BEFORE INDEPENDENT HEARING COMMISSIONERS APPOINTED BY THE CANTERBURY REGIONAL COUNCIL

IN THE MATTER OF	The Resource Management Act 1991
AND	
IN THE MATTER OF	Submissions and further submissions by Irrigation New Zealand on Proposed Plan Change 5 to the Canterbury Land and Water Regional Plan

STATEMENT OF EVIDENCE OF IAN MCINDOE

22 JULY 2016

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STATEMENT OF EVIDENCE OF IAN MCINDOE

Introduction

1 My name is Ian McIndoe.

2 I am a Soil and Water Engineer, currently employed as Managing Director of Aqualinc Research Ltd.

3 Irrigation New Zealand (**INZ**) has asked me to provide evidence in respect of its submission on Plan Change 5 (**PC5**) to the Canterbury Land and Water Regional Plan (**LWRP**).

4 My evidence relates to Schedule 28 of PC5 and the rule for "Irrigation and water use" (**Irrigation Rule**).

Qualifications and Experience

5 I hold the qualifications of BE (Hons) from Canterbury University and Dip Bus Stud (Finance) from Massey University. I am a member of the New Zealand Hydrological Society. I was on the Board of Irrigation NZ for 16 years, retiring in October 2015.

6 I have nearly 40 years' experience in water resources, hydrology and irrigation related work. I have specialised in water allocation for irrigation, irrigation reliability, irrigation efficiency and irrigation design.

7 I have presented on these matters at many field days, workshops, conferences, resource consent hearings, plan change hearings, and in the Environment Court. That includes evidence presented at the LWRP Variation 1 and Variation 2 hearings.

8 I have read the code of conduct for expert witnesses in the Environment Court Practice Note 2014, and confirm that I have complied with the code in the preparation of my evidence. I will comply with that code when giving this evidence.

Scope of Evidence

9 In my evidence I:-

9.1 Discuss the proposed Irrigation Rule and what it assumes should happen in practical terms;

9.2 Discuss whether the Irrigation Rule is practicable with reference to what farmers are currently doing and what they can do;

9.3 Consider whether the Irrigation Rule represents industry agreed Good Management Practice (**GMP**);

9.4 Suggest an alternative to the Irrigation Rule and discuss why I consider it represents GMP;

9.5 Evaluate the effect of the alternative I suggest;

9.6 Discuss why the Farm Portal will not reflect GMP losses in every case, even if the Irrigation Rule is amended as I suggest; and

9.7 Respond to relevant aspects of the s42A Report.

The proposed Irrigation Rule

10 The proposed Irrigation Rule is attached as **Appendix A** for ease of reference.

11 Details of how OVERSEER treats irrigation are given in the evidence of *Nicole Phillips*. Essentially, OVERSEER is a single bucket soil water balance model that takes into account different climate effects and soil properties. It offers a range of irrigation options to the user, including different irrigation methods and management options.

12 OVERSEER has a number of default application depths and return periods for all irrigation system types that can be used if detailed information on actual operation is not available.

13 A further input into the OVERSEER soil water balance model is an allowance for distribution system and evaporative losses, which

account for irrigation water lost between the water source and the soil. This is normally in the range of 3-5% of the water delivered.

14 No other efficiency factors are applied. It means that all water that reaches the soil is stored in the soil if the application depth is less than or equal to the soil moisture deficit in the soil. It means that no drainage below the root zone occurs whenever the soil moisture after an irrigation event does not exceed field capacity.

15 If water is applied at a depth that exceeds the soil moisture deficit, then OVERSEER assumes that water drains below the root zone of the crop. The overall water lost in that situation can be calculated by adding together the 3-5% lost in distribution and the percentage of applied water draining below the root-zone.

16 The Farm Portal uses similar logic to the OVERSEER model, except that it overrides the parameters entered into OVERSEER and restricts them to what it considers to be GMP, regardless of what has been entered into the OVERSEER software. *Nicole Phillips* has explained the difference between OVERSEER and the Farm Portal.

17 As I understand it, for an irrigation event, the Farm Portal subtracts the 3-5% distribution loss from the total application depth and then uses an Irrigation Rule that triggers an irrigation event at a 50% soil moisture deficit and applies a depth of water that brings the soil moisture up to 90% of field capacity.

18 As the soil moisture never reaches field capacity, deficit irrigation always occurs. The practical effect of the Rule is that after subtracting the 3-5% loss, the application of water is 100% efficient. That is, it defines GMP as meaning there is no drainage arising from the application of irrigation water.

Practicable irrigation efficiencies

What is irrigation efficiency?

