
In the matter of: Clauses 6 and 8 of Schedule 1 – Resource Management Act 1991 – Submissions on publicly notified plan change and variation – Proposed Plan Change 1 and Variation 1 to Waikato Regional Plan – Waikato and Waipa River Catchments

And: **Wairakei Pastoral Ltd**

Submitter

And: **Waikato Regional Council**

Local Authority

STATEMENT OF EVIDENCE OF RICHARD GEORGE CRESSWELL

Block 2 Hearing Topics

Dated: 3 May 2019

STATEMENT OF EVIDENCE OF RICHARD GEORGE CRESSWELL

SUMMARY

TOPIC C1. DIFFUSE DISCHARGE MANAGEMENT

1 I rely on my evidence under Block 1 of these hearings as well as that of Mr Ford, regarding the short-comings of the OVERSEER® software and consequence of using OVEREER® as the determinant of nitrate leach at the farm scale.

2 Specifically, the use of OVERSEER® as the nutrient transport model is restrictive, due to its fundamental steady-state (static or time invariant), empirical (data-driven), deterministic (each set of input data will always produce the same output data) nature which fails to capture temporal variability and struggles to model the consequences of changing practice, or predict future outcomes, including under changed climate scenarios.

3 Further, the use of OVERSEER® to calculate the NRP presents four significant constraints for integrated property or enterprise or sub-catchment management:

3.1 OVERSEER® only provides an annually-averaged discharge value for individual farms (averaged over 30 years of similar practice).

3.2 OVERSEER® has limited predictive capabilities and cannot be used for mitigation strategies dealing with multiple operations or at a fine time-scale (daily, weekly) resolution.

3.3 Multiple versions of OVERSEER® have been shown to generate significantly different results under comparable scenarios. Comparisons across versions is not possible.

3.4 Of the specified environmental indicators, OVERSEER® can currently only model nitrogen and phosphorous flux.

3.5 These limitations are highlighted in the Parliamentary Commissioner for the Environment's recent review of "*Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways*" (PCE, 2018, p. 47).

4 In my opinion the use of a transient (temporal), mechanistic (process-driven), stochastic (statistical) model is required to integrate property, enterprise and sub-catchment processes to provide meaningful end-of-catchment discharge loads (limits and

targets) and numerics for freshwater objectives which reflect the values for the river in the Vision and Strategy.

5 APSIM has been developed as a transient, mechanistic model with stochastic capabilities and is used in the RDST to generate farm-scale leaching rates that can be spatially integrated across sub-catchments.

6 APSIM provides sub-catchment-scale outputs from farm and enterprise-scale modelling that can account for temporal and spatial variability and provide a preditive tool to evaluate changing land-use, climate and management actions.

Nitrogen management/Nitrogen Reference Point

7 The use of a NRP as a universal guide to N control results in four constraints to future development and catchment health:

(a) The NRP if calculated by OVERSEER® only provides a generalised steady-state, constrained (spatially and temporally), consolidated target that glosses over the variabilities and different biophysical processes that combine to produce a TN output load at the catchment scale.

(b) The only possible means to achieve improvement via this methodology is through restriction to inputs and sub-soil outputs at the property scale.

(c) This does not consider transient processes linked to weather and length of groundwater flow paths or spatial variability (changes in soil and aquifer hydraulic properties), nor the potential for short-term loss to generate long-term gain, i.e. this is a short-term approach to nitrogen management.

(d) The NRP does not take into consideration the effects of nitrogen attenuation between the farm and the waterways.

8 Long-term, transient modelling, however, can be used to target key sub-catchments (in particular) and allow modified farming practices to facilitate long-term gains.

9 At the scales proposed for modelling (property, enterprise, and sub-catchment), this would have the outcome that the mix of land use can be tailored to allow off-sets for high impact activities (e.g. dairy) and high vulnerability areas (e.g. riparian and floodplain areas), or for long-term mitigation strategies to off-set initial (establishment) short-term increases in loads.

10 This methodology is undertaken with the RDST and provides a more comprehensive and resilient result to nitrogen management. This has been explored further in the evidence of Mr Conland.

Relative importance of N

11 I rely on my evidence under Block 1 of these hearings as well as to that of Mr Williamson, regarding the nature of denitrification and the apportioning of risk across all catchments with regard to nitrate loading.

