BEFORE THE HEARINGS PANEL

IN THE MATTER	of the Resource Management Act 1991 ('the Act')
AND	
IN THE MATTER	of Proposed Plan Change 9 to the Hawke's Bay Regional Resource Management Plan

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STATEMENT OF REPLY EVIDENCE OF CHANNA RAJANAYAKA FOR HAWKE'S BAY REGIONAL COUNCIL

19 May 2021

CONTENTS

1. INTRODUCTION

1.1 My full name is Channa Nilanga Rajanayaka.

1.2 I hold the position of Surface Water - Groundwater Modeller at National Institute of Water & Atmospheric Research Ltd (**NIWA**). I am the Manager of NIWA's Hydrological Modelling Group.

1.3 I hold the qualifications of Ph.D. from the Lincoln University (awarded 2003), Postgraduate Diploma in Management from the Open University, Sri Lanka (awarded 1993) and B.Sc. (Civil Eng.) from the University Peradeniya, Sri Lanka (awarded 1991). I am a member of the New Zealand Hydrological Society (since 2004), the International Association of Hydrogeologists (since 2008), the International Environmental Modelling and Simulation Society (since 2001), the European Geosciences Union (since 2016) and the Asia Oceania Geosciences Society (since 2018). In my Ph.D. research, I investigated and developed methods to estimate aquifer properties using mathematical modelling and inverse methods (i.e. inversely estimating the aquifer properties using observations such as concentration of nutrients [e.g. Nitrogen]).

1.4 I have 23 years of experience in hydrology- and hydrogeology-related research, consultancy and teaching, and a further six years of experience in general civil engineering.

1.5 Since 2017, I have been employed by NIWA. Prior to NIWA, I was employed by Aqualinc Research Ltd (Aqualinc) as a Senior Water Resource Scientist for 13 years, and by Lincoln University as a Lecturer where I taught Mathematics and Environmental Modelling. I was a recipient of a Bright Future – Top Achiever Doctoral Scholarship, with which I undertook my Ph.D. study.

1.6 I have extensive experience in all areas of hydrology and the modelling of hydrology systems. My work primarily involves developing innovative scientific solutions to hydrological problems, and providing technical services and advice to Central Government (e.g. Ministry for the Environment (**MfE**)), regional authorities, local government authorities and private interests to improve water use efficiency, and strategic management of water resources.

1.7 I have authored or co-authored more than 100 reports and more than 60 conference presentations.

1.8 My work in Aotearoa-New Zealand over the last 20 years that is relevant to this hearing includes:

(a) Co-authoring the "Water Accounting Guidelines for regional authorities for the National Policy Statement – Freshwater Management" (**NPSFM**); specifically, I authored the 'Water Quantity' section[1];

(b) Undertaking hydrological assessments, providing evidence, and engaging in hydrologists' caucusing for several proposed Regional Plan Changes: Auckland Unitary Plan, Canterbury (Waitaki Plan Change 3), Hawke's Bay (Plan Change 6), Waikato (Variation 6), and Otago (Plan Change 6A).

(c) Development of 'Water Allocation Guidelines for Irrigation' for Waikato, Otago and Gisborne. These irrigation guidelines provide information on how much irrigation water is required (for a specific level of reliability), to keep crops well-watered. Guideline values have been developed to meet reasonable water demands for different crops (vegetable [taking rotations into account], pasture, viticulture, and fruits), based on climate data and soil properties.

(d) Development of irrigation water demand and groundwater recharge estimates using soil-water balance modelling for hydrology studies in Hawke's Bay, Northland, Auckland, Waikato, Taranaki, Gisborne, Marlborough, Tasman, Canterbury, Otago and Southland.

(e) Updating national indicator data on freshwater allocation in New Zealand in 2006 and 2010. This work included collating consented water takes from all regional authorities, quality checking, correcting data where necessary in consultation with the relevant regional authority, producing indicators, and comparing results with those reported in previous studies. The 2010 project included estimating the actual abstraction volumes of the consented takes.