19 Before I discuss practical irrigation efficiencies, I will explain what I believe irrigation efficiency to mean in the context of the irrigation rules and the Farm Portal.

20 Irrigation efficiency is a very poorly-understood concept. There is little understanding of how irrigation efficiency is defined and measured. For example, different regional councils confuse terms such as irrigation system efficiency with irrigation application efficiency.

21 In a previous study that I was involved in (Edkins and McIndoe, 2006)[1], over 30 definitions of irrigation efficiency were identified. We concluded:

> *"in terms of gaps in knowledge, a significant amount about current irrigation practices and measures required to improve irrigation efficiency exists, but has not been well transferred to the general public or practitioners in the field. The biggest gap therefore, was communicating the knowledge to stakeholders."*

22 I was the key author in an INZ initiated project to remove the confusion and uncertainty surrounding irrigation efficiency, leading to a nationally consistent approach. The main issues raised were: what is irrigation efficiency?, why is it useful?, what irrigation definitions are recommended and how should they be used? This work was summarised in a report, which was completed in May 2011, entitled "What is irrigation efficiency?"[2].

23 Key factors relating to irrigation efficiency are:

23.1 It needs to be applied to an area with defined boundaries, - an irrigation run, paddock, farm, district or region.

23.2 The time frame must be stated – single irrigation event, day, month or season.

23.3 It must consider beneficial use of the water.

23.4 It needs to take into account soil water storage and rainfall.

23.5 It should consider all uses.

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[1] Edkins, R., McIndoe, I. (2006). "Irrigation efficiency gaps – review and stock take."
Report prepared by Aqualinc Research Ltd for Irrigation New Zealand. February 2006. http://www.maf.govt.nz/sff/whats-on/irrigation-efficiency-gaps.pdf.

[2] McIndoe, I. (2011). What is irrigation efficiency? Report No C10043/1 prepared for Irrigation New Zealand/ MPI Sustainable farming Fund, May 2011.

24 A key finding from the study was that there is no single definition that adequately covers all aspects of irrigation efficiency. However, by considering irrigation efficiency in terms of stakeholder need, several key definitions were identified as suitable for use by the various stakeholder groups.

25 My understanding is that the definition Canterbury Regional Council uses is irrigation application efficiency, which is defined as follows.

$$\textit{Irrigation Application Efficiency} = \frac{\textit{Water stored in crop root-zone}}{\textit{Water delivered to irrigation field}}$$

26 The difficulty with this definition is that while the water delivered to a field can be measured (assuming the timeframe is defined), water stored in the crop root zone is not easily measured. Although several studies have been carried out to determine irrigation application efficiency (they are referenced in the reports I have mentioned), most assessments of efficiency are calculated from water balance models.

27 Irrigation efficiency is treated as an input in most models – e.g. for 80% efficiency, 20% of the water delivered to the field is “lost” and 80% is assumed to be stored in the soil. The 20% lost is assumed to be evaporated in the air, blown off the target field (drift), runs off the target field, or drains beneath the root zone into groundwater. Rarely is the loss partitioned into the loss components, however.

28 In reality, irrigation efficiency is an output. Water “lost” depends on the conditions that exist at the time of each irrigation event. The application efficiency of every irrigation event is different because of variations in soil properties, application depths, trigger levels and the many other factors that affect irrigation.

29 In my experience, I would say about one quarter of the losses occur above the soil surface and three quarters below the soil surface, although these proportions can change significantly depending on the depth of water applied and the conditions at the time of irrigation.

Portal/OVERSEER Efficiency

30 In terms of efficiency, the Portal/OVERSEER is a hybrid of an assumed value and a calculated value. One of the inputs is the assumed “loss” , which is an input, to account for items such as evaporation in the air or wind drift, or distribution losses. Typically, that value is 3-5%.

31 The other component of irrigation efficiency in the Portal/ OVERSEER is drainage, which is simply determined by carrying out a soil water balance. The soil is treated as a bucket. Water applied in excess of the soil moisture storage available in the bucket, whether it is from irrigation or rainfall, is assumed to drain. If the depth of water applied to the soil (after the fixed component has been subtracted from irrigation applications) is less than the soil moisture storage available (the deficit), all of that water is assumed to remain in the soil for plant use.

32 Whenever the soil moisture deficit exceeds the applied water depth, the approach taken by OVERSEER and the Portal results in an efficiency of 100% less the assumed losses.

33 Most of the time, the rules currently used in the Portal will result in zero irrigation drainage. A small amount of drainage from irrigation could occur with travelling irrigators and spraylines but not otherwise.

