BEFORE THE PROPOSED NATURAL RESOURCES PLAN HEARINGS PANEL

IN THE MATTER	of the Resource Management Act 1991
AND	
IN THE MATTER AND	of Water quality
IN THE MATTER	of the submissions and further submissions set out in the S42a Officer Report

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STATEMENT OF PRIMARY EVIDENCE OF ALEXANDER (SANDY) HEWGILL ELLIOTT ON BEHALF OF WELLINGTON REGIONAL COUNCIL

TECHNICAL – WATER QUALITY

12 January 2018

TABLE OF CONTENTS

1. SUMMARY

1.1 My name is Alexander (Sandy) Hewgill Elliott. I am a water quality modeller with 30 years' experience in water quality modelling and over 20 years' experience specializing in catchment modelling for water quality. I have been employed for 19 years at the National Institute of Water and Atmospheric Research (NIWA), where I am Principal Scientist for Catchment Processes and Programme Leader for the Causes and Effects of Water Quality Degradation programme. I have a Ph.D. in Environmental Engineering Science from the California Institute of Technology and a B.E. in Engineering Science from the University of Auckland. I am a member of the New Zealand Hydrological Society, the New Zealand Freshwater Sciences Society, and the International Environmental Modelling and Simulation Society. I am an expert with regard to mathematical modelling of contaminant generation and transport in catchments and streams, with particular emphasis on catchment modelling for diffuse sources of water quality degradation. I have developed and used a range of catchment models at a range of spatial and temporal scales, routinely applying these to inform catchment planning and policy development in New Zealand. I have also conducted associated monitoring, field experiments, and data analysis.

1.2 I have been asked to provide evidence in response to submissions received coded to topic Water Quality for the following specific matters/areas/schedules:

(a) Setting region-wide nutrient limits as a means for raising MCI values to meet target values in Wellington streams and rivers.

1.3 The scope of my evidence includes assessing the evidence by Adam Canning relating to establishing nutrient load limits as a means for achieving target nutrient concentrations in streams and rivers of the Wellington region. My evidence assesses the fitness-for-purpose of that evidence, including the technical rigour of the modelling methodologies employed.

1.4 The methodology for assessing submissions involved critically assessing Mr Canning's modelling methods and results. I

assessed whether the calculation method was complete and robust, and also performed some analysis of water quality records to support my arguments.

1.5 Having examined Mr Canning's evidence, I have concluded that the proposed methods are not suitable for setting on-land load limits. This is because the methods are unclear and not documented appropriately, there are many inappropriate approximations, the methods for determining in-stream loading for dissolved phosphorus are inappropriate, and the method for determining loading from the land is unduly approximate.

2. INTRODUCTION

2.1 My name is Alexander (Sandy) Hewgill Elliott. I am a water quality modeller with 30 years' experience in water quality modelling and over 20 years' experience specializing in catchment modelling for water quality. I have been employed for 19 years at the National Institute of Water and Atmospheric Research (NIWA), where I am Principal Scientist for Catchment Processes and Programme Leader for the Causes and Effects of Water Quality Degradation programme. I have a Ph.D. in Environmental Engineering Science from the California Institute of Technology and a B.E. in Engineering Science from the University of Auckland. I am a member of the New Zealand Hydrological Society, the New Zealand Freshwater Sciences Society, and the International Environmental Modelling and Simulation Society. My area of expertise is in mathematical modelling of contaminant generation and transport in catchments and streams, with particular emphasis on catchment modelling for diffuse sources of water quality degradation. I have developed and applied a range of catchment models at a range of spatial and temporal scales in New Zealand.

2.2 I have been engaged by Great Wellington Regional Council to provide evidence relating to the Proposed Natural Resources Plan for Water Quality.

3. CODE OF CONDUCT

3.1 I confirm that I have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note and that I agree to comply with the code. My evidence in this statement is within my area of expertise. I have not omitted to consider material facts known to me that might alter to detract from the opinions which I express.

4. SCOPE

4.1 I have been asked to provide evidence in response to submissions received coded to topic Water Quality for the following specific matters/areas/schedules:

(a) Setting region-wide nutrient limits as a means for raising MCI values to meet target values in Wellington streams and rivers.