12 Generally, denitrification is a prominent process across the region and the "load to come" is unlikely to eventuate as:

12.1 Shallow groundwaters exhibit young (<50 years) mean residence times (**MRT**) reflecting relatively quick transport through the sub-surface to waterways. Deeper groundwaters show older MRT reflecting the longer travel paths.

12.2 Deeper groundwaters exhibit low to negligible nitrate concentrations, whilst shallow groundwaters exhibit variable concentrations (including some very low values).

12.3 Old groundwaters exhibit low oxygen levels which promotes rapid denitrification.

12.4 Upper Waikato stream baseflow generally exhibits young MRT, suggesting significant input from the shallow groundwaters.

12.5 Any load related to previous land use change over the past 40 years would be transported in shallow groundwaters and would have (already) signalled as a pulse in nitrate and other groundwater-transported indicators.

12.6 Rapid response to land use can be observed in monitoring data, supporting the assertions above.

13 I conclude that denitrification is an active process across the Upper Waikato and the spatial differences in denitrification be included in any assessment of nitrogen transport towards waterways.

14 The RDST effectively allows, and calibrates to, denitrification processes within the groundwater modelling component and provides for spatial variability in the landscape's capacity to attenuate nitrogen prior to groundwater discharge to waterways.

15 The calibration process for groundwater transport and nitrate attenuation in the RDST is described in Zhao, et al. (2019). I have

reviewed this methodology and find it rigorous and defensible with good calibration statistics.

BLOCK 2 HEARING TOPICS

1 My name is **Richard George Cresswell**. I have the qualifications and experience recorded in my statement of evidence filed in relation to the Block 1 Hearing Topics.

2 My statement of evidence has been prepared in accordance with the Code of Conduct for Expert Witnesses set out in Section 7 of the Environment Court of New Zealand Practice Note 2014.

Scope of evidence

3 This evidence focusses on the scientific basis for the use of the Nitrogen Reference Point (**NRP**) when determining relative nitrogen impacts; the use of OVERSEER as the primary tool for evaluating nitrogen (**N**) leaching (including assessment of other contaminants as relevant); and denitrification as an important and necessary process to be considered when evaluating stream nitrate levels and potential mitigation scenarios.

4 Particularly, this evidence focusses on the use of the Agricultural Production Systems sIMulator (**APSIM**) nutrient transport model as a viable alternative to OVERSEER to allow predictive modelling at relevant spatial and temporal scales.

5 I will demonstrate that APSIM derives a spatially and temporally explicit NRP and provides a tool for evaluation of farm management practices that can predict the consequences of mitigation strategies on nitrogen leaching and implicitly include multiple pathways and dependencies within farming systems.

6 Results from APSIM can be directly compared to those from OVERSEER, with the advantage of providing a timeseries for incorporation into a predictive, catchment decision support tool to guide mitigation responses to target exceedances (in the context of Table 3.11-1 attributes) and evaluate mitigations.

7 I also discuss my review of the groundwater elements of the Ruahuwai Decision Support Tool (**RDST**) including its predictive performance and management of the nitrogen transport in the Ruahuwai catchment.

8 Lastly, I summarise my findings from my Block 1 assessment of the Collaborative Stakeholder Group (**CSG**) technical work undertaken for the PC1 process, particularly as they relate to considering and modelling nitrate attenuation

TOPIC C1.1 OVERSEER

9 The use of OVERSEER® as the nutrient transport model is restrictive, due to its fundamental steady-state (static and time-averaged), empirical (data-driven and constrained), deterministic (repetitive and in-flexible) nature which fails to capture spatial and temporal variability and cannot model the consequences of changing practice, nor predict future outcomes, including under changed climate scenarios or changing landuse.

10 Further, the use of OVERSEER® to calculate the NRP presents four significant constraints for integrated property or enterprise or sub-catchment management:

10.1 OVERSEER® only provides an annually-averaged discharge value for individual farms (generally averaged over 30 years of similar practice).

10.2 OVERSEER® has limited predictive capabilities and cannot be used for mitigation strategies dealing with multiple operations, or at a sufficiently fine time-scale (daily, weekly) resolution to facilitate management response.

10.3 Multiple versions of OVERSEER® have been shown to generate significantly different results under comparable scenarios. Comparisons across versions as the modelling platform has evolved is not possible.