Efficiency in practice

34 Research into irrigation application efficiency in NZ and internationally shows that the simple approach taken by OVERSEER (and the Farm Portal) fails to account for several factors that impact on efficiency. The key ones include:

34.1 Non-uniform application of water – variations in application depths in space and time.

34.2 Non-uniform soil properties – variation in soil depths, texture and water holding capacity.

34.3 Non-uniform crop characteristics – difference in crop water use resulting in different soil moisture deficits.

34.4 Surface redistribution of water on the soil surface, caused by irrigation application intensities exceeding soil infiltration capacities.

34.5 Less pervious soil pans causing sub-surface redistribution of water, particularly on sloping ground.

34.6 Worm holes and cracks in the soil – macropore flow.

35 These factors mean that while we can measure application efficiency using instruments such as lysimeters, the measurements, because of variability at the field or farm scale, are only relevant to the specific location and conditions at the lysimeter sites. In my view, they are best used to help us calibrate models to better account for the natural variability found at the field or farm scale.

36 Because neither the Portal nor OVERSEER account for these factors yet, they will not have any effect on the difference in outputs between OVERSEER and the Portal. If, however, OVERSEER started to account for them but the Portal did not, there would be difficulty in reconciling the outputs.

37 The studies that have focussed on measuring field irrigation application efficiency show that efficiencies of 100% are the exception, and very difficult to achieve.

38 Typical irrigation application efficiencies are summarised in the following figure:

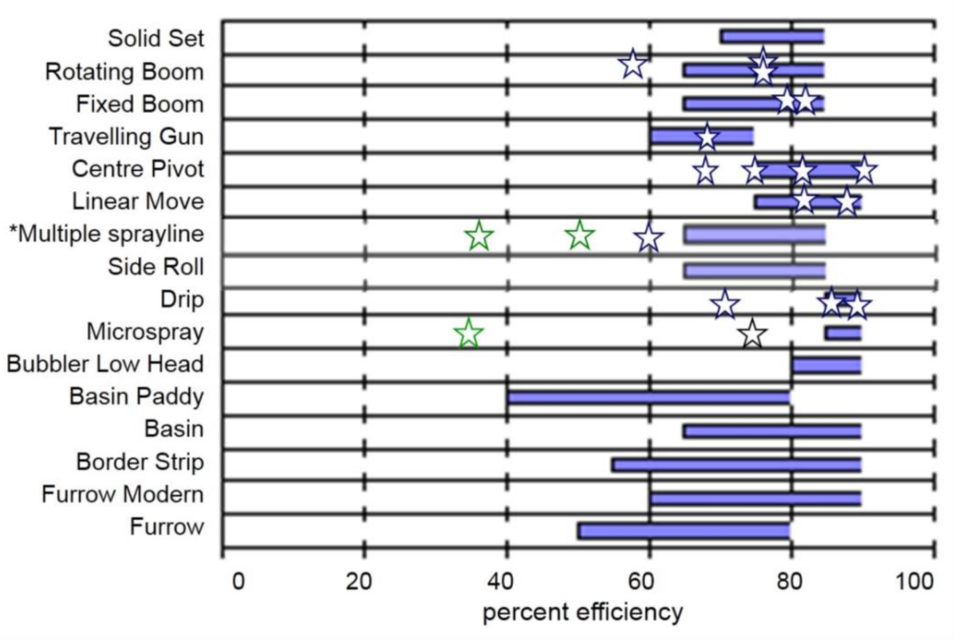

Figure 1: Measured irrigation efficiencies in NZ and the USA

39 The blue bars in Figure 1 are efficiencies measured by Professor Bert Clemmens[3] from Arizona State University. The stars are efficiency calculated from distribution uniformity measurements carried out on irrigation systems in New Zealand by scientist Dan Bloomer (Page Bloomer & Associates).[4] Because the Bloomer measurements are based on application uniformity measurements at ground level, they will overstate application efficiency in terms of what is stored in the soil.

40 Dr Tony Davoren has also determined application efficiencies from irrigation systems managed using specific advice from HydroServices (now a division of Aqualinc). HydroServices provide an irrigation management service to farmers. This information was first reported in McIndoe (2002)[5]. Some of the results are listed below:

[3] Clemmens, AJ (2000): Measuring and improving irrigation performance at the field level. Proceedings of 2000 National Conference and Exhibition, May 2000, Irrigation Association of Australia
[4] McIndoe, I. (2014): Irrigation efficiency today. Presentation to NZ Hydrological Society, Dec 2014.
[5] McIndoe, I. (2002): Natural Resources Regional Plan – Efficient Irrigation. Report No 4521/1 Prepared for Canterbury Regional Council, May 2002.