4.2 The scope of my evidence includes:

(a) assessing the evidence by Adam Canning relating to establishing nutrient load limits as a means for achieving target nutrient concentrations (both nitrogen and phosphorus) in streams and rivers of the Wellington region.

(b) assessing the fitness-for-purpose of that evidence, including the technical rigour of the modelling methodologies employed.

4.3 My evidence does not address the suitability of the methods that were used to relate MCI targets to in-stream nutrient concentrations.

4.4 **SUMMARY OF SUBMISSIONS ADDRESSED BY MY EVIDENCE**

My evidence addresses the written evidence of Adam Canning dated 24 May 2017 for the Proposed Natural Resources Plan for the Wellington Region, which is being used in submissions by Fish & Game to propose interim limits for diffuse nutrient sources in the Wellington Region. The Fish & Game submission mainly addressed limits for nitrogen, but also mentions phosphorus in relation to trading of emissions for phosphorus. Both nutrients are addressed in Adam Canning's evidence. The Canning evidence proposes source limits based on the following approach:

(a) Concentration limits for dissolved inorganic nitrogen (DIN) and dissolved reactive phosphorus (DRP) are obtained from the analysis by Professor Russell Death, which identifies nutrient concentrations required to target macroinvertebrate index objectives, and is appended to Mr Canning's evidence.

(b) The concentration limits are used to derive an in-stream load limit (tonnes of nutrient passing down the stream per year) for 13 flow monitoring sites where concentration data are available from nearby water quality monitoring sites.

(c) Diffuse 'on-land' mean annual loading of nutrients are related to in-stream loads using an attenuation factor, for the subcatchments of each of the monitoring sites.

(d) If reductions in stream loading are required to meet the in-stream limit, the associated on-land load loading limit for each subcatchment is determined.

(e) As a further step, the on-land load limit is allocated to Land Use Capability (LUC) classes in the relevant subcatchment, based on weighting factors for each LUC, to derive a load limit for each LUC class in each subcatchment. My evidence does not address this allocation step.

5. METHODOLOGY

5.1 I critically assessed Mr Canning's modelling methods and results. I assessed whether the calculation method was complete and robust, following and where appropriate checking the steps of his method. I also analysed some water quality records to check Mr Canning's results and to support my arguments. I centred my assessment around key steps of Mr Canning's approach:

(a) Determination of required in-stream load reductions.

(b) Determination of load generated on the catchment (on-land load).

(c) Determination of catchment attenuation and on-land load limits.

5.2 Documents that were referred to in preparing this evidence include the PNRP and the references listed at the end of this evidence.

5.3 I obtained water quality records for the sites used in the Canning evidence, from the Greater Wellington Regional Council or from National River Water Quality Network data held by NIWA, for the same time period as in the Canning evidence. I obtained the PNRP River Classes of each location from the Greater Wellington Regional Council, to enable me to look up the corresponding concentration limits from Professor Death's tables appended to Mr Canning's evidence.

5.4 I raise the following issues related to Mr Canning's evidence:

(a) Several critical pieces of information on the methodology for determining load limits are missing from the evidence or incomplete, so that the soundness cannot be assessed fully. In particular:

- Methods for determining in-stream load limits from concentrations are not presented.

- Methods for determining attenuation factors for nitrogen are not presented.

- For several subcatchments, no on-land load limit or current on-land loading information is provided.
- The method for accounting for loading from upstream subcatchments is unclear.
- Methods for allowing for the influence of point sources are not presented.
- Methods for quantifying non-pastoral sources of nutrients are not clear.

(b) The methods for calculating on-land loading for DRP and the associated in-stream loading are not fit for purpose.

(c) The analysis does not explicitly take into account the fact that only a portion of total nitrogen loading is in the nitrate form.

(d) The proposed percentage reduction of in-stream loading does not relate to required concentration reductions that I have calculated, raising questions about the suitability of the method for determining percentage reductions of loading.

