories are also associated with soil type classifications (see Table 4.1). Proposed standard total water allowances for intensive pasture and arable for each PAW group are summarized below and presented as part of a proposed schedule in Table A1 (Appendix 1)." The "proposed standards" are values taken from the

[10] Information provided by Dr Davoren in an email message 6 February 2009.
[11] An 80% application efficiency irrigation whenever soil moisture fell to 50% of available water holding capacity.

stepped line which 'envelopes' all but one "outlier" value of Total Seasonal Demand. These values, and values similarly displayed as Total Seasonal Demand results in Figure 4.2 of Davoren and Scott (2005) for arable crops, are what have been incorporated in Table WQN24 of Schedule WQN9.

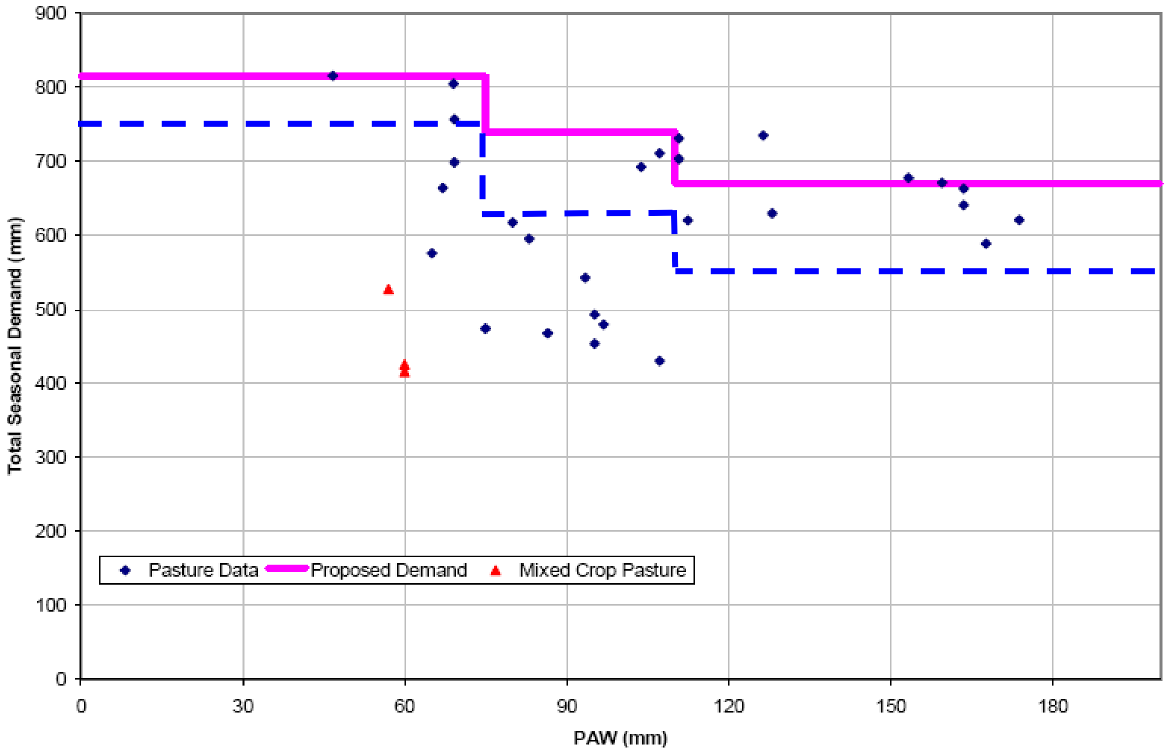

Figure 2. Proposed seasonal allowance for intensive pasture superimposed on the estimated total seasonal demand exceeded only 20% of the time [Figure 4.1 from Davoren and Scott (2005)]. The dashed line is for arable crops [from their Figure 4.3].

Table 4.1. Profile Available Water and proposed Total Seasonal Demand for Arable and Intensive Pasture land use activities [Davoren and Scott (2005)].