Table 1: Application efficiencies derived from HydroServices soil moisture monitoring

System type	Number of measurements	Average application efficiency (%)	Efficiency range (%)
Linear move	13	89	80-93
Centre-pivot	7	88	85-94
Side roll	8	90	86-92
Hand shift	2	89	88-91
Soft hose gun	4	89	86-93
Fixed boom (low pressure)	18	80	63-90
Fixed boom (medium pressure)	3	85	79-88
Rotary boom	18	72	48-90

41 Although this work was completed several years ago, it is still relevant. The irrigation methods and irrigation scheduling used by HydroServices were the same then as they are today.

42 Currently, my colleagues and I estimate less than 17% of irrigation management is carried out in New Zealand using reliable irrigation scheduling, either soil moisture monitoring or water budgeting. The same percentage applies in Australia. Most of the farms that are using irrigation scheduling in Canterbury are monitored by HydroServices.

43 My view of the reasons why farmers are not more widely using some sort of irrigation scheduling relate to cost (perceived cost relative to perceived benefits) and the belief that they can do it themselves without the investment.

44 Also impacting on irrigation performance is the standard of irrigation design and installation. The top performers, who are the most likely to be using irrigation scheduling, will have irrigation systems designed and installed according to good practice. Many of these farmers have had their irrigation systems independently audited against the Irrigation New Zealand Standards[6] at the design stage or after installation.

45 My opinion is that the HydroServices results indicate best practice rather than good practice and illustrate the high degree of variability

[6] Irrigation New Zealand Design Code of Practice. Irrigation New Zealand Design Standards (2013)

around the average seen in irrigation application efficiencies. On the basis of this data, best-practice average irrigation efficiencies are in the range of 80-90%, and closer to 90% for systems such as linear moves and centre-pivots.

What level of efficiency does Good Management Practice" require?

46 With respect to irrigation and water use, the *Industry-agreed Good Management Practices (GMP) Relating to Water Quality (18 September 2015) Report* (**GMP document**) describes GMP as:

46.1 Manage the amount and timing of irrigation inputs to meet plant demands and minimise risk of leaching and runoff.

46.2 Design, calibrate and operate irrigation systems to minimise the amount of water needed to meet production objectives.

47 There is nothing in the GMP document about implementing Irrigation Rules as per the Farm Portal or that otherwise describes just how much drainage is "acceptable" in terms of the narrative requirements.

48 Minimise is not defined in the GMP document. Likewise, production objectives are not defined.

49 It appears that PC5 has put an interpretation on this that GMP is about eliminating leaching and runoff (at least according to the application of water within the water balance model), not minimising the risk of it.

50 That being the case, I do not believe the rules reflect GMP. In my opinion the Portal/OVERSEER application efficiencies are almost certainly beyond best practice, let alone good practice. I do not believe that irrigators can practicably achieve the levels of efficiency indicated by OVERSEER/ Portal at a field or farm scale.

51 The Portal effectively decides everyone must deficit irrigate for every irrigation event that takes place, except for a small number of cases with travelling irrigators and spraylines. Although in theory it appears to be the best way to manage irrigation, it is unreasonable to assume everyone should deficit irrigate. That is because of the inability of some irrigation systems to be managed in that way, and because of the risks

involved in always deficit irrigating. I discuss the risk aspect later in my evidence.

52 It is important to understand that the current design and function of irrigation equipment limits the efficiency that can be achieved. Improving irrigation efficiency is not just a matter of improving irrigation management.

53 An application efficiency of 80% is generally regarded as being good practice. It is the figure that is used by most regional councils in New Zealand to allocate water for irrigation. Water is usually allocated on the basis that crop water demand can be met in 9 years out of 10, allowing for 20% of the water allocated to be non-productive.

54 The expectation is that if irrigators operate at higher than 80% efficiency, they will reap the benefits in terms of fully meeting crop water demand in better than 9 out of 10 years. If they operate at lower than 80% efficiency, they will suffer production losses more frequently.

55 The 80% figure most likely came from a report that I prepared for CRC in 2002 (Natural Resources Regional Plan – *Efficient Irrigation*)[7], where I recommended that 80% be used for spray irrigation (Section 7.2). My recommendation was based on a review of the best available information on achievable irrigation efficiencies at that time.

56 Since 2002, there have been some changes in the relative proportions of different equipment types used for irrigation. Wider use is now made of centre-pivots, which provide the potential for better than 80% application efficiency. However, centre-pivots are unsuitable for perhaps 40% of farms, primarily because the circular or semi-circular layout required for pivots does not fit all farms, and alternative methods, with lower efficiency, need to be used.