(f) Development of an approach (and ultimately a model) for estimating cumulative catchment streamflow depletion accounting for surface and groundwater abstractions.

(g) Strategic water studies within Auckland (rural south in 2006 and Franklin local Board area in 2014), Bay of Plenty, Taranaki, Gisborne and Waikato regions. These studies included assessment of current and potential future (up to next 50 years) requirements for water in study areas, the availability of surface

1 Rouse, H., Cooke, J. and Rajanayaka, C. (2014). Freshwater accounting systems - Guidance for regional authorities. Prepared for Ministry for the Environment by NIWA, Streamlined Environmental Ltd and Aqualinc Research Ltd. July 2014.

and groundwater resources to meet these demands, and identification of appropriate mechanisms and options to manage water availability in the areas where water shortfalls were identified.

(h) Feasibility studies, where future irrigation water supply options in Northland Region, Galatea-Murupara and Raukokore District (including surface water, groundwater and storage) were assessed.

1.9 I have prepared this evidence in my capacity as an expert, and although this is not a court hearing I confirm that I have read and understand the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note dated 1 December 2014. I have complied with it when preparing my evidence, and I agree to comply with it when I give any oral evidence. Other than where I state that I am relying on the evidence of another person, my evidence is within my area of expertise. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

Purpose and scope of evidence

1.10 This evidence in reply is intended to address matters raised in the statements of evidence filed by submitter's expert Dr Andrew Laughton Dark on water quantity measurement and modelling.

1.11 I provide narrative on matters raised by Dr Dark only where I consider that what he has stated may not be correct, or that it should be qualified.

1.12 My evidence addresses the following matters:

(a) Irrigation water allocation and use.

(b) Appropriateness in using existing crop coefficients.

2. KEY FACTS AND ASSUMPTIONS RELIED ON

2.1 In preparing my evidence, I have reviewed the following documents and evidence:

(a) Evidence submitted by Dr Andrew Laughton Dark.

(b) Policies and rules related to water quantity measurement and modelling in Proposed Plan Change 9 - Tūtaekurī, Ahuriri, Ngaruroro and Karamū Catchments.

(c) Relevant sections related to water quantity measurement and modelling in the Section 32 Evaluation Report.

(d) Relevant sections related to water quantity measurement and modelling in the Section 42A Hearing Report.

3. EXECUTIVE SUMMARY

3.1 Proposed Plan Change 9 (**PPC9**) proposes to define the ‘Actual and Reasonable’ allocation limits for irrigation takes as the least of the maximum annual amount as measured by an accurate water meter or the quantity required to meet the modelled crop water demand. In my opinion, this approach is fair and will encourage irrigation water users to increase water use efficiency using modelling tools and related approaches.

3.2 I consider the crop coefficients for grapes developed by Plant and Food in current use are ‘fit for purpose’.

4. WATER ALLOCATION FOR IRRIGATION

4.1 PPC9 states that Actual and Reasonable allocation for irrigation takes will be determined as the least of either: [2]

(a) the maximum annual amount as measured by an accurate water meter in the ten years preceding 2 May 2020, if accurate data are available; or

(b) the quantity required to meet the modelled crop water demand for the irrigated area with an efficiency of application of no less than 80% as specified by the IRRICALC water demand model (if it is available for the crop), or otherwise estimated using an equivalent method.

4.2 In paragraph 21 of his evidence, Dr Dark poses the question "Is the use of measured water-use data a reasonable approach for setting ‘Actual and Reasonable’ water use limits on resource consents"?

4.3 In paragraph 57 of his evidence, Dr Dark states that ‘Actual and Reasonable’ use should be determined using measured historic water use data in conjunction with soil moisture measurements, to provide evidence that the historic use of water has been efficient.

4.4 I address the two methods (water meter data and crop water demand modelling) proposed in PPC9 and matters raised by Dr Dark for determining ‘Actual and Reasonable’ volumes for irrigation in following paragraphs.