PAW	Total Seasonal Demand, mm	
	Intensive Pasture	Arable Crops
< 75mm	815	750
75-110mm	750	625
> 110mm	670	550

4.3 Derived Effective Rainfall Values

Step 2 of Schedule WQN9 uses map values of "effective irrigation season rainfall". The Variation 2 values have been derived from NIWA values of 1972-2003 daily rainfall on a 0.05 degree latitude/longitude grid[12]. Daily values over 5 mm, increased by a "10% ground level correction" to allow for under-catching by standard raingauges, were accumulated for each of the 1972-73 to 2002-03 1 October to 30 April seasons, provided rainfall on two consecutive days was less than 50 mm. If rainfall on two consecutive days was greater than 50 mm, any rainfall after the first day was considered to be excess to the PAW and was omitted from the accumulation. The 6th-lowest of the 31 ranked seasonal

[12] Supplied to David Scott of ECan and referred to in Appendix 1 of his report on land-based recharge, Scott (2004).

values was taken to approximate the 80%ile effective rainfall [only 1 year in 5 lower] at each grid point. These grid values were then used to generate the effective rainfall contours presented in Figure WQN12 of the Schedule.

4.4 Seasonal Irrigation Demands Other Than Standard

There is provision under Rule WQN26 for discretionary activities for a seasonal irrigation volume which exceeds the standard to be sought when circumstances are such as to make the Schedule WQN9 standards inappropriate. It is therefore useful to consider how the methods used to determine the values contained in the Schedule WQN9 method might be used for such a purpose.

The way in which effective rainfall has been calculated for Figure WQN12 means that it is independent of irrigation application method and efficiency, but tied to a particular reliability [80%]. The way in which the seasonal irrigation volumes have been calculated [before being converted to an enveloped maximum] means that a similar method could be used with 'adjustment' [see Section 4.2] to application efficiency other than 80%.

5.0 Aqualinc Method

5.1 The Method Itself

Application of the method to provide estimates of the seasonal irrigation demand standard for the intended land use is a 2-step procedure. It is similar to that described in Section 4.1 for the Schedule WQN9 method, but does not involve a separately estimated effective rainfall.

1. find the seasonal irrigation demand standard for the particular land use and soil type(s) (PAW class);
2. compare this seasonal irrigation demand standard with the water depth equivalent to the volume applied for.

The seasonal irrigation demand standard values are different from those for the Schedule WQN9 method described in Section 4.1 [see Section 6.2.3].

5.2 Derived Seasonal Irrigation Volume Standards

The current implementation of the Aqualinc method is based on a daily time step water balance computer model ['Irricalc'] and validated against data measured at a site[13] with lysimeter measurements of SW, R, I and D. To provide seasonal irrigation demand [and therefore standards] for various soil types and irrigation management, it requires potential evapotranspiration [PET] and irrigation application uniformity as additional inputs. AET is derived from PET using calibrated crop factors $CF = \frac{AET}{PET}$. PET was calculated using the FAO Penman-Monteith method (Allen et al. 1998); values provided by NIWA for the Lincoln Climate Station [H32641] were used for a calibration period 1 July 1999 to 30 June 2001.

'Irricalc' is based on an equation equivalent to Equation (2), in the form:

[13] An Environment Canterbury lysimeter site on J Donkers' property near Dunsandel, stated to be representative of irrigated intensive pastoral farms in Canterbury.

$$SW_{end} = SW_{start} + R + I - D - AET$$

in which AET = CF x PET. During the calibration period, measurements were available[14] of all variables except CF. A time series of CF values was derived and simplified to monthly values as in Figure 3.