10.4 Of the specified environmental indicators, OVERSEER® can currently only model nitrogen and phosphorous flux. The manner in which these are modelled, however, is not clear from the documentation and has not been adequately peer-reviewed, particularly for phosphorous, which has multiple transport pathways.

11 These limitations are highlighted in the Parliamentary Commissioner for the Environment's recent review of "*Overseer and regulatory oversight: Models, uncertainty and cleaning up our waterways*" (PCE, 2018, p. 47).

12 Specifically, the report states that OVERSEER®:

12.1 Assumes "best practice" and will generate a production output regardless of the viability of the inputs.

12.2 Does not automatically check that updated inputs result in a realistic result.

12.3 Does not model soil processes explicitly, particularly the important processes of decomposition of crop residues and nitrogen mineralization, nor changes with time or land use.

12.4 Has good calibration for pastoral enterprises, but poor calibration for crops and trees.

12.5 Models at a "whole of farm" scale, where distinct blocks may not be linked (e.g. collection in effluent ponds does not automatically distribute nutrients during fertiliser applications).

12.6 Only models to the base of the root zone (assumed to be 60 cm).

12.7 Has very limited transparency of the modelling process and no peer review for many components (e.g. urine patches; non-background nitrogen losses).

12.8 Has an inherent uncertainty estimated at 25-30%, but likely to realise +/-50% if uncertainty in input data is considered. This generally means that maximum values for leaching rates can be three times the possible minimum values when considering the same input data.

13 OVERSEER® does, however, provide a good starting point for modelling best-practice, steady-state nutrient transport and greenhouse gas emissions for the most common farming practices and mitigations for multiple land uses and can estimate maintenance of fertiliser requirements (the efficiency of fertilizer application being the original reason for development of OVERSEER®). This allows direct comparison to process-based models (e.g. APSIM or the RDST) during the calibration phase of those models.

14 Plan Change 1 (**PC1**) acknowledges that other models can be used. Other models should be considered particularly where greater temporal and spatial context can be generated from the results and where nitrogen-N (and other indicator) levels can be aggregated using an integrating tool (e.g. eWater Source), providing a constrained spatial and temporal context.

15 The use of other appropriate models (e.g. APSIM) should be provided for where they are suitably calibrated and validated (i.e. calibrated to observed data) with on-going refinement and up-date as additional data is collected.

16 The RDST incorporates APSIM to simulate biophysical processes in agricultural systems and model N pathways under different land uses. This generates N leaching values that can be integrated

across sub-catchments, providing integrated, catchment-scale outputs from property and enterprise-scale modelling that can be input to the RDST at a daily time-step.

17 APSIM is a modular modelling framework developed by the Queensland Department of Primary Industries (**DPI**), the Commonwealth Scientific and Industrial Research Organisation (**CSIRO**), and the University of Queensland involving interacting sets of biophysical, management and data entry modules. The modular framework affords potential for new modules to be added to the model from various research initiatives or for parameters of varying soil or management activities to be shared. APSIM offers several advantages to the commonly used industry and government standard farm-modelling platform, OVERSEER®, including:

17.1 Ability to integrate daily climate inputs;

17.2 Ability to integrate dynamic management inputs;

17.3 Finer temporal resolution in modelling processes and calculating outputs.

18 Outputs can be derived that are directly comparable to OVERSEER® values, with the bonus features of:

18.1 Direct integration into transport models for the key indicators.

18.2 An ability to develop temporally varying inputs (e.g climate), or land use change.

18.3 Calibration is to temporally-constrained field data and field trials can be specifically designed to provie data to parameterise the process modules.

18.4 Provision of temporally and spatially explicit outputs.

19 APSIM is increasingly being used in New Zealand to help understand and quantify farming practices and the efficacy of the program has been evaluated against OVERSEER® results.

20 APSIM has been shown to generate comparable long-term results, whilst also providing additional short-term temporal information and agricultural process capability (Cichota, et al., 2012; Cichota, et al., 2013; Snow, et al., 2009; Snow, et al., 2016; Vibart, et al., 2015; Vogeler, et al., 2013).

21 In particular, greater flexibility in development of management practices and the ability to incorporate time-sensitive and transient farming scenarios (such as variable fertiliser applications; changing

practice with time, and climatic variability) allows realistic farming scenarios to be developed and provides a solid platform for future impact predictions at a daily time-step.