(e) There are several inaccuracies or inappropriate approximations. For example:

- no allowance is made for water quality sites being at a different location from flow monitoring sites;
- DIN (which includes both ammonium and nitrate) is used interchangeably with nitrate concentrations;
- the source load estimation method is quite approximate, when more precise assessments are available.

(f) The method does not take account of variability of River Class (and associated limits) within a subcatchment.

6. IN-STREAM LOAD REDUCTIONS

6.1 Mr Cannings evidence (paragraph 23 in his evidence) does not provide sufficient information on the method for determining in-stream load limits, and the methods include inappropriate approximations, as outlined below.

6.2 No information is provided on how the concentration limit is converted to a load limit. Was it obtained by ensuring that the target concentration is achieved at all times? Or, is it based on scaling the measured load by the required reduction in concentration? These methods would typically give different results. Natural variability in concentration means that the measured load is typically greater than would be obtained by applying a constant concentration (e.g., Oehler and Elliott 2011). Hence this is an important detail which has implications for the source load limits.

6.3 The Death limit tables appended to Mr Canning's evidence are for nitrate, whereas the Mr Canning's assessment is based on DIN, which includes both nitrate and ammonium forms of nitrogen. Typically, ammonium is only a few percent of DIN, but my analysis of the water quality data for the sites used by Mr Canning show that in some cases the ammonium contribution is significant. For example, for the Ruamahanga River and McLays, the median ammonium concentration is 12.5% of the median DIN concentration. This introduces error into the analysis. The submission by Fish and Game to the PNRP plan (S308) provides DIN limits, which may be more relevant to Mr Canning's analysis.

6.4 Mr Canning seems to have incorrect MCI limits in his Table 1 for several streams (Pauatahanui Stream at Gorge, Porirua Stream at Town Centre, Akatarawa River at Cemetery, and Kopuaranga River at Stuarts). I obtained the River Classes from GWRC, checked these on their online mapping system (which is the definitive source), and looked up the relevant MCI values for the River Class from Table 3.4 in the PNRP, so I am reasonably confident in my MCI limit values.

6.5 Percentage concentration reductions do not align with required in-stream load reductions. As a sensibility check of the required in-stream load reductions, I estimated the concentration reduction (expressed as a proportion) that would be required to reduce measured concentrations to the concentration limit derived from the correct River Class, and compared these with the load reductions from Mr Canning's Table 1. The concentration limits were based on the upper end of Prof. Death's range, which is relevant for the monitored streams (personal communication from Prof. Death, relayed by Dr Richard Storey). For nitrate (my Table 1), the direction of change required is consistent with Mr Canning's (both agree whether or not a reduction is required. However, there are some significant differences in the magnitude of change required for several of the sites. For the Akatarawa site, the values in Mr Canning's Table 1 are not internally consistent for N, because the measured load (for the combined method which he seems to adopt for other sites) is less than the load limit, while the stated required load reduction (-42.3%) implies that current loads are greater than the load limit. This suggests an error in the calculation or a flaw in the methodology. For DRP, there are also discrepancies, three of which overlap with errors in River Class allocation. It is difficult to make definitive statements about Mr Canning's limiting loads because he does not present the details of the method. Nevertheless, the above comparisons raise concerns about the robustness of the method used by Mr Canning to achieve the required load reductions.

6.6 Loads are calculated at the flow sites, which do not always align with water quality monitoring sites. There does not seem to have been any correction for this. In most cases this is not an issue because the sites are at the same location or close, but for the Waikanae site, significant errors could arise because the water quality site (presumably Waikanae River at Greenaway Rd, although this information is not provided in the evidence), is 4.8 km downstream of the flow station and there is intervening intensively farmed catchment which could alter the concentrations. A solution to this problem would involve use of the water quality sites for load assessment and load limits, making corrections to the flows at these sites where necessary.

6.7 In summary, the method for determining required load reductions are not presented in sufficient detail or include inappropriate approximations.

(a) No information is provided on how the concentration limit is converted to a load limit, and this has implications for setting source limits.

(b) Nitrate concentrations are confused with DIN concentrations, and there is a significant difference in some cases.