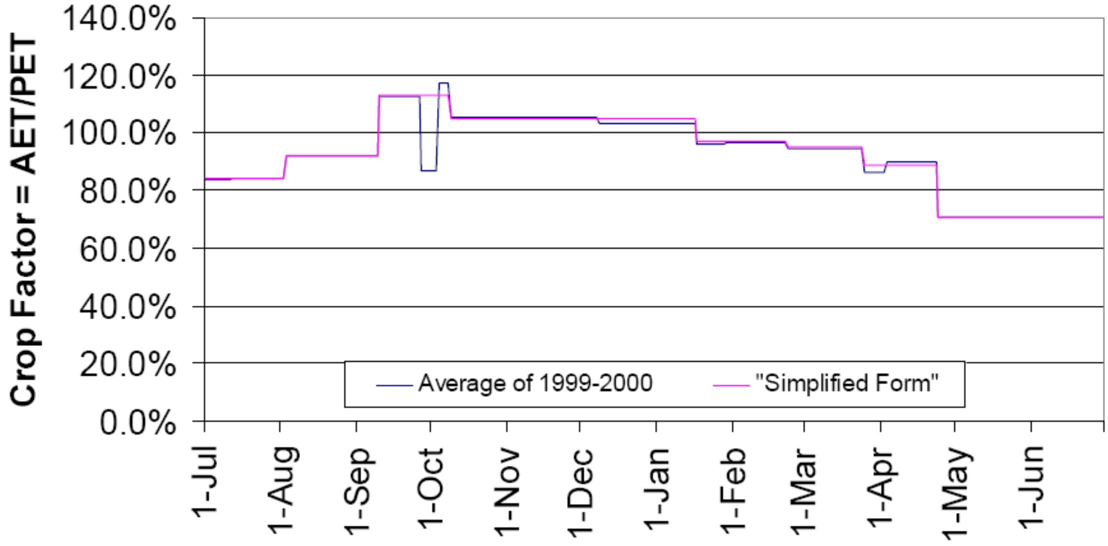

Figure 3. Crop Factor for Pasture [Figure 1 from Bright (2008)].

The calculations were verified[15] by running the model in time-step mode for the calibration period with the calibrated crop factors and in the form:

$$D = SW_{start} - SW_{end} + R + I - AET$$

It was then validated[16] by running it with all data except drainage, for a different period [1998/99] than the calibration period, and comparing the results with measured drainage from the lysimeter.

Total Seasonal Irrigation Demands are given in Tables 5.1 to 5.3 for different irrigation managements:

i. Average "application efficiency" approximately 80%
ii. Simulated "Rotorainer" operation
iii. Simulated centre pivot and lateral move irrigators

5.3 Derived Effective Rainfall Values

The method does not require effective rainfall as an input. (R – D) would be available from the computation if required. This (R – D) contains effects of both application non-uniformity or over-watering from the application device and inopportunely timed rainfall. ($R - D_R$) as in Equation (2a) is more correctly termed "effective rainfall". It could be made available from the computations if time series of I and R are available in addition to D.

[14] Lysimeter measurements do not distinguish between R and I; the combined time series was separated into its two components [by Dr Tony Davoren] using knowledge of the timing of irrigation and rainfall events. AET values are not directly measured; they are the residuals knowing all other values in the equation.
[15] 'Verification' merely checks that the code does not contain mistakes.
[16] 'Validation' checks that the model reproduces 'reality' to an acceptable degree.

5.4 Seasonal Irrigation Demands Other Than Standard

The method used to derive SIDS can be used in the same way for different irrigation management and application efficiencies. It is not dependent on having a separately specified effective rainfall, as drainage is estimated during the procedure. As part of the model outside the computation routine, application efficiency is calculated as $\frac{I-D}{I}$. This "application efficiency" thus includes effects of both application non-uniformity or over-watering from the application device and inopportunely timed rainfall. It is the same as recommended in McIndoe (2002) and is equivalent to my Distribution Pattern Efficiency [see Section 3.4].

Table 5.1 Table 1 from Bright (2008)

Irrigator Set One: Application depth adjusted to achieve average application efficiency of 80%

Table 1: Seasonal irrigation water use and AET for soils with 60 mm, 80 mm, and 120 mm plant available water levels

Rainfall station	Soil PAW	Application depth	Return period	Average Application Efficiency	Seasonal irrigation water use			Actual ET		
					80 percentile	90 percentile	Average	80 percentile	90 percentile	Average
Lincoln	60	40.5	8	80.1	729	770	613	813	854	769
	80	53	10	79.5	689	742	591	815	857	771
	120	78	15	79.9	702	741	557	815	858	771
TePirita	60	40	8	79.6	680	720	601	826	857	781
	80	52.5	10	79.9	683	735	580	829	859	783
	120	77	15	80.4	678	693	531	832	860	783
Hororata	60	39.5	8	79.8	592	632	507	814	855	770
	80	52	10	80.2	572	624	469	816	859	771
	120	77	15	80.1	539	539	426	816	859	772

Table 5.2 Table 2 from Bright (2008)

Irrigator Set Two: Irrigation Setup to Simulate Rotorainer Operation

Table 2: Seasonal irrigation water use and AET for soils with 60 mm, 80 mm, and 120 mm plant available water levels

