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

**AND**

**IN THE MATTER OF** The Canterbury Proposed Land and Water Regional Plan.

# Evidence of Dr Anthony Davoren, HydroServices Ltd for Irrigation New Zealand

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## Background and Qualifications

1. My full name is Anthony Davoren. I hold the qualifications of Bachelor and Master (First Class) of Science in Earth Sciences from University of Waikato and Doctor of Philosophy in Engineering Science from Washington State University. I am a self-employed consultant, and owner and director of HydroServices Ltd.

2. I have 30 yearsô experience in soil moisture, irrigation management, groundwater and surface water research and other related consulting. After graduating from University of Waikato, I spent two years surveying the peat resources of New Zealand, followed by three years studying for a PhD on a National Advisory Council Fellowship. Water and Soil Division (Ministry of Works and Development) then employed me as a research scientist in the Hydrology Centre in Christchurch (now part of NIWA).

3. Since 1987, I have been involved as a specialist in soil moisture measurement and irrigation management. HydroServices now provides irrigation management advice to more than 350 clients in Canterbury. I have had a large involvement in preparing or supervising the preparation of technical assessments for resource consent applications irrigation.

4. In 2007 I founded HydroTrader Ltd with two other persons, Warwick Pascoe and Gus Walkden. In the five years trading and transferring water permits we have gained invaluable experience and expertise with regard to the transfer, transferee, their reasons to or for transfer, the volume of water transferred and where it is transferred

5. With respect to irrigation and groundwater, I have specialised in crop water requirements for irrigation, irrigation efficiency and irrigation design.

6. I was instrumental in developing Adaptive Management for applicantsô at the Rakaia-Selwyn, Selwyn-Waimakariri and Valetta-Ashburton River Groundwater Zone Hearings.

7. I am a past board member of Irrigation New Zealand and managed a Sustainable Farming Fund project Irrigation System Design Standards and Code of Practice for Irrigation New Zealand (INZ).

8. I acknowledge that I have read the code of conduct for expert witnesses contained in the Environment Courtôs Practice Note dated 31 March 2005. I have complied with it when preparing my written statement of evidence and agree to comply with it when giving oral evidence.

## Information Sources Relied Upon

9. In preparing my evidence, I have drawn on the following relevant information sources:

- The Proposed Canterbury Land and Water Regional Plan (pLWRP);

- The Proposed Canterbury Land and Water Regional Plan Section 42A Report - Volume 1;

- Management of irrigation system design experts in the preparation of the Irrigation System Design Standards and Code of Practice, and the associated NZQA Certificate in Irrigation Design; and
- The expertise and experience of, and knowledge gathered by HydroServices Ltd with regard to irrigation systems, efficiency and management throughout New Zealand since 1983.

## Key Issues Addressed in this Evidence

10. I have prepared this evidence on behalf of and in consultation with INZ. Where possible I have avoided repetition of other submitters with regard to the key issues.

11. The fundamental issues addressed in this evidence are:

    a) The use of the Overseer model to determine nutrient leaching;
    b) Key factors influencing irrigation efficiency and any resulting drainage;
    c) Examples comparing drainage calculations from Overseer and daily water balance models; and
    d) Corrective measures to improve the Overseer predictions and/or alternative models.

## Overall Summary

12. In relation to the key issues outlined in Paragraph 11 of the submission to the pLWRP, INZ have concluded:

    a) Support for the overall intent of the plan with regard to water quality and nutrient management policies and rules;

    b) Opposition to the use of the Overseer model in its current form to determine the degree of nutrient leaching, and importantly the subsequent use of these results to ascribe a nutrient loss limit to a farming operation by way of an absolute number, through a consent condition for example.

    c) There is a fundamental lack of understanding with regard to irrigation efficiency and the factors that affect or determine irrigation efficiency and water (rainfall and irrigation) that then contribute to drainage and therefore nutrient leaching as estimated by Overseer;

    d) The Overseer model is more difficult and complex to use in multiple crop farming situations; and

    e) There is no capability to incorporate advances in irrigation technology and better irrigation management practices.

## Overseer and Irrigation

13. Overseer is a simplistic model and while a valuable tool to assist farmers to improve farm profitability, optimise meat and milk solid production, optimise nutrient use and minimise impacts on air, soil and water quality it does not currently adequately account for irrigation and seasonal allocations.