57 Portable spraylines or moveable sprinklers are commonly used for filling in corners of centre-pivot areas and on other areas. To achieve 80% application efficiency on many of those systems would require best practice performance. It would require shifting systems several

[7] McIndoe, I. (2002): Natural Resources Regional Plan – Efficient Irrigation. Lincoln Environmental Report 4521/1 prepared for Environment Canterbury, May 2002.

times a day to reduce application depths, and specific actions to compensate for poor uniformity. Good practice alone is unlikely to achieve 80% application efficiency in those circumstances.

58 Other systems such as rotary booms, which are still very widely used in Canterbury, also have their limitations. They do not operate well below a given flow rate (wind slows them down), which limits their minimum application depth. However, they have other advantages such as high reliability and minimal ponding and runoff.

59 An argument could be made for not allowing irrigation methods that cannot practically achieve 80% application efficiency (in the field) to be used. While I support that as a longer-term objective, 80% efficiency is probably not being achieved on 25-40% of currently irrigated land in Canterbury (my estimate based on the distribution of different irrigation system types in Canterbury). Part of the reason is due to a lack of irrigation scheduling (which can be addressed) and part due to irrigation system limitations (which is a more challenging problem). Even centre-pivots are not operating at GMP in some cases.

60 The level of efficiency associated with GMP, while taking into account the variability at a field or farm scale, is not easily determined. The best information I have is based on irrigation efficiency modelling, using an Aqualinc in-house irrigation efficiency model. An example of the outputs from the modelling for a 120 mm PAW60 soil based on good practice are given below.

61 This information was presented at the Irrigation NZ Conference in April 2014.

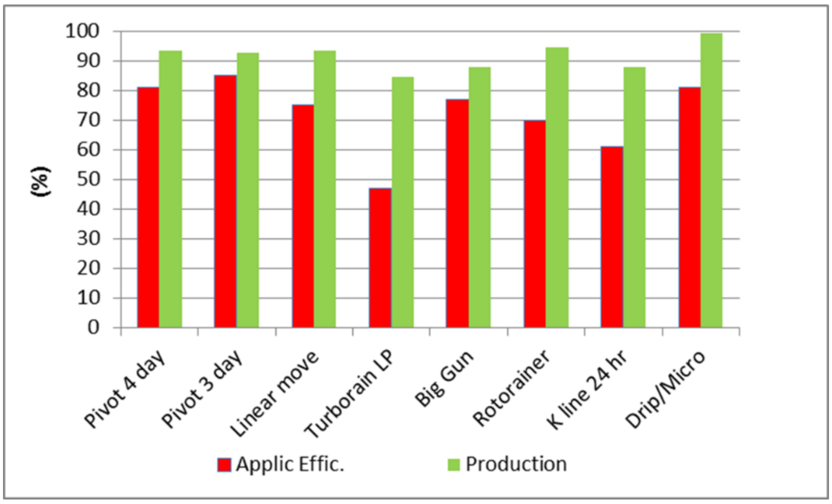

Figure 2: Example of calculated irrigation efficiencies under GMP

62 Achievable efficiency under good practice is very site specific, but we are able to categorise different irrigation methods relative to each other, so we know where in the range they would be expected to operate. We can use that information to inform us about which systems can be used in different circumstances.

Does the Irrigation Rule give effect to the GMP Guidelines or does it go further? How much further?

63 If we accept that deficit irrigation results in no drainage of irrigation water in both OVERSEER and the Farm Portal, then deficit irrigation, at first glance, will achieve the objectives of GMP.

64 Dr Bright's analysis (see Figure 3 below), derived from water balance modelling, shows that as the magnitude of the deficit increases (in his figure, the refill percentage decreases from 100% down to 65%), the amount of drainage and irrigation reduces. This is because, with the lower refill percentages, there is more soil water capacity to store rainfall after irrigation events.

65 The logical conclusion from that is to deficit irrigate as much as possible – irrigate at low trigger percentages and apply small depths of water. While that will meet the first of the industry GMP objectives, it will not meet the second objective for four key reasons:

65.1 Firstly, applying small depths of water, say 5 mm per event, substantially increases the proportion of irrigation water lost to evaporation compared to the water able to be used by crops. That approach is not recommended as efficiency overall is reduced.

65.2 Secondly, because all irrigation methods do not apply water evenly (there is always a degree of variability), and because soil and crop properties also vary, additional water has to be applied to compensate for the unevenness so that adequate irrigation is achieved. Adequate irrigation in this sense is ensuring that 7/8ths of a field receives at least the target depth of water.