Rainfall station	Soil PAW (mm)	Application depth (mm)	Return period (days)	Soil moisture trigger point (%)	Application Efficiency (%)	Seasonal irrigation water use (mm)			Actual ET (mm)		
						80 percentile	90 percentile	Average	80 percentile	90 percentile	Average
Lincoln	60	50	10	50	68.5	850	875	705	809	844	764
	80	55	11	50	77.8	715	770	606	814	854	770
	120	60	12	62	80.3	720	720	579	818	861	773
TePirita	60	50	10	50	67.4	800	850	697	820	854	777
	80	55	11	50	77.1	715	737	599	827	858	782
	120	60	12	62	79.7	708	720	576	834	862	785
Hororata	60	50	10	50	65.9	700	750	603	813	850	767
	80	55	11	50	76.9	605	660	491	815	857	771
	120	60	12	61.5	80.4	540	600	450	818	862	773

Table 5.3 Table 3 from Bright (2008)
Irrigator Set Three: Irrigator Setup to Simulate Centre Pivot and Lateral Move Irrigators

Table 3: Seasonal irrigation water use and AET under a centre pivot or lateral move irrigation system

Rainfall station	Soil PAW (mm)	Application depth (mm)	Return period (days)	Application Efficiency (%)	Seasonal irrigation water use (mm)			Actual ET (mm)		
					80 percentile	90 percentile	Average	80 percentile	90 percentile	Average
TePirita	60	16	3	98.5	570	598	481	832	861	784
TePirita	60	21	4	97.3	584	617	501	832	862	784
TePirita	60	26	5	92.3	624	660	545	832	862	784

6.0 Comparison and Discussion

"All models are wrong, but some are useful." George Box, Empirical Model-Building and Response Surfaces [co-author Norman Draper], 1987

"All useful models are equal, but some are more equal than others." George Orwell, Animal Farm, 1984 [adapted]

6.1 Scientific Defensibility

The basic principle underlying both methods is 'conservation of volume'. Both use measured values in a time series moisture budget as one aspect of validation: the Schedule WQN9 method uses measured rainfall and irrigation and monitored soil moisture measurements at a number of irrigation sites on the Canterbury Plains; the Aqualinc method uses lysimeter measurements at one site near Dunsandel. Both intend to estimate total seasonal irrigation water demand for an 80%ile [only 1 year in 5 exceeds] year of high demand. Both make estimates available for either pasture or arable crops and for a variety of soil conditions. Both take account of the contribution of effective rainfall in determining the total seasonal irrigation demand. But there are important differences in the scientific defensibility of the ways the two methods do this.

6.1.1 Schedule WQN9 Method

The Schedule WQN9 method accumulates an estimate of total seasonal demand in a form equivalent to Equation (2b). However, it does so first for a particular year of data [1998/99], originally thought to represent approximately 80%ile [exceeded only 1 year in 5] high demand at all sites. Because this was later found to be not so, corrections were made increasing 1998/99 demand values by between 5% and 37% using a separate water budget, climate values on a 1 km square grid and assumed irrigation of "application efficiency" 80% whenever soil moisture deficits reached 50% of available water holding capacity. A first point is that it is not clear to me that these corrections do result in 80%ile values of demand at the measurement sites; a second point is that 'corrections' up to 37% are very large; a third point is that this is a different 'effective rainfall' from that mapped in Figure WQN12.

The effective rainfall mapped in Figure WQN12 is calculated using NIWA-derived daily rainfall on a 0.05 degree latitude/longitude grid and the 1951-1980 mean annual rainfall surface. The computational procedure accumulates daily rainfall depths if they are over 5 mm, and if there is less than 50 mm accumulated on consecutive days. Amounts less than 5 mm are apparently considered unlikely to reach the crop root zone [being evaporated from plant and soil surfaces]. Whether or not large daily rainfall depths are 'effective', and how much is stored, depends on soil water storage available at the time they occur. So this method makes a reasonable assumption, but not one as accurate as can be determined from the kind of measurements made by a lysimeter and employed in the Aqualinc method.