14. Simplistically, Overseer relies upon mean annual data inputs for climatic quantities (Figure 1); i.e.

- Mean Annual Rainfall,
- Mean Annual Potential Evapotranspiration (PET),
- Mean Annual Temperature, and
- Assessment (monthly distribution) of the seasonal variation of rainfall and PET**.**

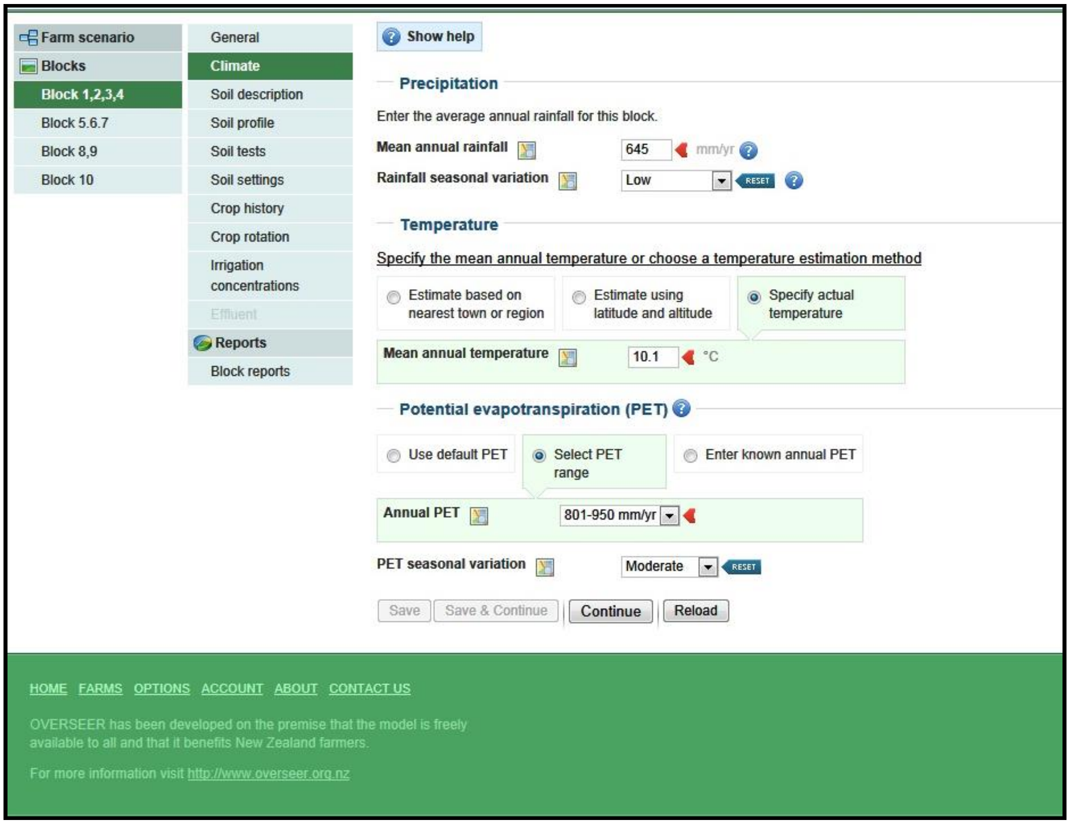


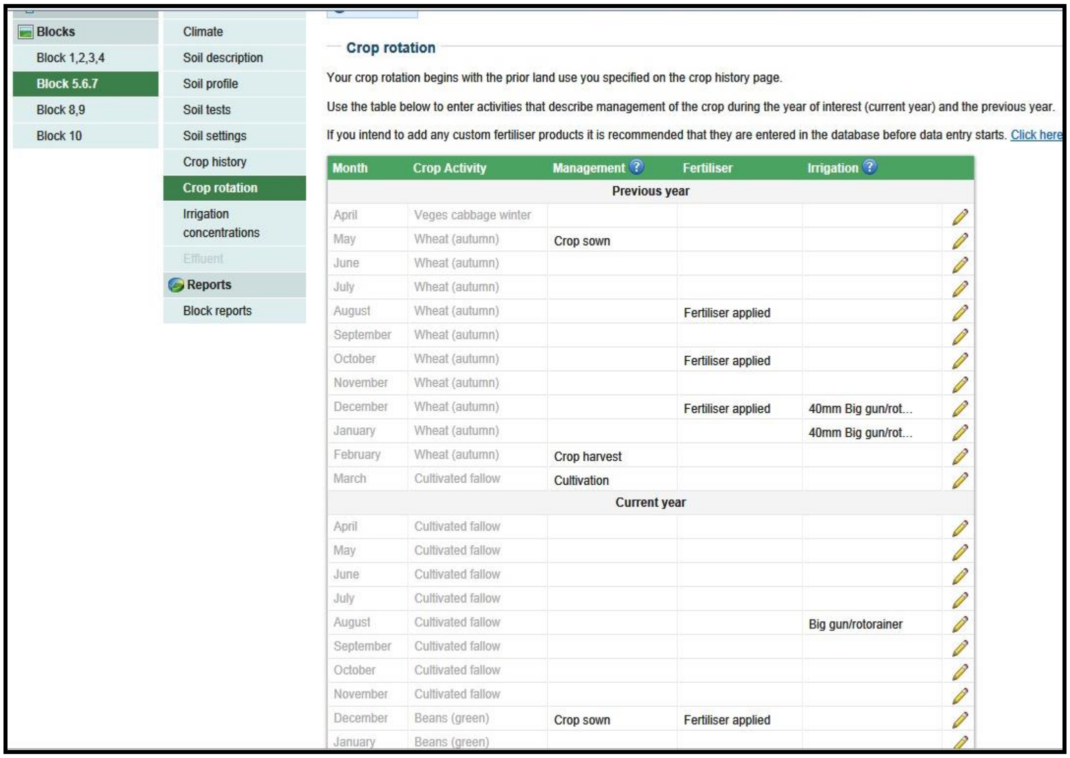

Figure 1. Screenshot of climate input for Overseer scenario.

15. If an actual irrigation volume is to be used (input in the Block, Crop Rotation details as an amount (mm) per month - Figure 2), the model requires depths to be input per month.

16. This can be a relatively simple task for mono-cultural pastoral agriculture, but extremely complex for arable farming where multiple crops, planting dates and harvest dates are involved. For example:

    - A pastoral farm growing only grass could have the annul allocation divided equally across the months September to April (likely to result in unrealistic drainage in the shoulder seasons) **or** weighted according to the month.

    - Arable farms could be growing 10-20 different crops, some planted in February or March but not harvested until March or April in the following year and, others planted and harvested within weeks. There is no set pattern to crop planting dates ï being driven by both market and seasonal factors. This results in much complexity and subsequent transaction cost for arable growers. The model is too simplistic to accommodate crops spanning multiple years, while attributing drainage and nutrient leaching to a particular year.




| Month | Crop Activity | Management | Fertiliser | Irrigation |
|---|---|---|---|---|
| **Previous year** | | | | |
| April | Veges cabbage winter | | | |
| May | Wheat (autumn) | Crop sown | | |
| June | Wheat (autumn) | | | |
| July | Wheat (autumn) | | | |
| August | Wheat (autumn) | | Fertiliser applied | |
| September | Wheat (autumn) | | | |
| October | Wheat (autumn) | | Fertiliser applied | |
| November | Wheat (autumn) | | | |
| December | Wheat (autumn) | | Fertiliser applied | 40mm Big gun/rot... |
| January | Wheat (autumn) | | | 40mm Big gun/rot... |
| February | Wheat (autumn) | Crop harvest | | |