2 PPC9 Chapter 9 gives the complete definition.

4.5 For efficient water resource management, it is important that we measure relevant parts of water movement because, as the well-known saying goes, "You can't manage what you can't measure". For efficient irrigation water management, we can measure water abstraction rates and volumes using water meters, soil water state within soil-water reservoir (sometimes 'loosely' referred to as root zone) using soil-moisture sensors and drainage below the soil-water reservoir using lysimeters etc.

4.6 Whilst water meter data represents the irrigation water use for a large area (e.g. entire farm or orchard), a soil-moisture sensor or lysimeter represents the point location of the measurement. However, in reality we cannot measure everything, at least not all the time, for a number of practical reasons. It is therefore important that the limited measurements made are representative of the whole area of interest. For example, it would be inappropriate to determine the irrigation water demand for a farm where both light soils (low water holding capacity) and heavy soils (high water holding capacity) occur by using a soil-moisture sensor installed in light soils – the results would be inaccurate for the farm as a whole.

4.7 Models have become essential in water resource management because we cannot measure everything. Accepting that models of complex soil/hydrological process are relatively crude representations of reality, and that "all models are wrong, but some are useful", it is important that model outputs/predictions are compared with field measurements to ensure that model structure (processes that the model simulates), inputs and parameters are sufficiently accurate for the purpose of model use. This process is known as 'ground-truthing'.

4.8 As Dr Dark noted, use of a model to calculate water requirements does not guarantee that the modelled water use is efficient. It is therefore essential that model set up (representations of the soil-water dynamics at a suitable level of accuracy, and selection of model parameters) is assessed by using observations to validate the model outputs/predictions, and enhance the model's ability to better simulate water use, thereby iteratively improving water use efficiency. A model can account for the variability in conditions across a farm (including soils and crops) explicitly. If adequate data and information existed, it would be possible to calibrate and parameterise a model so that it could be used to manage water application rate at much finer scale (say tens of metres) across a single paddock – this is the basis of precision agriculture.

4.9 Due to inherent limitations with models, and because of practical limitations and costs associated with measurements, I support the PPC9's proposed approach in using both water meter data and crop water demand modelling to determine ‘Actual and Reasonable’ rates and volumes of water for irrigation.

4.10 In paragraph 59 of his evidence, Dr Dark uses an example to propose that if annual measured values were consistently 10% higher than the model values, and soil moisture measurements indicated that water was being used efficiently, it would be reasonable to allocate the model estimate value plus 10%.

4.11 In my opinion, Dr Dark’s example is too simplistic and such approach is associated with several issues:

(a) It is inaccurate to estimate the water use efficiency at one point and use that information to determine the ‘reasonable’ water requirements for the entire farm, because soil and crop conditions across the farm are likely to vary (paragraph 4.6), and a single point measurement of soil moisture is highly unlikely to represent the entire farm perfectly.

(b) If measurements made at a single point are unlikely to represent conditions across an entire farm perfectly, it would be inappropriate to “exploit” the unrepresentativeness of these results to justify use of point scale measurements over the predictions of a model. It is also worth noting that a model is based on data collected over multiple sites and locations – in essence, a whole series of point scale measurements, at a spatial density that no single fam is ever likely to achieve.

(c) For similar reasons, a point soil moisture measurement cannot reliably be used to identify a pipe leak – the leak will not become evident until soil moisture measurements indicate a requirement to abstract completely excessive amounts of water to the farm, because insufficient water had been reaching the measurement point for some time. In Dr Dark’s example, demonstrating the irrigation management is efficient at the measurement location could potentially occur with a pipe leak of 10% between the water meter and irrigated area, where soil moisture measurement occurs. Note that I do not imply that irrigation systems are 100% efficient, which is unrealistic, but use the same percentage Dr Dark used to demonstrate that a simple comparison of water meter data against model output is an inaccurate approach.