65.3 Thirdly, operating at greater deficits exposes the crop to production losses if water supply is restricted or the irrigation system breaks down (as systems often do). There is insufficient buffer in the system to accommodate times when irrigation cannot take place for whatever reason. In reality, triggering irrigation at a 50% deficit in mid-summer is very unwise, and our proposed rules reflect that.

65.4 Finally, irrigation systems are not designed to meet maximum ET demand and crops need to rely on moisture stored in the soil to get through high ET periods, such as several days of NW conditions in a row. The lower the irrigation system capacity is to keep up with high demand periods, the greater exposure to production losses. The practical approach to dealing with situations like this is to initiate irrigation at smaller deficits and refill the profile to field capacity or close to it.

66 Where compromise is needed between minimising drainage and maintaining production, provided that the irrigation system is in good condition and operated using irrigation scheduling, it will be meeting the objectives of the Industry GMP.

67 I understand that OVERSEER can accept irrigation rules that replicate GMP in situations where irrigation operation is constrained by water supply reliability issues or low irrigation system capacity, but the Farm

Portal cannot do that. The Farm Portal rules are fixed and there is no guarantee that the drainage values will match the OVERSEER values.

68 The most likely outcome is that N-loss rates using the Portal will be lower than the rates using OVERSEER.

Alternative Rules

69 I have outlined in **Appendix A** a set of irrigation rules that I consider to be good practice. These rules have been discussed and agreed with Dr John Bright and Dr Tony Davoren as being good practice.

70 The rules take into account the practical realities of operating different types of irrigation systems on a range of soil PAW's. The rules are based on observations of actual irrigation systems on farms, taking into account the practical limitations of each irrigator type.

71 Note that the range of soil and irrigator type combinations is wider than currently including in the OVERSEER options. For example, linear (or lateral) move irrigators are lumped together with centre-pivot irrigators in OVERSEER and the Portal, while my proposed list in **Appendix A** separates them out. Changes of that type are necessary to recognise that linear move irrigators and centre-pivots operate very differently.

72 Some combinations of irrigation system types and soil PAW values, such as movable spraylines on low PAW soils are not included on my list because they do not represent GMP in my view. They have been defaulted to the rules for centre-pivots even though I know those combinations do exist in practice.

73 Because the alternative rules are based on practical operation of irrigation systems under good practice, they are consistent with GMP and the industry agreed objectives outlined in the GMP document. In summary, the Rules end up assuming:

73.1 A travelling irrigator is used on all soils except those with PAW_{60} below 80 mm;

73.2 A pivot is used on soils below 80 mm for travelling irrigators and lateral moves and below 60 mm for spraylines;

73.3 Some of the water applied by a travelling irrigator (rotary boom) to some soils is lost to drainage.

74 I have read page 11 of INZ's submission on PC5. INZ asked the Portal to be "refined" to:

74.1 Assume at least 80% application efficiency (or 20% lost to drainage); or

74.2 Reflect a travelling irrigator scenario (with no less than 80% application efficiency).

75 In my view the alternative rules I suggest are consistent with what INZ asked for because all will achieve 80% application efficiency – that is, no more than 20% of what is applied will be lost to drainage. In some cases, the efficiency is much higher than 80%. If one specific irrigation method is to be used to establish a baseline, it could equally be a travelling irrigator or a sprayline as both represent GMP irrigation in my opinion (if applied in accordance with my **Appendix A**).

76 The benefits of the alternative rules I have proposed are that:

76.1 They are based on good practice.

76.2 They will require a step-up in performance for many irrigation operators.

76.3 They will result in an overall reduction in drainage below the root zone of crops and pasture than is currently the case.

76.4 To move every irrigator to deficit irrigation would come at a cost and/or simply not be achievable in all cases.

77 Implementation of the alternative rules will require investment by many irrigators in improved systems design, maintenance and irrigation management.

78 While the alternative rules appear to result in additional irrigation drainage than predicted by the Farm Portal, they will still result in an improvement compared to the status quo. They also leave room for

additional improvement should further reductions in drainage be required beyond GMP.

79 Applying the alternative rules does not require a major difference in the overall approach. It simply requires the Farm Portal to accept a different set of inputs that are more practical and are achievable, and can match OVERSEER inputs that are based on GMP.

Effect of my suggested alternative rules

80 Dr John Bright (Figure 3 below) has modelled an example of a scenario that includes a number of irrigation rules covering a range from poor practice (to the left) to better than best practice (to the right).