| March | Cultivated fallow | Cultivation | | |
| **Current year** | | | | |
| April | Cultivated fallow | | | |
| May | Cultivated fallow | | | |
| June | Cultivated fallow | | | |
| July | Cultivated fallow | | | |
| August | Cultivated fallow | | | Big gun/rotorainer |
| September | Cultivated fallow | | | |
| October | Cultivated fallow | | | |
| November | Cultivated fallow | | | |
| December | Beans (green) | Crop sown | Fertiliser applied | |
| January | Beans (green) | | | |

Figure 2. Screenshot of Crop Rotation (and Irrigation) input for Overseer scenario. Irrigation is input to the Crop Rotation to utilise the annual volume allocated for the consented activity.

17. Use of mean annual rainfall, temperature and PET, and entering in an annual volume for irrigation is inconsistent because:

- If mean annual rainfall, temperature and PET are the driver for the model, the annual volume **must also** be the mean annual volume required for irrigation. There is presently no method for doing this (converting the allocated irrigation volume to a mean volume).

  Note: Over time (10+ years) it may be possible to derive an accurate mean irrigation annual volume from measurement. However, as measurement has only been compulsory since 2012 it will be at least 2022 before this is possible. NZ has much seasonal variation in irrigation requirement and also typically has decadal weather patterns (wet to dry). For example, compare 2011-12 (where some irrigators on heavier soils did not irrigate) with the drought season of 2012-13.

- Some suggest that the consented annual volume (the irrigation depth required to meet 90-percentile demand season) should be the input for the model. If this is to be, the annual rainfall, temperature and PET must be the 10 percentile values (simplistically).

In summary data inputs to the model have to be consistent, otherwise outputs from the model become a statistical contradiction and thus result in aberrant outcomes.

18. Two examples are provided to demonstrate the aberrant nature of the results when statistical quantities are ñmix and matchedò:

Farm 1 ï arable farm with two soil types, Eyre shallow silt loam (PAW 65mm) and Wakanui moderately deep silt loam over silty clay gravels (PAW 97mm.