(d) Due to the reasons in paragraphs 4.11(a)-(c), it is not possible to prove that historic use of water for a farm has been efficient by using point scale soil moisture measurements.

(e) The data produced by an installed soil moisture sensor may not represent average soil moisture dynamics of the farm. As noted in paragraph 4.6, if the sensor is installed on light soils but the farm area also covers heavy soils, use of unrepresentative soil moisture data may bias assessment of water use efficiency.

4.12 In my opinion, use of the lesser of measured water use and estimated water use predicted by demand modelling is a robust and transparent mechanism to promote water use efficiency.

4.13 As suggested by Dr Dark, the measurement and use of soil moisture is an extremely important and effective approach for developing suitable irrigation strategies for a specific farm and for irrigation scheduling. By coupling soil moisture sensors with tools such as Irrimate (https://irrigationinsight.co.nz/resources/tools), irrigators can further improve water use efficiency. Information derived from the use of soil meters will also help to develop better parameters for models.

4.14 Dr Dark stated (paragraph 47) that "Under the irrigation rules that have been applied in model runs underpinning the online tool, the daily volume of water applied is determined by the model inputs, rather than being a result of the simulation. This represents the system capacity of the irrigation system – i.e. how much water can be delivered to the irrigated area in a day. In most cases for grapes this is 24 m^3/ha/day, which can also be expressed as 2.4 mm/day or 0.28 l/s/ha. Other land uses have higher daily volume requirements. For example, pasture on a light soil is allocated up to 58 m^3/ha". I address the issues associated with the 'daily application depth' inputs in the online tool in following paragraphs.

4.15 The above approach noted by Dr Dark generally uses an 'arbitrary' daily application depth (or system capacity) deemed 'appropriate' for estimating irrigation water demand. However, irrigation demand is a function of climate (rainfall and potential evapotranspiration) and soil water holding capacity. Climate and soil properties vary from location to location. Therefore, the daily application depth needs to be changed/optimised for different spatial locations to realise the most efficient water use.

4.16 I developed the guidelines for irrigation water allocation for Waikato Region by optimising the system capacity to achieve greater water use efficiency. An abstract of a presentation I delivered to the New Zealand Hydrological Society Conference based on the Waikato work is given in Appendix A. The modelled results showed that the optimised system capacities not only reduce the daily water use but also reduce the annual water volumes and decrease drainage and potential nutrient losses below the soil-water reservoir (root zone). Reduced water application will also lower the energy use and capital cost of irrigation systems. Therefore, optimised system capacities enhance the social, environmental and economic wellbeing of the community.

4.17 As described above, more nuanced modelling has demonstrated that there is potential for greater efficiencies to be made by using optimised system capacities. I therefore recommend that soil water balance modelling (either online tool or farm specific) should consider using optimised system capacities rather than 'arbitrary' values, at least for large takes, to enhance water use efficiency in the Hawke's Bay Region.

5. CROP COEFFICIENT

5.1 Dr Dark suggests (paragraph 35) that further research is required to quantify the crop coefficients for grape vines because the crop coefficients vary according to how the vineyard is planted and how the vine canopy is managed.

5.2 I agree that crop coefficients for a crop may vary between farms and even within a farm. It is possible that crop coefficients developed for any crop (e.g. pasture) through research at a location may not be representative of a different location. The differences between farms and within farms lead to variations in crop coefficients.

5.3 Further research may well lead to development of better crop coefficients for different locations – ones that better represent a range of farm management practices. However, I consider that the existing crop coefficients for grapes developed by Steve Green of Plant and Food (see paragraph 34 of Dr Dark's evidence) are 'fit for purpose' because they:

(a) are sufficiently representative; and

(b) permit tolerably accurate water allocation.

5.4 In my opinion, it is not practical for a regulatory authority such as HBRC to develop crop coefficients for different farm conditions. However, consent holders could acquire further research and develop more accurate crop coefficients for their farms/orchards.