22 APSIM can make a comparison for each dominant land use with reference to the expected and historical need for nitrogen fertiliser application. ASPIM simulates fertiliser application to the prescribed soils and for specific crop and stock rotations. This generates theoretical nitrate profiles that evolve with time depending on rainfall, soil factors and soil saturation. The results can be compared to field examples and averaged to compare to results obtained from OVERSEER®, or other N loss estimators, and can provide a spatially and temporally explicit dataset of nutrient leaching across the landscape which can then be used as input to deep drainage and subsequent transport modelling using surface and groundwater modelling packages.

23 Further, unlike OVERSEER®, APSIM can also be used as a pre-experimental tool to explore the potential response from different conditions imposed on a farm and hence constrain experimental parameters (e.g. Buckthought, et al., 2011). This also allows the exploration of additional management strategies, such as fertiliser application rates, stocking rates and seasonal changes and hence can be applied to development of mitigation and management strategies.

24 As an example of the distinction between APSIM and OVERSEER®, Figure 1 compares the monthly output (leach) of N beneath an established dairy property or enterprise on well-drained Taupo soils, typical of the Upper Waikato region. On this hypothetical property, both APSIM and OVERSEER® long-term (annual) averages are similar at this climate location (~45 kg/ha/a).

25 The impacts of seasonal rains over the 45-year climate record on leaching of fertiliser application can be readily seen in the APSIM results, whilst OVERSEER® only represents this as a single average value. The implications of the OVERSEER® result can only be considered through expert opinion.

26 The potential outcome of this exercise is that, rather than requiring all farming activities to satisfy similar rules referencing N and blanket management rules for the other indicators (which are both hard to model and problematic to monitor), the use of APSIM and the RDST allows targeted mitigations both spatially (in a more sophisticated way by property, enterprise, or sub-catchment) and temporally (through daily assessment) to achieve the PC1 anticipated environmental outcomes.

27 APSIM thus provides the initial inputs to an integrated modelling platform that combines farm processes, surface water drainage and groundwater transport to provide spatially and temporally explicit

predictions of nutrient and other indicator levels across the model domain. This modelling process has (to date), however, only been applied to the upper reaches of the Upper Waikato (the 10 RDST sub-catchments), but this provides a model framework that could be applied across the entire Waikato (and Waipa) catchments.

28 The predictive nature of this modelling allows forward consideration of mitigation actions and allows consideration of future land use changes in the context of whole-of-catchment management and targeted actions.

29 APSIM provides the necessary temporal resolution to couple with other components of the RDST to investigate seasonal as well as inter-annual variability and generate scenario datsets for predictive analysis of farm management options, including the incorporation of land use changes and climatic variability.

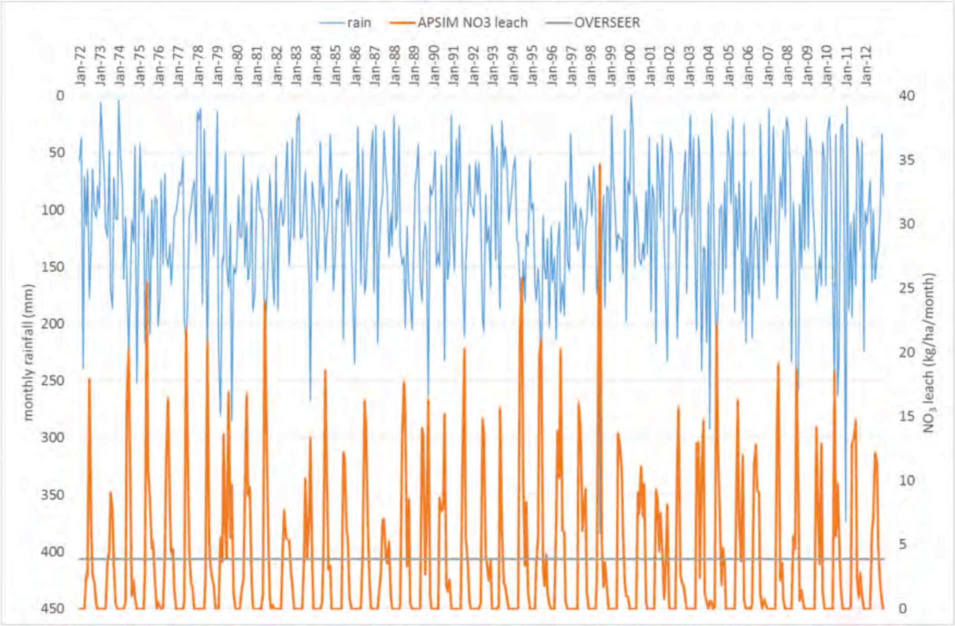

Figure 1: Example comparison of APSIM and OVERSEER® monthly nitrate leaching rates for a theoretical mature dairy farm in the Upper Waikato compared to the rainfall record from 2008 to 2012