Farm 2 ï dairy farm, Lismore and Eyre shallow silt loam (PAW 80mm) and, Temuka and Pahau moderately deep silt loam (PAW 100mm).

19. In both examples Overseer and Irricalc models were run using the same data (Winchmore climate station, length of record etc.) to determine drainage estimate. In these examples the allocated annual volume is ñspreadò across the potential irrigation months; i.e. September to April. Two irrigation volumes are tested ï both farms made application to increase the annual irrigation volume from the 80-percentile to 90-percentile demand and Irricalc was used to demonstrate the result was no significant increase in drainage.

20. Table 1 and Figures 3-5 show the drainage estimates for Farms 1 and 2.

| | **Soil PAW, mm** | **80%-ile Demand Irrigation, mm** | **Overseer Drainage, mm** | **Irricalc Drainage, mm** | **90%-ile Demand Irrigation, mm** | **Overseer Drainage, mm** | **Irricalc Drainage, mm** |
|---|---|---|---|---|---|---|---|
| **Farm 1** | 97 & 65 | 464 | 642 | 271 | 570 | 732 | 279 |
| **Farm 2** | 100 | 465 | 382 | 251 | 570 | 487 | 266 |
| | 80 | 465 | 414 | 254 | 570 | 497 | 266 |

Table 2. Comparison of Overseer and Irricalc drainage estimates for ñaverageò rainfall and PET and allocated irrigation volume, Farm 1 and 2.

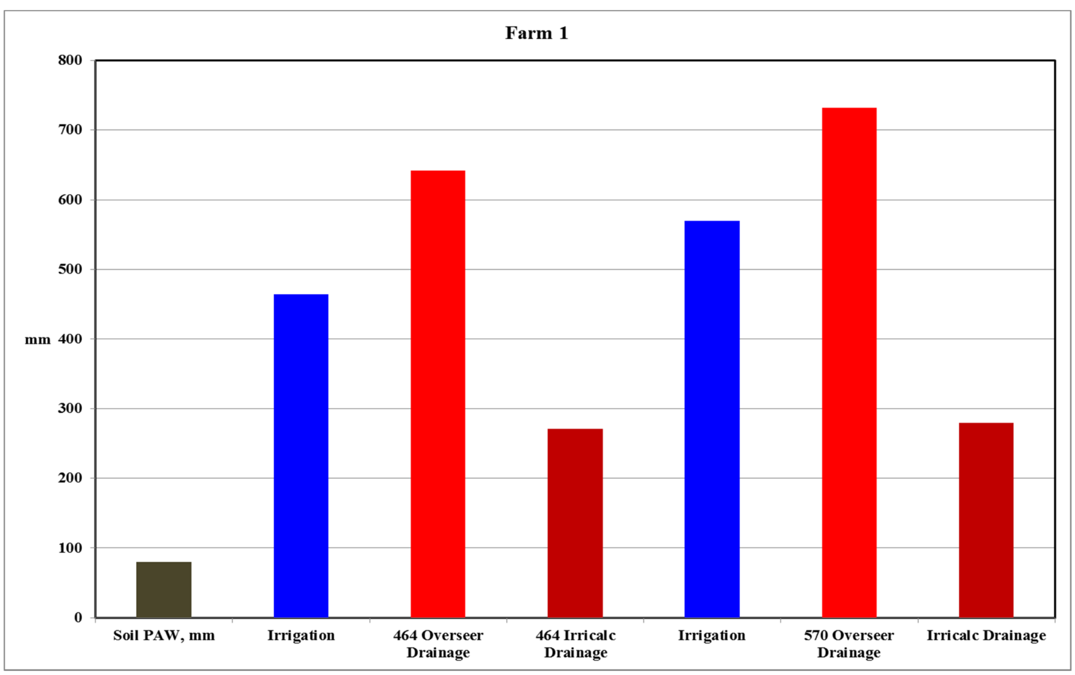



Figure 3. Comparison of Overseer and Irricalc drainage estimates for Farm 1, where the PAW plotted is the average of the two areas of soil PAW.