In the Schedule WQN9 method effective irrigation was adjusted "to allow for a uniform irrigation application efficiency" of 80%, as described in Section 4.2. Some "approximation" is introduced in this process. For arable crop values, a procedure was used to "weight" the demand values to be appropriate for a "representative crop rotation". I am not aware how this relates to the many actual rotations put in place by arable farmers on the Canterbury Plains. The totals were also 'adjusted' for season length other than the 'standard' season from 1 October to 30 April inclusive. Plant available water PAW was determined from "freely available water" by multiplicative and additive factors chosen for three soil and stoniness conditions. The reason for the particular numerical values used is not clear to me but there is an element of arbitrary choice, although no doubt based on field experience[17].

The overall effect of the various corrections and adjustments is to introduce unknown amounts of error in relation to a complete water balance following an equation like Equation (2b) to determine total seasonal demand. The final process deserving comment is the choice of constant demand values according to three soil PAW classes for each of intensive pasture and arable, as in Figure 2. It is clear from Figure 2 that not all computed values of Total Seasonal Demand are as high as the proposed standard values. So if the method is robust, there must be other factors not taken into account. Placing an 'envelope curve' on data to indicate possible extreme values has been used in a variety of situations, including in climatology and meteorology. An example of a valid application is that used in the process of estimating 'Probable Maximum Precipitation' in Tomlinson and Thompson (1995). But the placing of the "Proposed Seasonal Allowance" lines on Figure 2 poses more questions than it answers:

i. If all of the data points are for 80%ile demand with 80% application efficiency, what factor(s) lead to them having a vertical range for any PAW?
ii. If all of the data points are for 80%ile demand, what probability of occurrence does the envelope line represent?
iii. On what basis is the division into PAW classes made?
iv. Why is it considered valid to call the 126 mm PAW, 715 mm demand point an "outlier" (Davoren and Scott 2005) rather than to include it in an 'envelope' for a class 75 < PAW < 130?
v. Why are there the same PAW classes for arable as for intensive pasture?
vi. Why are the allowances for arable a lower percentage of intensive pasture allowances for the two higher PAW classes than for the lowest?
vii. Given the paucity of arable data points, and point ii above, how are the envelope lines for arable decided?

Overall, I am not convinced that these particular envelope lines do represent appropriate 80%ile total seasonal demand standards. In particular, it would not surprise me to find that data gathered from other farms of different irrigation management, analysed in the same manner as those illustrated in Figure 2, lead to some data points above these lines.

6.1.2 Aqualinc Method

The Aqualinc method stays quite close to its underlying Equation (2), with very few adjustments or corrections, and employs 'best practice' where there is a departure from measured values. It is limited by having monthly "crop factors" calibrated at one intensive irrigated pasture site and because the "crop factors" themselves involve simplification of reality.

Non-weighing[18] lysimeter measurements of soil water, rainfall and irrigation inputs and drainage are potentially subject to various measurement errors: edge effects, 'oasis' effects, unrepresentative macropore flows, unrepresentative 'crop' parameters and unrepresentative vertical soil profiles. Nonetheless, they represent 'best practice' for field water balance measurements and measures can be taken to minimise all of these errors. Obtaining AET as the residuals in Equation (2) with all other variables measured is standard practice. The error in AET estimates is thus affected by errors in all the measured values.

[17] Of Dr Davoren, presumably.
[18] Weighing lysimeters can also directly measure average soil water content and actual evaporation.

PET values were imported from NIWA climate data for the Lincoln Climate Station [H32461]. These values are calculated using the FAO Penman-Monteith method (Allen et al. 1998). These are also 'best practice' for the purpose. The use of the ratio of AET to PET as a 'crop factor' has some limitations: it is not generally a simple constant and it is not simple to measure by lysimetry for tall, deep-rooting or row crops. As used here for intensive irrigated pasture, where soil moisture does not fall to low levels, it can also be regarded as 'best practice'.

6.2 Appropriateness of Data and Use Requirements

6.2.1 Schedule WQN9 Method

The method for determining SIDS requires only a knowledge of site location, land use [intensive pasture or arable] and soil category or Profile Available Water. It is therefore simple and appropriate to use. The actual values in Table WQN24 and Figure WQN12 have been derived in ways which have been criticised in Section 6.1.1 and the actual values are therefore effectively also criticised. In particular, the enveloping process leading to the numerical standards of seasonal demand chosen does not convince me that these are indeed 80%ile values. Further, there seems little justification for the numerical values chosen for arable seasonal demand standards, based on the information in Figure 2.