Schedule B – The Nitrogen Reference Point (NRP)

30 The use of an NRP as a universal guide to N control can have multiple benefits to future development and catchment health, but its use in the context of the PC1 results in four significant constraints:

30.1 The NRP only provides a steady-state, spatially and temporally constrained, generalised, consolidated target that glosses over the variabilities and different biophysical processes generating the value. A prescriptive determination of the NRP needs to carefully consider climatic variability and existing land use condition if it is to be effectively employed. Specifically, use of a single (or even two) year average approach will not capture the natural variability inherent in the region or with time.

30.2 The only possible means to achieve improvement via this methodology is through restriction to inputs/outputs at the farm scale. Many properties or enterprises have little or no control on up-stream inputs and the variability in natural processes may favour one area over another and hence result in biased responses to management practices.

30.3 The NRP does not consider transient processes or spatial variability in management practice, nor the potential for short-term loss to generate long-term gain, i.e. this is a short-term approach to nitrogen management.

30.4 The NRP does not take into consideration the effects of nitrogen attenuation between the farm and the waterways. Specifically, denitrification of nitrate in groundwater and within the waterways can significantly reduce the load to the river.

31 Long-term, transient modelling as performed by the RDST, however, can be used to target key sub-catchments (in particular) and allow modified farm practices to facilitate long-term gains.

32 At the scales proposed for modelling (property, enterprise, and sub-catchment), this would have the outcome that the mix of land use can be tailored to allow off-sets for high impact activities (e.g. dairy), or for long-term mitigation strategies to off-set initial (establishment) short-term increases in loads.

33 An appreciation of historical and temporal variability across the sub-catchments, can therefore provide for a more equitable distribution of targets. Thus, poorer-performing (greater leaching) farmers in critical sub-catchments might be targeted and this would provide

greater catchment health benefits whilst allowing best-practice farmers and low leaching operations to continue to develop

The 75th Percentile

34 The objective of PC1 is to reduce all outputs (from elevated sources of N) to below a common 75th percentile (the NRP) based on land-use data for 2015/16. This is seen by WRC as equitable as it targets the high polluters (especially dairy) and is (relatively) easy to manage. However:

34.1 This penalises early adopters (pre-2016/17) of best practice who have already achieved reductions in outputs and improvement in waterway health.

34.2 Does not account for spatial and temporal variability, both natural (e.g. climatic) and human (e.g. interpretation of "best practice").

34.3 There is considerable variability in nitrogen leaching across different sub-catchments and low leaching operations within high leaching catchments would be penalised even if their leaching rates were not critical, based either on absolute outputs or due to significant attenuation processes between the enterprise and the waterway.

34.4 Land uses currently in transition will not provide accurate representation of final land use leaching rates.

35 An appreciation of historical and temporal variability (e.g. Figure 2) across sub-catchments can therefore provide for a more equitable distribution of targets.