(c) Incorrect MCI targets seem to have been used for four sites.

(d) Concentration reductions (expressed as percent) do not align with required in-stream load reductions.

(e) The load calculation method does not account for differences between the location of flow sites and water quality sites.

7. LOAD GENERATED ON LAND

7.1 Mr Canning's method for determining DRP loads generated on the land is unclear. Mr Canning states that he uses DRP leaching losses from a presentation by Grinter and Parminter (2016a). Those yields are in the order of 1 kg/ha, whereas yields from Table 3 in Cannings's evidence are mostly in the order of 0.1 kg/ha. It is unclear how DRP loadings were derived from the values presented by Grinter and Parminter. Canning refers to DRP loading from Elwan et al. (2015) for non-farm land-uses, yet that reference only addresses nitrogen, so the source of information is unclear.

7.2 The method for determining DRP loading from land is inappropriate. Consequently in-stream loads and catchment limits are not appropriate. This is because the DRP loading is derived from the OVERSEER model. OVERSEER does not provide losses of DRP – it only provides losses of TP. The tables in Grinter and Parminter (2016a) do refer to 'leaching losses to root zone', which might possibly be interpreted as DRP losses. However, the report by Grinter and Parminter (Ministry for Primary Industries, 2016, Table 5) states that those numbers are taken from are taken from the OVERSEER farm-level phosphorus budget output. That budget only contains the total losses of P, and the tables in Grinter and Parminter seem to be total losses of P. Even if the 'leaching other' in the 'losses to water' breakdown Nutrient Budget report in OVERSEER were used to somehow generate DRP loading, the documentation for OVERSEER (Gray et al. 2016) clearly state that the 'leaching other' is not leaching, but refers to losses such as losses from ponds and raceways. More generally, there is no clear way to establish DRP losses from TP losses. In high-erosion areas, much of the loss is in particulate, not dissolved form. My analysis of data from the Wellington stream sites indicates:

(a) median DRP is 34 to 84% of TP,

(b) the load fraction of DRP will likely be less because during high flows there tends to be a preponderance of particulate P, and

(c) loads are dominated by conditions in high flows for P, based on my analysis of national datasets.

7.3 For several catchments, no on-farm loads are provided. There is no underlying reason why the loads generated on the land could not be calculated, and why they are not reported. This makes it difficult to assess the suitability of the load estimation in these catchments.

7.4 The analysis by Canning assumes that the loss per unit area for a particular land use is uniform over the region. Nutrient losses are known to vary with factors such as soil type, slope, and rainfall, yet those factors are not taken into account. More recent work in the Ruamahanga catchment does take these factors into account, providing more refined estimate of loads (Bright, 2016). The method for calculating on-farm loads is tied to method for determining load limits, because they are used in conjunction with measured loads and in-stream loads. Hence, inaccuracies in on-land load estimation will translate into inaccuracies in load limits.

7.5 In summary, there are several aspects of Mr Canning's method for determining the load that make the methods unsuitable or of questionable robustness:

(a) Methods for determining DRP loads generated on-land are unclear and inappropriate. Consequently in-stream loads and catchment limits are not appropriate

(b) On-farm loads are not provided for several catchments, with no justification. This raises questions about the suitability of the values.

(c) Methods for calculating losses from the land are inappropriately approximate.

8. CATCHMENT ATTENUATION AND LOAD LIMITS

8.1 For four out of 13 sites, no attenuation factors or load limits were provided for nitrogen. On-land loads are not provided either, so that the attenuation cannot be inferred. This makes it difficult to assess the robustness of the method.

8.2 For N, no information is provided on how the attenuation factor is determined. However, my analysis suggests that the attenuation factors may have been tuned based on measured in-stream loads. I calculated in-stream load from on-land per-area loads from Canning's Table 3 multiplied by the corresponding areas derived from Canning's Table 2. I rejected sites which were in nested subcatchments because this introduces additional complications. I also rejected one site where the areas from Table 2 were inconsistent with my independent assessment. For the remaining five sites where data loads were provided (Waikanae, Horokiri, Akatarawa, Kopuaranga, and Taueru), the inferred instream-loads were 86% to 89% of the measured loads. Possibly the attenuation factor may have been tuned to provide an in-stream load that is about 85% of the measured instream load, and it is quite common to adjust attenuation to match measured loads. However, there seems to be some bias (predictions low by about 15%), and the associated load limit will also be biased low.