6.2.2 Aqualinc Method

As for the Schedule WQN9 method, the procedure for determining SIDS requires only knowledge of site location, land use [intensive pasture or arable] and soil category or Profile Available Water. It is therefore simple and appropriate to use. The lack of locally calibrated crop factors for other than intensive pasture land use is a deficiency, not of the method, but of current data availability. The values in Tables 5.1 to 5.3 above apply for irrigated intensive pasture at the three named sites and for the specified irrigation management.

6.2.3 Schedule WQN9 and Aqualinc SIDS Compared

A direct comparison of Table WQN24 and corresponding Aqualinc values is not possible with the data I currently have. Values from Table 5.1 [approximately 80% Application Efficiency] for 80%ile reliability and PAW = 60, 80, 120 mm can be used to give a general comparison. Effective Rainfall from Figure WQN12 has been estimated to allow the comparison in Table 4[19]. The magnitudes of these differences are high enough to suggest that either the two methods are not estimating the same quantity or at least one of them is giving incorrect values.

[19] The WQN9 values of Seasonal Irrigation Demand Standard differ for the two higher PAW classes from higher values ['Version 3'] suggested at a December 2008 ECan workshop. The higher values remain less than Aqualinc values.

Table 4: Seasonal Irrigation Demand Standards for 80% Application Efficiency and Intensive Pasture.

Site	PAW WQN9	PAW Aqualinc	R-D_R WQN9	SIDS WQN9	SIDS Aqualinc	Aqualinc % greater
Lincoln	< 75	60	190	625	729	17
	75 - 110	80	190	560	689	23
	> 110	120	190	480	702	46
Te Pirita	< 75	60	250	565	680	20
	75 - 110	80	250	500	683	37
	> 110	120	250	420	678	61
Hororata	< 75	60	300	515	592	15
	75 - 110	80	300	450	572	27
	> 110	120	300	370	539	46

6.3 Fitness for Purpose

There is a possible point of view that the SIDS in Schedule WQN9 are an administratively convenient means of dividing activities into 'consented' and 'discretionary' and for that purpose it is not particularly important how they were derived or how accurately they represent real demands of a fixed probability. For at least two reasons that is not an appropriate point of view for ECan to hold:

i. Such standards need to be scientifically and legally justifiable.
ii. There needs to be equity between consent holders obtaining consents under the two different activity categories.

The two methods are similarly simple to apply for determining the seasonal irrigation demand standard and comparing it with a seasonal volume application. To that extent, they are both fit for purpose.

The WQN9 method closely matches policy requirements. This is not surprising as the method was developed by and for ECan as part of preparation of Chapter 5 of the pNRRP. Thus it has 80% 'application efficiency' built in to it, as specified in Policy WQN17 (2) (b). Likewise, it uses 80%ile total seasonal irrigation demand as the reliability of supply criterion, as is used in other parts of the pNNRP Chapter 5.

The Aqualinc method is capable of providing 80%ile total seasonal irrigation demand as the reliability of supply criterion, and of approximating 80% 'application efficiency', but these are not built in to the method.

6.4 Applicability in Various Resource, Irrigation System and Management Contexts

If there is a need to apply a procedure similar to that used in the derivation of the standards, e.g. to examine the merits of an application [as a discretionary activity] where the seasonal irrigation volume falls outside the standard, it is desirable that such a procedure should be consistent with that used to derive the standards. The Schedule WQN9 method involves a number of 'approximations' and 'adjustments' [see Section 6.1.1], some of which appear to have a level of subjectivity, if not arbitrariness. As already noted, it is not obvious to me that it does produce 80%ile seasonal demand estimates without the enveloping process used to produce demand standards. These difficulties make it an unsatisfactory candidate for use as envisaged here.

The Aqualinc method is applicable at any site for which PET and rainfall estimates are available, together with the necessary soil, crop and irrigation management information. At present, its use is limited by the lack of validated crop factors, especially for arable crops, and under other than optimal agronomic and soil conditions.