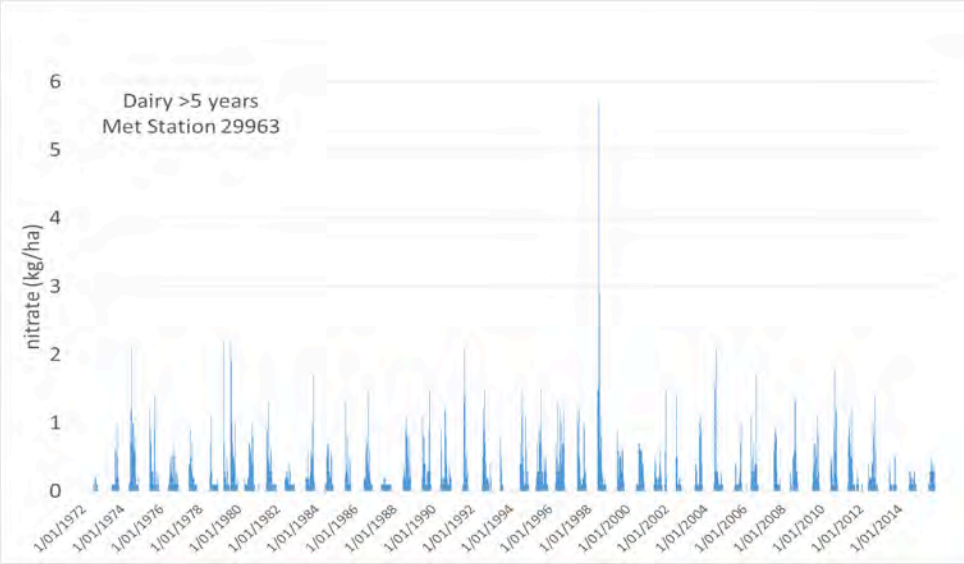

Figure 2: Daily nitrate leach modelled under mature dairy land use with the rainfall pattern observed at a rainfall station with ~1200 mm average long-term (45 years) annual rainfall

36 Thus, poorer-performing (greater leaching) farmers in critical sub-catchments might be targeted and this would provide greater catchment health benefits whilst allowing best-practice farmers and low leaching operations to continue to develop.

Role of denitrification in RDST

37 Biological denitrification occurs naturally when certain bacteria use nitrate in the absence of adequate oxygen to facilitate their respiratory process. Denitrifying bacteria are ubiquitous in nature, hence denitrification occurs wherever oxygen levels are low and a suitable electron donor (such as carbon, or iron sulphide) is present to promote the enzymatic reaction (e.g. Tesoriero, et al., 2011). Rates are variable, however, dependent on the relative availability of oxygen and two distinct denitrification pathways can be defined:

37.1 Shallow, vertically-controlled denitrification where shallow recharge (leaching) waters reach a de-oxygenated water-table, commonly associated with peaty soils or organic-rich clay soils where water movement is slowed. Denitrification tends to be rapid as long as sufficient organic carbon is present and oxygen levels are below 2 mg/L.

37.2 Deeper, horizontally-controlled denitrification where reduced waters promote gradual denitrification over variable time frames dependent on oxygen and carbon concentrations.

38 Thus, even where conditions promote denitrification (low oxygen levels, high carbon concentrations), reduction, or attenuation, of nitrate may not be significant if the source of nitrate either outstrips the denitrification rate, or the travel time from source to receptor is too short for the rate to be effective.

39 An important consideration for the efficacy of denitrification is therefore whether there is sufficient time for denitrification to occur and it is also important to understand this potential lag time when considering changing sub-soil drainage fluxes and the measured changes in the stream nitrate discharge downstream in order to characterise any future impacts that are yet to occur (the potential load to come). Forward prediction can be achieved through numerical modelling of solute transport, for example with the use of MODFLOW and MT3D/RT3D, as is used in the RDST.

40 Calibration techniques within the groundwater component of the RDST undertakes this assessment and facilitates spatial awareness of denitrification rates.

41 Calibration of the groundwater modelling within the RDST is described in Zhao, et al. (2019). I have reviewed the methodology and results and I am satisfied that a good calibration has been achieved, both for steady-state and transient modelling and appropriate sensitivity assessment has been performed identifying the level of uncertainty in the model results and highlighting where additional monitoring would be useful to refine the model precision and accuracy.

42 The methodology used in the RDST requires quantification of the two denitrification pathways identified in paragraph 35. This was undertaken largely through the calibration process of the model development. An alternate comparison can be made through assessment of monitoring data for groundwater across the model domain.

43 I have therefore analysed forty-three tritium analyses (17 groundwaters and 26 surface waters) collected over the period 2004 to 2015 to estimate mean residence times (MRTs) for water feeding these sites to gain an appreciation of the time scale of groundwater discharge and hence whether the methodological approach in RDST is sound.

44 In summary, I find that:

44.1 Tritium-derived MRT for the surface water sites are young (more than 75% record MRT less than 40 years, with over a third indicating less than 15 years), which are similar to values recorded from shallow groundwaters;

44.2 Calculated MRT for deep groundwaters exhibit variable ages, but include very old waters that appear to contribute little water to surface water discharges;

44.3 Estimated flow path lengths for the shallow groundwater feeding the surface water sites ranges from one to six kilometres; and,

44.4 Indicative flow paths for deeper groundwaters, with older MRTs, can be in excess of 10 km.

45 Deeper waters take longer paths over longer periods of time which favour greater attenuation of nitrate prior to discharge downstream.