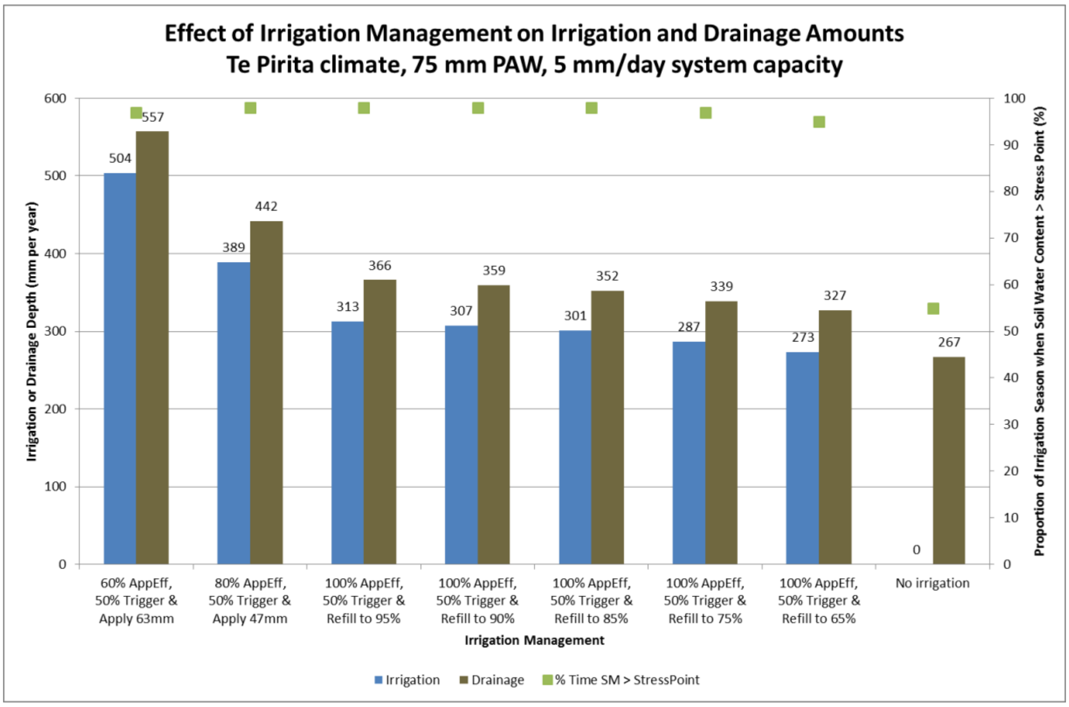

Figure 3: Example of effect of irrigation management on irrigation and drainage

81 Although the graph does not specifically show N leaching, it is reasonable to assume that N leaching is proportional to drainage.

82 The graph presents irrigation depth applied (mm), the amount of water draining below the root-zone (mm) and the percentage of time soil moisture is below a 50% stress point (a surrogate for production loss).

83 Note that drainage includes all water applied in excess of field capacity (when the soil moisture bucket is full)) that drains through the soil profile. Most of the drainage is due to rainfall, not irrigation losses, as

drainage through the soil profile at 100% application efficiency does not occur.

84 The most left-hand example is for a low efficiency system (60% application efficiency) and results in the highest water use and drainage, as expected.

85 Note that the first two options are applying a fixed depth of water at a known deficit, which reflects actual practice in the field. Very few irrigators apply variable depths of water to achieve a fixed refill point because (a) what the refill point is in all parts of the field is not known, and (b) soil moisture after irrigation is not measured everywhere to know if the target has been achieved. What irrigators do know (for those that measure soil moisture or schedule irrigation) is what the soil moisture is likely to be at the locations where it is measured or calculated.

86 The 80% application efficiency example, in my view, represents good practice for an irrigator such as a rotary boom or sprayline under the irrigation rules in **Appendix A**. While the efficiency data I have presented shows that achieving 80% application efficiency for a rotary boom irrigator or sprayline is not easy, I think it is a reasonable target and would be representative of good management practice.

87 One of the issues I see is the close link between irrigation system type and expected performance, and the messages it portrays to farmers. Using travelling irrigators or spraylines operating on GMP as a baseline has some advantages as (a) it would help to bring existing rotary boom and sprayline irrigators up to GMP, and (b) would give credit to those that had invested in more efficient systems.

88 Once the rules move to a variable depth option and deficit irrigation is imposed, 100% application efficiency (in theory) is achieved. Beyond that, the benefits of tighter irrigation rules in reducing irrigation water use and drainage level off. There is virtually no difference between operating to a 50% trigger and refilling to 95% and operating to a 50% trigger and refilling to 85%. The Farm Portal rule irrigates from 50% to 90% (fourth from left in Figure 3).

89 What the graph shows is that the Farm Portal rule is at a level that is hard to improve on, which is why I have concluded that it is beyond best practice. Virtually all of the possible improvements have been realised at that point.