6.5 Applicability in the Context of RDR Schemes

The RDR irrigation schemes have a combination of attributes making them unique in New Zealand. Some of these are:

- They have been in place for more than 70 years
- They have many resource contents which pre-date[20] the RMA (1991)
- They are the largest combined area, with about 64 000 hectares irrigated
- They are the largest border-dyked area
- They have the highest surface take from one river source
- There is a marked contrast in application efficiency between older border-dyked and newer centre-pivot application methods

As explained in Section 6.4, the Schedule WQN9 method has a number of difficulties which make it an unsatisfactory candidate for use in contexts other than that for which it was put forward. Those difficulties remain when it is considered for use in the context of RDR schemes. In other words, the main reason that the Schedule WQN9 method is less satisfactory than the Aqualinc method for use in this context is that the limitations described in Section 6.2 also apply to its use in the context of RDR schemes.

The only attribute listed above which is directly related to the current comparison is the last. A second reason that the Aqualinc method is more suitable than the Schedule WQN9 method for use in the context of RDR schemes is that the former can more accurately assess seasonal irrigation demands[21] for application systems of different application efficiency. This might well be a two-edged sword if it is used to highlight the additional water required to satisfy crop needs when application systems of low application efficiency are used. It both provides an incentive to move, over time, to more efficient systems and draws attention to the low application efficiency of existing border-dyke application.

Should Chapter 5 of the pNRRP be revised such that Schedule WQN9 takes account of losses of water between the take and the application devices,[22] the RDR schemes could be subjected to scrutiny concerning infiltration losses from main and distribution races. This is a significant point, but not one which directly involves a comparison of the present Schedule WQN9 and Aqualinc methods.

[20] In their original form.
[21] Note ‘demands’, not ‘demand standards’.
[22] e.g. by adopting a definition like my Equation (4).

7.0 Conclusions

The questions in the 'Work Brief' were quite specific; I provide specific conclusions in Section 7.1. Some other matters arising have been discussed and seem relevant to the overall task set; conclusions related to these are in Section 7.2. Neither method reviewed is yet in a form which can be regarded as 'final' [see the Introduction in Section 1]. This comparative review has been based on available information related to Schedule WQN9 Variation 2, with comment on subsequent changes as appropriate, and on available information on the Aqualinc method as at December 2008.

7.1 Work Brief Conclusions

1. Both methods are based on forms of 'conservation of volume' equations which are appropriate to the purpose.
2. Both methods make use of appropriate field measurements of water balance components.
3. The two methods differ markedly in the assumptions and approximations incorporated, the computational procedures employed and the seasonal irrigation demands they arrive at.
4. The Aqualinc method has the more robust methodology relative to scientific defensibility and the appropriateness of data and use requirements.
5. The Aqualinc method can be criticised for requiring data for calibration and validation that are not widely or locally available, such as lysimeter data for arable crops.
6. The Schedule WQN9 method more closely matches policy in the pNNRP than does the Aqualinc method.
7. The Schedule WQN9 method has too many approximations, adjustments and corrections to allow confidence in the values it provides.
8. The Aqualinc method is more appropriate for use in relation to the Rangitata Diversion Race schemes.

7.2 Related Conclusions

1. Both Schedule WQN9 and Chapter 5 Variation 2 more generally refer to "Application Efficiency" defined in a manner at variance with more conventional use.
2. The use of 80 %ile reliability of seasonal irrigation demand in connection with the Schedule WQN9 method has not been adequately justified in the relevant parts of Chapter 5 of the pNNRP[23].
3. Should Chapter 5 of the pNRRP be revised such that Schedule WQN9 takes account of losses of water between the take and the application devices, the RDR schemes could be subjected to scrutiny concerning infiltration losses from main and distribution races.

[23] It has not been part of my task to explore this fully. I note previous work such as Robb and McIndoe (2001), but I also note the concerns raised at Hearing 14 by submitter, AW Macfarlane.