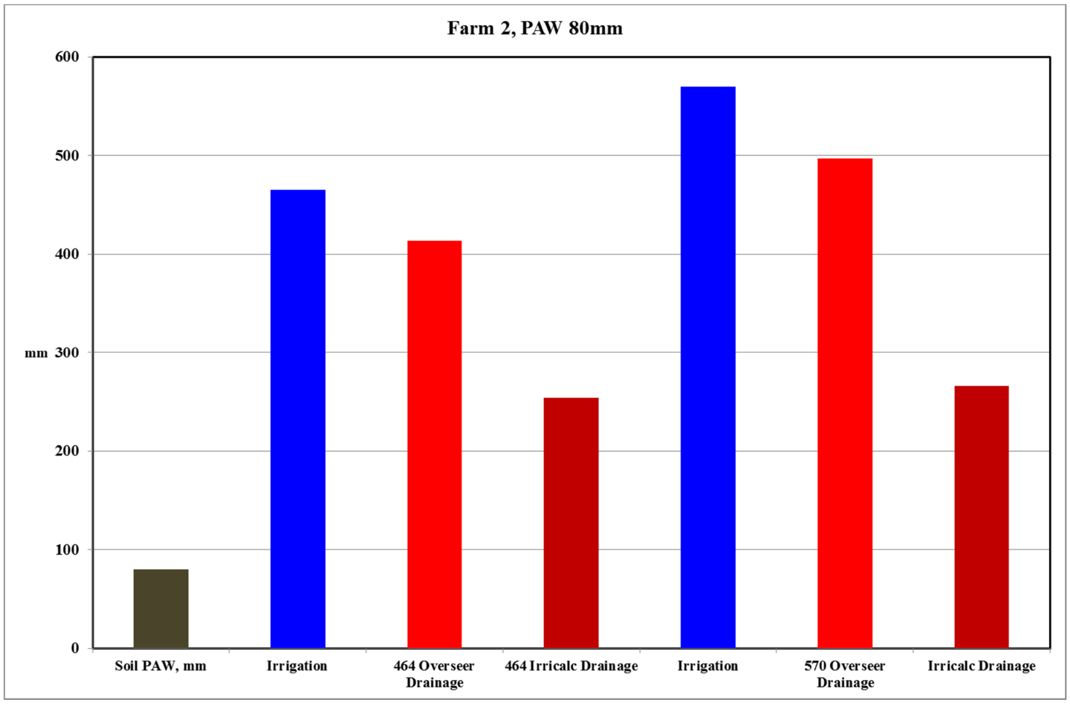



Figure 4. Comparison of Overseer and Irricalc drainage estimates for area of Farm 2 with soil PAW of 80mm.

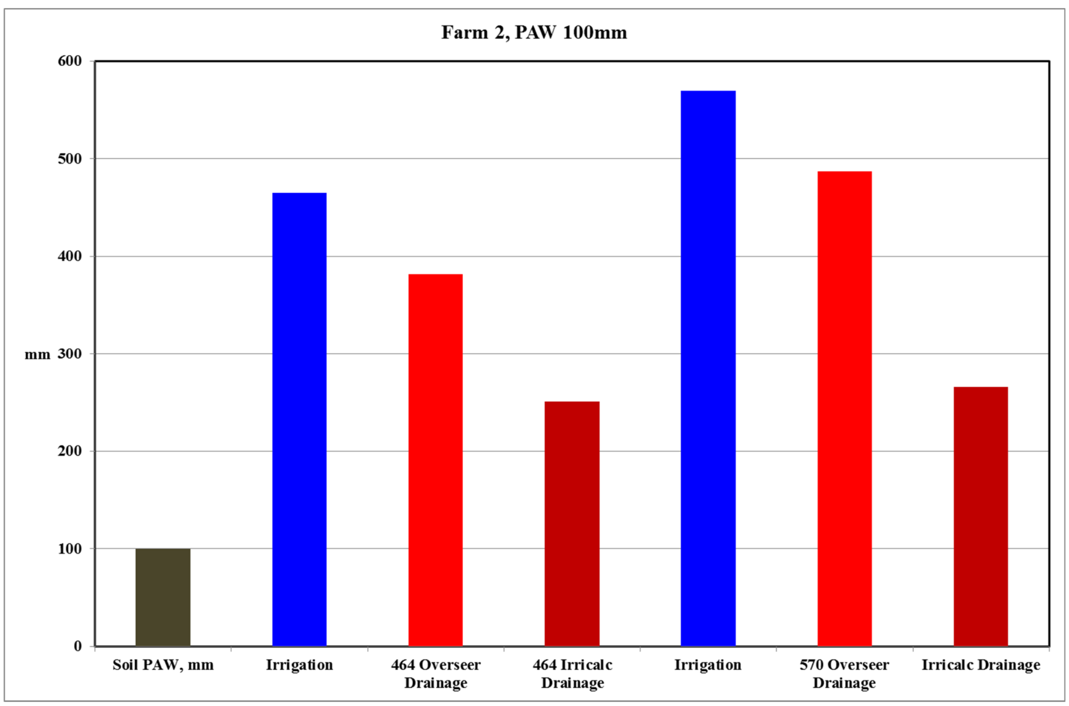



Figure 5. Comparison of Overseer and Irricalc drainage estimates for area of Farm 2 with soil PAW of 100mm.