8.3 For DRP, no attenuation factor is provided. However, for the five sites above, the on-land yield times area is close to the measured yield based on measured in-stream loads. This implies an attenuation factor of 1, without justification, and possibly some adjustment of sources or in-stream loads.

8.4 The N calculation method does not take account of the fraction of N that is not in nitrate or ammonium form. The losses from OVERSEER are for total N (TN), and typically a large proportion of this is in the nitrate form. However, by the time the nutrient reaches the monitoring site, a considerable proportion appears in non-DIN forms. From my analysis of the monitoring station median concentrations, nitrate is typically only 60% of TN (range 38 to 81%), with similar results for DIN/TN. This should be taken into account when converting on-land loading of TN to instream loading of nitrate or DIN.

8.5 No account is taken of spatial variation of attenuation within a subcatchment. In reality, losses from different parts of a subcatchment will be subject to varying attenuation, which may arise from factors such as denitrification processes within groundwater, different flow paths and lengths of time spent in groundwater, riparian conditions encountered, and length of time of passage in the stream network.

8.6 It is unclear how the on-land load limits are adjusted for upstream inputs. Such adjustments are referred to in Canning's Table 3, and are required for nested subcatchments (Hutt River at Taita Gorge, Ruamahanga River at Wardells, and Ruamahanga River at Waihenga Bridge). Specifically, in setting the load limit, it is unclear whether it is assumed that upstream subcatchments have adjusted their load to meet the in-stream load limit. Presumably this is the case (as would be appropriate) but it is not clear and difficult to infer from the limited data provided.

8.7 The method used to for account for point sources when establishing or applying on-land load limits is unclear. Were these subtracted from the in-stream load limit before determining the degree of load reduction required? The method for making such corrections has implications for limit-setting, yet is not described.

8.8 In summary, the methods for determining catchment attenuation and on-land load limits are unclear or inappropriate, for the following reasons:

(a) Attenuation factors and load limits, and on-land loading are not provided for several catchments, with no justification or rationale.

(b) No information is presented on how the attenuation factor for N is determined, when this is a key part of the method. My analysis of five sites suggests that the attenuation may have been tuned so that predicted loads are about 85% of the measured loads, introducing some bias, with the associated load limit being lower than they need be by about 15%.

(c) No account is taken of spatial variation of attenuation within a subcatchment.

(d) For DRP, no information is presented regarding P attenuation, and it seems that a value of one may have been used to adjust loads.

(e) The N method does not explicitly take account of the fraction of N that is not in nitrate or ammonium form. While it is possible that this fraction is accounted for implicitly in the attenuation factors, this is not made clear in the method description.

(f) The method(s) used to adjust on-land load limits in nested catchments for upstream inputs is not presented, despite the implications for establishing on-land load limits.

(g) The method used to account for point sources when establishing or applying on-land load limits is unclear

9. COMMENT ON OVERALL METHODOLOGY

9.1 The overall approach of setting on-land load limits to achieve specified in-stream concentration limits is a fundamental part of the National Policy Statement for Freshwater Management. This is a challenging technical task because there is limited knowledge of the transport and transformation of contaminants, and it is difficult to translate loads into concentrations. Inevitably, approximations and assumptions are required, as well as tuning of predictions to match measured in-stream loading or concentrations.

9.2 The method proposed by Mr Canning establishing on-land load limits includes assumptions and approximations, which is a necessary aspect of limit setting. However, many aspects of the method have not been documented properly and are unclear, inappropriate approximations have been made, and inappropriate assumptions adopted, as detailed earlier in my evidence. Together, these limitations make the proposed method for setting load limits unfit for the intended purpose.