Channa Rajanayaka
19 May 2021

APPENDIX A

WHAT DOES OPTIMISING THE SYSTEM CAPACITIES FOR IRRIGATION SYSTEM ACHIEVE?

Rajanayaka C[1], Barkle G[1], Jaramillo A[1], Brown E[2]
[1] Aqualinc Research Limited
[2] Waikato Regional Council

Introduction

Most water resources, particularly the more easily available surface waters, are highly allocated in many regions in New Zealand. Demand for water has intensified over the past decade at a phenomenal rate with the irrigated area in New Zealand estimated to have nearly doubled between 2000 and 2010 (Aqualinc, 2010). The critical period for managing water resources is in the summer months; stream flows and groundwater levels are at their lowest, and demand is highest for seasonal uses such as irrigation. Irrigation water is allocated in many regions with the emphasis on managing annual volumes, i.e. the total allowable volume allowed to be extracted over an irrigation season (m^3/year). These annual volumes are often calculated using an arbitrary "daily irrigation system capacity" of between 4 to 5 mm/day, considered to be appropriate to meet crop water demand. The system capacity is the minimum depth of water that an irrigation system must apply to be able to meet the plants water requirements without reducing yield. Due to soil water storage, the system capacity is less than the peak daily evapotranspiration requirement; however the key question is "how much less can it be"?

What is often overlooked are the ramifications for how the system capacity is used in resource allocation. The total allocable resource from run-of-stream is determined to be an instantaneous flow rate (i.e. l/s or m^3/s). This total allocable resource must not be less than the cumulative sum of the system capacities for all of the irrigators (and other users) that wish to use the resource. Therefore, the system capacities determine how many irrigators can use a resource and the area that maybe irrigated from a resource. Consequently, it is essential to optimise the system capacity to ensure that the maximum area can be effectively irrigated and thereby capture the full economic benefits from the available resource.

This presentation will demonstrate the advantages of optimising irrigation system capacities for achieving the best economic, social and environmental outcomes for a region. Additionally, it will show the effects of using 'arbitrary' system capacities on annual irrigation water volumes required and on drainage losses.

Method

Most resource consent applications for pastoral irrigation within the Waikato region are designed to apply a daily application depth of 4 mm/day. In Canterbury, the arbitrary system capacity is 5 mm/day or more. In this example we have modelled five different locations within the Waikato region and one location in Culverden, North Canterbury to determine what the optimum system capacities, annual volumes and drainage losses are.

A plant available water (PAW) of 100 mm for a plant water extraction depth of 600 mm has been modelled, using Aqualinc's Irricalc soil-water balance model, for all six scenarios. A minimum irrigation return period of 7 days is used with the irrigation trigger point being a soil-water deficit of 40 mm. A Christiansen's uniformity coefficient (UCC) of 70% has been applied in all cases. The modelled irrigation season is September to May. Daily climate data for the Waikato scenarios was obtained from NIWA's virtual climate stations (VCS), and modelled from 1 July 1972 through to 30 June 2014. For Culverden, rainfall data from VCS P136096 and potential evapotranspiration data from Culverden recorder station, with gaps filled using Christchurch Airport data, was used. The modelled period for Culverden is from 1 July 1972 through to 30 June 2013.

In order to determine the irrigation water requirements, it is necessary to establish the criteria that the irrigation system must meet. The decision criteria used for this example are:

1. 90% of the time soil-water content should be more than 50% of PAW; and
2. 99% of the time soil-water content should be more than 25% of PAW.

The arbitrary daily system capacities of 4 and 5 mm/day were modelled for the Waikato locations and for Culverden, respectively. The system capacity for each scenario was then optimised by gradually reducing the arbitrary value until the lowest system capacity was determined that did not break either of the above two criteria.

Results

The difference between the arbitrary system capacities and the optimised values are shown in Table 1. This shows that, on average over all of the sites, a reduction of 21% in the system capacities can be achieved by optimisation.