21. In all three examples, the ñaverageò drainage estimated by Overseer is significantly greater than the average drainage estimated using the Irricalc model ï 1.5 to 2.6 times. It is no surprise that nutrient leaching will be exceedingly high when drainage is significantly over-estimated.

22. This result demonstrates the aberrant nature of the results when average data (Overseer rainfall and AET) are ñmix and matchedò with allocated irrigation volume (90%-ile).

23. The Overseer analysis for Farm 2 was repeated using average rainfall, PET and irrigation calculated from the Irricalc analysis for the location of Farm 2. Only Farm 2 was analysed to demonstrate the complexity and time required to carry out such an analysis.

| | **Soil PAW, mm** | **Average Irrigation, mm** | **Average Rainfall, mm** | **Average PET, mm** | **Overseer Drainage, mm** | **Irricalc Drainage, mm** |
|---|---|---|---|---|---|---|
| **Farm 2** | 100 | 435 | 744 | 860 | 433 | 266 |
| | 80 | 455 | 744 | 860 | 456 | 266 |

Table 2. Comparison of Overseer and Irricalc drainage estimates for ñaverageò rainfall, PET and irrigation, Farm 2.

24. The results in Table 2 show the same pattern and discrepancy of drainage estimation by Overseer and Irricalc, with Overseer over-estimating drainage by 1.6-1.7.

25. The above analysis and results show that Overseer as it is currently applied suggests the drainage protocol needs to be investigated. In the interim the protocol should be that drainage from irrigation should be estimated using a daily water balance model.

## Advances in Irrigation Technology

26. Currently Overseer does not have the ability to incorporate or analyse for advances in irrigation technology; e.g. Variable Rate Irrigation (VRI) or Precision Irrigation or advances in sprinkler technology.

27. VRI is no longer developmental technology. It is being retrofitted to existing centre pivot and linear irrigation systems, and is sold regularly with new centre pivot and linear irrigation systems where it has value. Fundamentally VRI applies different depths of water along the length of these irrigation systems.

28. VRI operates in a number of different manners; e.g.

- To irrigate different crops along the length of the centre pivot or linear move;
- To exclude headland area, tracks, overlaps, buildings, yards and the like; and
- To irrigate soils with contrasting texture (and therefore soil water holding capacity and soil water deficit) along the length of the irrigator.

29. Figures 6 and 7 illustrate the application of VRI in a field irrigated by centre pivot with contrasting water holding capacity (whc) for the same soil type classification.

30. Total application depths varied from 56mm on deepest highest whc soil (site 2) to 108mm on lightest lowest whc soil (site 6) ï nearly double the irrigation at site 6.

31. Currently, Overseer has no simple means or capability to deal with detailed soil subdivision in the same field growing the same crop.