46 The analysis suggests that nitrogen transport to the surface waters occurs primarily via shallow, relatively fast moving groundwaters and corroborates the methodology undertaken within the RDST and described in the evidence of Mr Williamson.

47 Critically, these results indicate that:

47.1 Any nitrate pulse associated with landuse changes over the past 40 years associated with shallow, faster-moving waters would therefore have already moved through the landscape to waterways.

47.2 Any nitrate associated with deeper, slower-moving groundwaters is likely to have been attenuated through denitrification.

48 The rise in nutrient levels recently observed in Waikato streams thus reflects the former; very low levels of nitrate observed in deeper groundwater bores reflects the latter.

49 The age dating results therefore validate the approach undertaken in the RDST.

50 Research carried out worldwide also highlights the important role riparian buffers play in denitrifying diffuse discharges.

51 For example, Rassam, et al. (2005) show results and modelling of groundwater discharging to organic-rich, slow-flowing surface waters resulting in a high potential for denitrification in the shallow (near-surface) groundwater system. They estimate that nitrate concentrations may reduce by a factor of two for each day the nitrate-rich waters spend in this environment.

52 In-stream denitrification can also be effective and Harvey, et al. (2013) and Roley, et al. (2012) highlight the importance of channel margins and effective riparian interactions that result in significant denitrification (up to 3 orders of magnitude reduction) in the hyporheic (water-sediment interface) zone. Numerous studies (e.g. Bowden, et al., 1991; Santoro, 2010; Sawyer, 2014, Morgenstern, et al., 2015; Clague, et al., 2019) support these findings, with Clague et al (2019) reporting on similar conditions encountered

within the Reporoa Basin (Waiotapu Catchment: WRC catchment #65) in the north of the RDST domain.

53 Relevant to this discussion of catchment-wide denitrification is work that I and other science experts undertook on the analysis and modelling of water flows, landuse and water quality in the Selwyn-Waihora catchment and Te Waihora / Lake Ellesmere[1]. That work highlighted the spatial and temporal variability across transmissive landscapes (such as is present across most of the Upper Waikato) and the capability of landscapes with discharging groundwaters to moderate nitrate concentrations in surface waters.

54 Detailed assessment of the hydrochemistry and hydrogeology of the Selwyn / Waihora catchment demonstrated that despite high nitrate leaching associated with increased agricultural landuse on the Central Plains, over 80% of the nitrogen species was reduced prior to any discharge (by surface or groundwater) to Te Waihora / Lake Ellesmere due to up-welling groundwaters at the coast and favourable conditions (low pH, high organic carbon) promoting denitrification.

55 Denitrification was shown to occur within the final 10 km prior to discharge and was associated with relatively young groundwaters. This highlights the efficacy of a good riparian zone adjacent to any water body to help reduce the impact of any nitrate incursion.

56 The presence of a significant riparian zone (which would need to be defined for each circumstance) would further act as a buffer for other contaminants. In particular, retention of sediment-bound phosphorous and sediments in general would be achieved, whilst the distance from the river would preclude direct transmission of pathogens to waterways.

RDST and scenario modelling

57 The RDST approach builds on the information acquired by WRC (via State of the Environment monitoring programmes) and develops it further with the additional data available for the broader RDST sub-catchments. The PC1 process may therefore be seen as an initial step towards sub-catchment management that has been superseded by modelling, monitoring and management for the Ruahuwai sub-catchments, which provides a case study for how PC1 could be amended by subsequent plan changes.

58 To provide confidence that APSIM is modelling farming activities appropriately and not merely providing a tool that scales leaching factors, APSIM also needs to demonstrate a close comparison to

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[1] Undertaken for the Sustainable Land and Water Group during the Variation 1 to the Land and Water Regional Plan.

other critical parameters, modelled by other protocols that have scientific acceptability for comparable conditions.

59 Comparison to field trials across New Zealand confirm that the APSIM results for nitrate leach are comparable to those physically observed under similar conditions (e.g. Vibart, et al., 2015).

60 Multiple APSIM models were created during the development of the RDST to mimic different land uses across the region. These incorporated different irrigation schemes, livestock variability (e.g. sheep vs cows) and cropping practices. Separate modules were created for forestry and to consider conversion from forestry to dairying. OVERSEER® inputs and parameterisations were used wherever feasible to allow meaningful comparisons.