9.3 An additional overall limitation of Mr Canning's methodology is that load limits are established only at monitoring stations and their associated subcatchments. Hence, potential variation of River Class and associated concentration limits are not accounted for in the analysis. For example, protection of headwater streams may entail more stringent on-land load limits. Also, a significant part of the region is outside of the monitored subcatchments, so load limits are not established for these areas at all.

10. CONCLUSION

10.1 The methods used by Mr Canning to set load limits are unclear, are materially incorrect, are overly coarse, or are questionable in many respects. As a whole, the methods employed are not sufficiently robust and are unsuited for setting load limits.

Table 1: Comparison of nitrate reductions. Highlighted cells have >19% difference between methods.

Site Number	Site Name	River Class (provided by GWRC)	Nitrate limit (g/m^3)	Measured median nitrate concentration (g/m^3)	Nitrate concentration reduction percentage to reach limit (negative for reduction)	Nitrate in-stream load reduction percentage from Canning Table 1 (negative for reduction)
1	Waikanae River at Water Treatment Plant	4	0.13	0.22	-40.9%	-30%
2	Horokiri Stream at Snodgrass	2	0.27	0.59	-54.2%	-66.9%
3	Pauatahanui Stream at Gorge	2	0.27	0.28	-1.8%	-20.8%
4	Porirua Stream at Town Centre	2	0.27	0.83	-67.5%	-63.2%
5	Hutt River at Te Marua	1	0.07	0.07	-4.1%	Margin of error
6	Akatarawa River at Cemetery	1	0.07	0.08	-12.5%	-42.3%
7	Hutt River at Taita Gorge	4	0.13	0.19	-32.5%	-26.6%
8	Ruamahanga River at Mt Bruce	1	0.07	0.02	233.3%	Within Limit
9	Kopuaranga River at Stuarts	5	0.61	0.98	-37.4%	-81%
10	Ruamahanga River at Wardells	4	0.13	0.52	-75.0%	-50.4%
11	Taueru River at Te Whiti Rd Bridge	3	0.27	0.70	-61.4%	-59.4%
12	Waiohine River at Bicknells Beach	4	0.13	0.35	-62.9%	-44.1%
13	Ruamahanga River at Waihenga Bridge	4	0.13	0.37	-64.9%	-56.3%

NRWQN data used for Ruamahanga River at Wardells and Ruamahanga River at Waihenga Bridge.

Table 2: Comparison of DRP reductions. Highlighted cells have >20% discrepancy between the Canning in-stream load reduction and the concentration reduction inferred from the measured concentrations and limit.

Site Number	Site Name	River Class (provided by GWRC)	DRP limit (g/m^3)	Measured median DRP concentration (g/m^3)	DRP concentration reduction percentage to reach limit (negative for reduction)	DRP in-stream load reduction percentage from Canning Table 1 (negative for reduction)
1	Waikanae River at Water Treatment Plant	4	0.01	0.008	25.0%	Within Limit
2	Horokiri Stream at Snodgrass	2	0.012	0.011	9.1%	Within Limit
3	Pauatahanui Stream at Gorge	2	0.012	0.015	-20.0%	Within Limit
4	Porirua Stream at Town Centre	2	0.012	0.0185	-35.1%	Within Limit
5	Hutt River at Te Marua	1	0.007	0.00385	81.8%	Within Limit
6	Akatarawa River at Cemetery	1	0.007	0.00315	122.2%	Within Limit
7	Hutt River at Taita Gorge	4	0.01	0.005	100.0%	Within Limit
8	Ruamahanga River at Mt Bruce	1	0.007	0.002	250.0%	Within Limit
9	Kopuaranga River at Stuarts	5	0.019	0.0149	27.5%	-20%
10	Ruamahanga River at Wardells	4	0.01	0.0085	17.6%	Within Limit
11	Taueru River at Te Whiti Rd Bridge	3	0.012	0.015	-20.0%	Within Limit
12	Waiohine River at Bicknells Beach	4	0.01	0.0121	-17.4%	-9.1%
13	Ruamahanga River at Waihenga Bridge	4	0.01	0.014	-28.6%	-25%

NRWQN data used for Ruamahanga River at Wardells and Ruamahanga River at Waihenga Bridge

11. REFERENCES

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