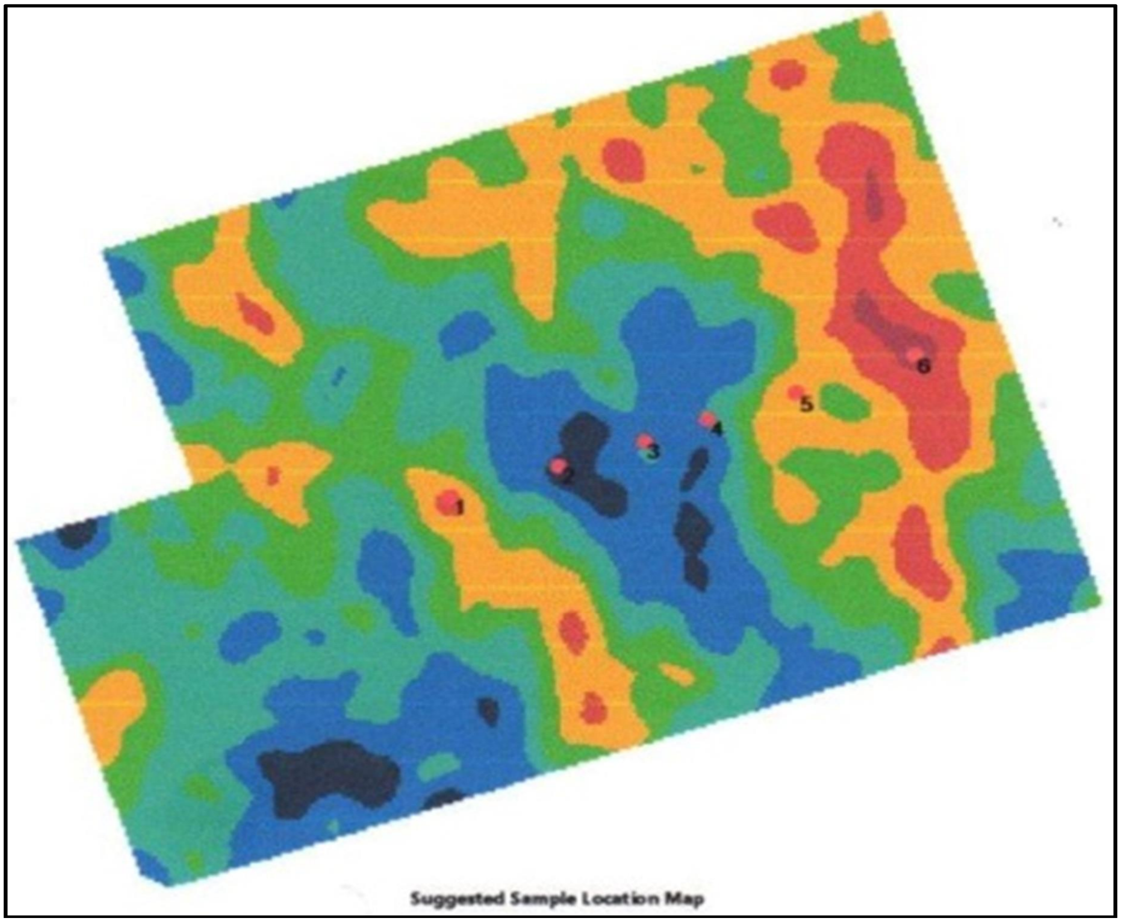



Figure 6. EM38 scan of centre pivot paddock, where red (■) indicates low whc, indigo (■) indicates high whc and 1-6 are the soil moisture sampling sites.

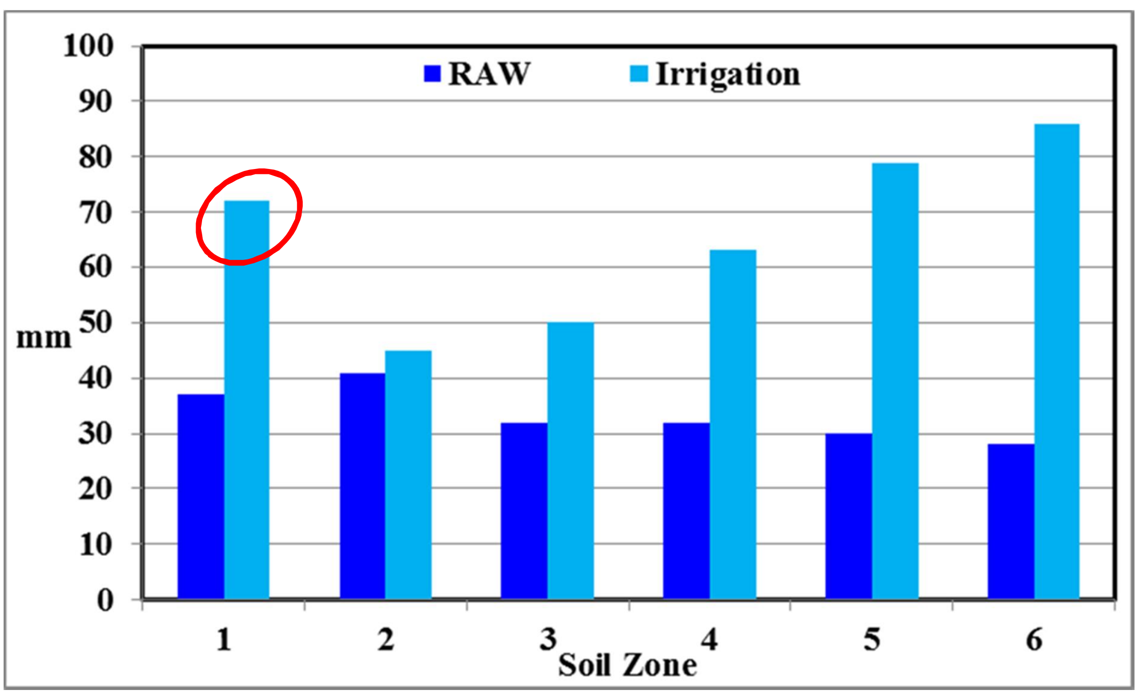



Figure 7. WHC and irrigation depths applied during the 2012-13 season, where (○) indicates a programming error for one irrigation when too much water was applied.

32. Within the last 5 years sprinkler technology for centre pivot and linear move irrigation has improved significantly. Distribution uniformity, hence potential irrigation efficiency has improved; e.g. the development of the orange multi-groove plate for Nelson R3000 rotators and Senninger I-Wob that have increased distribution uniformity by 2-3%. These sprinklers are also being adapted for existing fixed boom irrigation systems to improve distribution uniformity and therefore application efficiency. Overseer does not allow for user defined distribution uniformity/application efficiency.