90 In my view it shows that the Farm Portal is assuming a level of performance that is well beyond good practice. Dr Davoren's data shows that best practice will achieve average efficiencies in the range of 80-90% for most irrigation systems, but not all. The Farm Portal is based on a higher level of performance that in my view is not practically achievable.

Comments on the s42A Report

91 The part of the S42A report that is most relevant to my evidence is Appendix D.

92 My involvement in discussions around the development of the MGM irrigation proxy has been minimal, consisting only of a very brief appearance at the meeting of 18th September 2015. I assume the irrigation proxy is synonymous with the Farm Portal.

93 With reference to D(1), I agree that in general, using travelling irrigators to irrigate soils with low PAW60 is not recommended and is not good practice. The irrigation proxy changes them to centre-pivots. However, while centre-pivots can apply suitable depths of water for low PAW60 soils, they are unsuitable in many areas, as I have explained earlier, and are not always a practical substitute.

94 Spraylines are often not thought to be suitable for low PAW soils, but if they are shifted or operated to apply small depths of water, can be. In fact, Table B.3.1 in Appendix D shows spraylines with a minimum depth of application of 5 mm. I would never recommend that, but they can achieve GMP, so should not be excluded.

95 There are other irrigation methods that can be used for low PAW soils, such as solid set or fixed grid sprinkler systems, so why travelling irrigators and spraylines have been converted to only centre-pivot in the proxy, I am not sure.

96 With respect to D(2), it makes sense for travelling irrigators (in fact most irrigation systems) to apply a fixed depth of water, so the issue is about what the irrigation trigger point should be.

97 The proxy uses a 50% trigger point for all systems except travelling irrigators and spraylines, and applies a depth of water calculated from the difference between 50% and 90% of soil PAW. I question the approach of working to fixed trigger and refill points, because in practice, most irrigation is not operated in that way, and the alternative rules in **Appendix A** reflect that. I would expect that in OVERSEER, nearly all irrigation should be on a fixed depth-variable return basis. In practice, once the irrigation system design is established, the depth applied is set, and the irrigation management decision is primarily when to irrigate, not how much to apply.

98 The fixed depth, variable return period approach to irrigation management is the most practical. Changes to application depths almost always requires a change in machine speed for irrigation machinery that moves, such as travelling irrigators, guns, centre-pivots and laterals. The easiest to change speed on is centre-pivots. For the others, farmers rely on them moving at a known speed so that they complete their irrigator runs in a given time, usually 23 hours. They can then be moved at a fixed time of the day.

99 The comments around minimum application depths suggest that minimum depths of water such as those detailed in Table B.3.1 are good practice. I agree that applying small depths of water on low PAW soils (providing the target points are appropriate) helps to minimise drainage, but applying small depths will not achieve efficient application of water due to evaporative losses increasing relative to drainage losses. Because a lower percentage of the applied water reaches the soil, production objectives are negatively impacted. Such an approach is not GMP in my view.

100 With respect to the comments on irrigation efficiency, 80% application in the field is what I consider to be GMP as most, but not all irrigation systems, are able to achieve 80% efficiency. That level of efficiency will maintain production objectives and keep drainage losses to a

realistic minimum. As Figure 3 shows, under good management, drainage losses are mostly caused by rain falling on irrigated land, not the application of irrigation water.

Ian McIndoe
22 July 2016

Appendix A: Proposed Method s28.4

Plant Available Water capacity (mm)	Irrigator type	Irrigation trigger point	Application depth (mm)	Return period (days)
30	Pivot	55%	15	3
40		60%	15	3
50		65%	15	3
60		59%	15	3
70		62%	15	3
80		65%	15	3
90		64%	15	3
100		66%	15	4
110		68%	15	4
120		65%	15	4
140		69%	15	5
160		72%	15	5
200		77%	15	5
<80	Lateral move	As per centre-pivot		
80		65%	26	6
90		64%	26	6
100		66%	40	9
110		68%	40	9
120		65%	40	12
140		69%	40	12
160		72%	40	12
200		77%	40	12
<80	Rotary booms, linear booms, guns	As per centre-pivot		
80		50%	50	10
90		50%	50	10
100		50%	50	10
110		50%	50	10
120		55%	45	12
140		55%	45	12
160		55%	45	12
200		60%	45	12

Plant Available Water capacity (mm)	Irrigator type	Irrigation trigger point	Application depth (mm)	Return period (days)
<60	K Lines, long laterals, spraylines	As per centre-pivot		
60		55%	33	7
70		55%	33	7
80		60%	33	7
90		60%	33	7
100		50%	65	14
110		50%	65	14
120		50%	65	14
140		55%	65	14
160		60%	65	14
200		68%	65	14