7.0 References

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8.0 Appendices

Appendix 9.1 Documents Consulted [additional to References]

Title	ID	Date
Schedule WQN9 Revision [Review of Seasonal Use Approach]	U05/15/1	Nov-05
Variation 2 Proposed Canterbury Natural Resources Regional Plan Chapter 5 Water Quantity [including S32 Report]	R05/24	26-Nov-05
NRRP Hearing stage 14 OFFICER REPORT No. 14 Chapter 5 WQN8		Jul-07
Statement of Evidence of Will Nixon to Hearing 14		19-Oct-07
Brief of Evidence of Andy Macfarlane to Hearing 14		23-Oct-07
Brief of Evidence of John Bright to Hearing 14		2-Nov-07
Submission of Terry Heiler to Hearing 14		2-Nov-07
Appendices I-V to Response to the Minute		31-Mar-08
Response to the Minute from the NRRP Hearing Committee re Hearing Stage 14		31-Mar-08
Notes prepared for workshop on technical methods for estimating seasonal allocations …		18-Jun-08
A Way forward for the WQN9 [B Jenkins]		23-Jun-08
Additional Annual Demand Analysis by A Davoren [PowerPoint]		Dec-08
Outcomes of WQN9 Workshop [B Jenkins]		5-Dec-08
WQN9 Presentation by J Bright [PowerPoint]		5-Dec-08
Determination of Seasonal Irrigation Volumes … [Project Brief from ARL for INZ]		18-Dec-08
WQN9 Project - Scheme Acreage - Canterbury Province		13-Jan-09
Additional work briefs for John Bright and Tony Davoren		
Peer Review by Assoc Prof Hector Malano [of the Aqualinc model]		

Appendix 9.2 Policy WQN17

Policy WQN17 Reasonable and efficient use of water

(1) Ensure that the instantaneous rate of abstraction, the return period and the annual volume of water permits for taking, using or diverting water are no more than reasonable for the intended end use, and thereby avoid significant wastage of water and avoid or limit the adverse effect on water quality (See also to Policy WQL9 and WQL12).

(2) When assessing water permit applications for irrigation (new or replacement) in terms of (1) above, the instantaneous rate of abstraction, the return period and the seasonal volume of the proposal to take, divert or use water will be required to meet a reasonable use test, including:

(a) consideration of on-site physical factors such as soil water-holding capacity, climatic factors such as rainfall variability and potential evapotranspiration and land use activity; and

(b) assume that there is an irrigation application efficiency of at least 80% even if the actual system being used has a lower application efficiency. Where the water permit application is for an irrigation system with a higher application efficiency, the higher figure will be used.

(3) Further to Policy WQN17(2) above, provide for the use of water for irrigation to be:

(a) a permitted activity where the seasonal irrigation demand standards in Schedule WQN9 are met for seasonal irrigation use; and

(b) a discretionary activity where the seasonal irrigation demand standards in Schedule WQN9 are not met, provided that exception shall only be made:

(i) where it can be demonstrated that the demand conditions are different to those mapped on the Proposed NRRP Map Volume Part 1 Planning Maps, due to micro-climatic or other variations; or

(ii) for a lower efficiency level or a greater seasonal volume where mitigating circumstances are clearly demonstrated. These circumstances may include beneficial effects such as energy savings or prevention of wind erosion that would not be achieved otherwise, or recharge to groundwater, surface water or wetlands. There should be a demonstrable long-term community benefit from the proposal consistent with Objective WQN4(1). Where a long-term community benefit cannot be demonstrated, a programme of staged improvement may be considered as mitigation.

(4) For existing users, ensure that the water allocation specified on the water permit reflects the actual quantity needed to undertake the land use activity. Review the conditions of water permits where necessary when an allocation regime becomes operative under Schedule WQN1 or Schedule WQN3 as per Policy WQN14(11) or where monitoring indicates that they have been allocated more than is needed and have actually used.

(5) In addition to requiring the measuring and recording of water that is taken in accordance with Policy WQN16, encourage irrigators to monitor their water application rates, soil moisture, and production as a method for achieving more efficient use of irrigation water.

(6) Develop guidelines in conjunction with water users, other agencies and the community for cost-effective improvements in water efficiency and conservation, and promote these across the region.

(7) Promote the use of water audits for agricultural, industrial, hydro electricity and community water supply activities to identify areas for improvements in water use efficiency.

(8) Encourage and, where appropriate, require the progressive upgrade and piping of stock water races where there is an environmental or economic benefit for so doing, but recognise that some stockwater races may provide important habitats for indigenous species and may justify strategic continuance to protect these. (Refer to Policy WQN14(9)(f)).

(9) Encourage, and where appropriate, require territorial local authorities to take all reasonable steps to progressively upgrade those reticulated supply systems where there is a significant amount of leakage.

(10) Encourage owners and managers of irrigation schemes to minimise water losses through the beds of irrigation canals.