33. Therefore, centre pivot irrigation that operates with distribution uniformity greater than the default in Overseer is penalised. By contrast, daily water balance models allow for user defined distribution uniformity and therefore application efficiency.

## Irrigation Management Strategy

34. Currently Overseer does not have the ability to incorporate user defined practice for irrigation management. The simplest example is centre pivot irrigation where the practice is to ñdeficitò irrigate. This should not be confused with deficit irrigation described above in Paragraph 23.

35. Centre pivot deficit irrigation aims to maintain soil moisture within a targeted band between field capacity and stress point. Figure 4 illustrates the concept of deficit irrigation in a pasture irrigated by centre pivot, where the depth of applied irrigation is kept below the dashed blue line (Ƶ Ƶ ) and above the red dashed line (Ƶ Ƶ ).

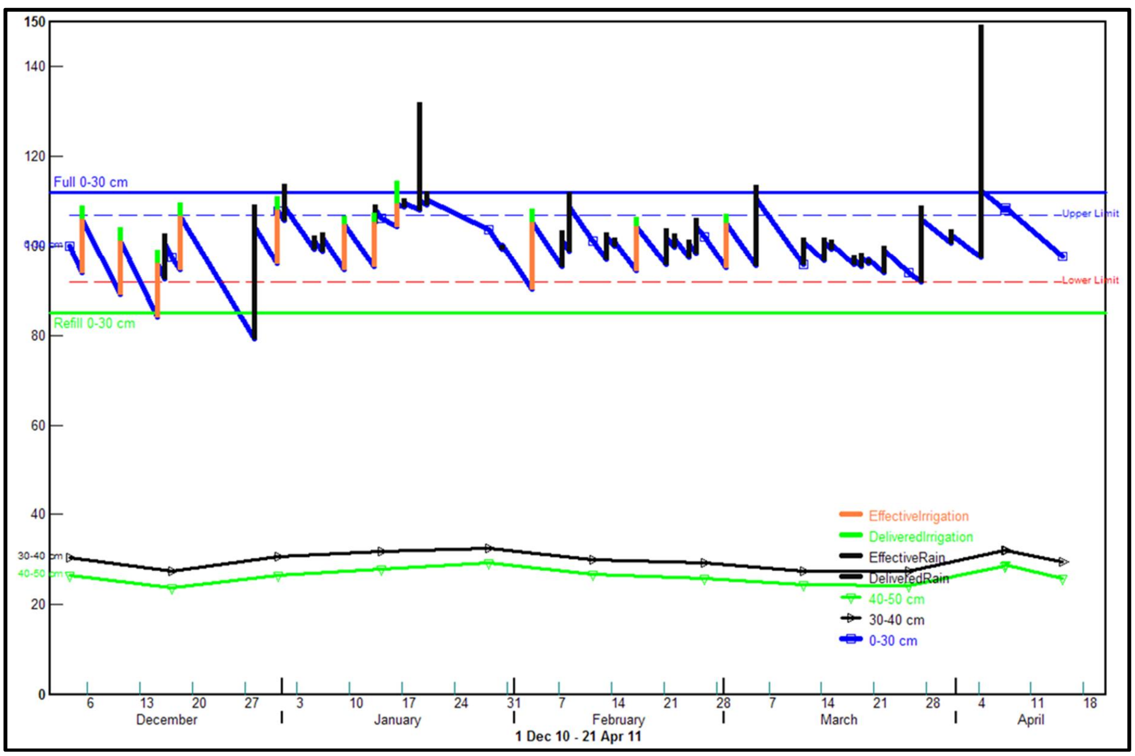


Figure 4. Example of deficit irrigation in a pasture irrigated by centre pivot, where irrigation is maintained above the stress point (Ƶ ) and for the most part does not exceed full point (field capacity, Ƶ ).

36. Overseer does not the capability to define irrigation management strategy. As described in Paragraph 18, irrigation is inserted as a monthly amount (depth) along with

the type of irrigation.  The user is left to accept the default for the irrigation type and no ability to define how the water will be applied or managed.

## Summary

37. Irrigation NZ is proactively working toward solutions to these issues and shortcomings of the Overseer model.  To this end a proposal has been presented to Aqualinc Research, but the work will not be carried out within the next year or two.

38. In the meantime, the Overseer model in its current form should not be used to determine the degree of nutrient leaching or subsequently use the results to ascribe an absolute number for nutrient loss limit to a farming operation.

*39.* Rather, the Overseer model should be used to indicate whether there is potential for nutrient loss that requires further investigation and confirmation, especially the amount of drainage.

**Dr Anthony Davoren**
**29 May 2013**