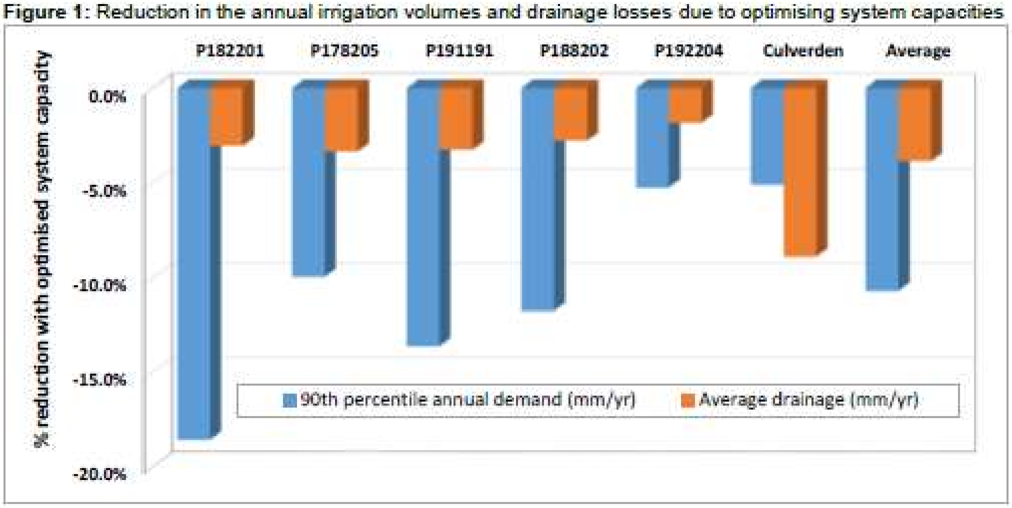
Table 1: Change in system capacities for the arbitrary and optimised approaches

System capacity	P182201	P178205	P191191	P188202	P192204	Culverden	Average
Arbitrary (mm/d)	4	4	4	4	4	5	
Optimised (mm/d)	2.8	2.9	3	3.3	3.6	4.1	
Percentage reduction	30%	28%	25%	18%	10%	18%	21%

As the system capacities are lowered, the areas irrigated can be increased for a given water resource allocation. For example, at P182201 in the Waikato region, the irrigated area can be increased by 43%. For water-scarce Culverden, 22% more area can be irrigated if the optimised system capacity approach is used.

Figure 1 shows that 90th percentile annual volume with the optimised system capacity is on average 11% lower that with the arbitrary system capacity, and drainage is reduced on average by 4% over the sites investigated. This occurs because optimised system capacities take better advantage of rainfall events and the storage capacity of the soil. This finding of a lower annual volume with optimised system capacity is valid for all irrigation takes, regardless of the water source, e.g. groundwater **or surface water** takes. The reduction in drainage has additional benefits such as reducing the potential for nutrient losses below the root zone, benefiting groundwater quality. Lower irrigation water use also reduces energy consumption (i.e. pumping cost). Also, the capital cost of irrigation systems are lower as pipe sizes can be smaller with the lower flow rates. Both of these gains represent a direct cost saving for the farmer.

Figure 1: Reduction in the annual irrigation volumes and drainage losses due to optimising system capacities



Conclusions

Use of optimised system capacities for irrigation water allocation from run-of-streams will allow a greater area to be irrigated from the same allocable resource. This is also important for groundwater takes that are strongly hydraulically linked to surface water. The modelled results shows that the optimised system capacities also reduce the annual water volumes and decrease drainage and potential nutrient losses below the root zone. Reduced water applied will also lower the energy use and capital cost of irrigation systems. Accordingly, optimised system capacities enhance the social, environmental and economic wellbeing of the community.

References

Aqualinc (2010) Update of water allocation data and estimate of actual water use of consented takes 2009–10. Prepared for Ministry for the Environment by Aqualinc Research Ltd, Report No H10002/3, October 2010.