61 For livestock land uses, multiple management modules are combined to represent the collective effects of urine patch distributions across grazed paddocks. As livestock practices potentially represent the greatest contributing land uses to nitrogen leaching through soil profiles to groundwaters, it is critical to understand and accurately model the effects of varying stock rates and the consequent distribution of urine patches and preferential nitrogen delivery.

62 In addition, APSIM models have been developed that capture both current stock and land management practices and also the stage of land development (conversion) from forestry to dairy farming. Thus, following clear-felling of existing pine plantations, pine slash is mulched and spread over paddocks. The first 1-2 years are then characterised by a reduction in leaching due to significant increase in surface and topsoil organic matter. Thus, as this organic matter breaks down, a significant nitrogen immobilisation demand is created as soil organisms and new growth convert available mineralised nitrogen (nitrate and ammonium) to organic nitrogen and isolate it from the nitrogen cycle. Soil conditions stabilise between five and ten years following conversion (e.g. Snowdon, et al., 2005) and after ten years all mulch is considered to have been broken down and the system stabilises, with rainfall variability becoming the primary control on nitrate leaching.

63 Other land uses prevalent within the Ruahuwai sub-catchments include sheep and beef farming, lucerne and kale cropping and lifestyle blocks. Each model was tailored to represent local conditions and farming practices and run for two soil types (poorly drained and well drained) based on the dominant Taupo soils and using management practices that include irrigation where relevant.

64 It was noted that early APSIM results consistently generated higher leaching rates compared to OVERSEER v.6.2. Subsequent updates to OVERSEER v.6.3, however, have

realised comparable leaching rates to the original APSIM results, validating the APSIM approach to nitrate leaching.

65 The Section 32 Report notes that:

> "Overseer is regularly upgraded, resulting in version changes. Following a version change, the results from the model could change, even if the approaches used on the farm have not changed. In other words, the same property-level inputs to each new Overseer version could give a higher or lower nitrogen output. It is not possible to predict how each landowner will be impacted, because each property has a different mix of inputs, and the changes are not constant for each version change. This means each farm is affected differently by a version change (for some more favourably, some unfavourably). There are ways to work around changing versions, but they take extra resources to run original input data through each changed version and public perception could be that landowners are not complying with property limits if nitrogen leaching numbers change." (p .148)

66 From this, it is appreciated that, "a nitrogen-related farm practice using one version of the model cannot be compared with a later version of the model." (p. 150).

67 It should be noted that APSIM models a farm at the point scale (i.e. in 1 dimension only). These results are then up-scaled to the size of the represented farm. Thus, multiple modules are combined to generate an equivalent farm to that modelled by a single OVERSEER® farm model.

68 This introduces increased complexity, but also increased flexibility and allows each component to be individually assessed and scrutinized.

69 The use of process-based models like ASPIM then allows the input of varying parameters and provides the capability to run predictive models to examine future potential outputs.

70 APSIM modelling successfully captures daily, monthly and seasonal variations associated with fertiliser application, rainfall events and expected plant growth for all land use modules.

TOPIC C1.4 REDUCTIONS

71 In the Section 32 Report discussion on scenario modelling, the Waikato-Waipa catchments were split into 74 sub-catchments and at this scale reduction of discharges of nutrients, pathogens and sediments was required universally and barely managed to

constrain key indicators to acceptable levels. At this scale, the RDST constitutes 10 of the sub-catchments in PC1 and introduces an 11th subcatchment Tahirakuri as 66A.

72 I believe the RDST can demonstrate that the variability seen by modelling in the 415 catchments in the RDST across the same model domain provides the scale required to identify critical source areas to target those sub-catchments that can make a substantial difference to attribute levels.

CONCLUSIONS

73 The RDST approach builds on the information acquired by WRC (via State of the Environment monitoring programmes) and develops it further with the additional data available for the broader RDST sub-catchments. The PC1 process may therefore be seen as an initial step towards sub-catchment management that has been superseded by modelling, monitoring and management for Ruahuwai, using the RDST as the basis for adaptive catchment management.

74 The RDST provides a case study for how PC1 could be amended, and how the aspirational expectations for the next planning period (post 2026) of PC1 might also be provided for by subsequent plan changes.

Dr Richard Cresswell
Principal Hydrogeologist and Water Discipline Lead
3 May 2019

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