IN THE MATTER OF	The Resource Management Act 1991
AND	
IN THE MATTER OF	Lake Rotorua Nutrient Management – **PROPOSED PLAN CHANGE 10** to the Bay of Plenty Regional Water and Land Plan

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SUMMARY OF EVIDENCE OF JAMES CHRISTOPHER RUTHERFORD ON BEHALF OF THE BAY OF PLENTY REGIONAL COUNCIL

Evidence topic: Catchment loads – ROTAN

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1. My full name is **James Christopher RUTHERFORD**. My qualifications, experience and compliance statement regarding the Environment Court Code of Conduct for expert witnesses is as set out in the full version of my evidence in chief and I refer to and confirm that in this summary via this cross-reference.

Summary of Evidence

2. My evidence concerns the effects that land use has on nitrogen losses within the catchment, and what proportion of those losses reaches the lake.

3. My evidence addresses four questions:

    (a) Are the results of ROTAN modelling reported in 2011 still valid?

    (b) What proportion of the total nitrogen loss from the catchment reaches the lake?

    (c) Will the nitrogen reductions in PC10 meet the lake load target?

    (d) How quickly will lake loads decrease after PC10 comes into force?

4. I lead the science team at NIWA which developed the computer model ROTAN (<u>RO</u>torua and <u>TA</u>upo <u>N</u>itrogen) and has used it to predict the effects of land use changes on nitrogen loads entering Lake Rotorua.

5. In 2011 ROTAN was calibrated to match monitored stream nitrogen concentrations using OVERSEER version 5.4.2 to estimate nitrogen losses from farmland, together

with groundwater residence times [1] and aquifer boundaries [2] published by GNS-Science (hereafter called the ROTAN-2011 study) [3, 4, 5]. This study informed the PC10 process by estimating the reductions in nitrogen loss required to meet the target lake load, together with the likely rate of recovery.

6. OVERSEER has been upgraded since 2011 and BoPRC is using version 6.2.0 in the PC10 process which, I understand, calculates losses 88% higher than version 5.4.2.

7. In 2016 NIWA was asked to recalibrate ROTAN but this was not possible because upgrades to software within ROTAN-2011 require it to be extensively reprogrammed.

8. Instead I developed a simplified version of ROTAN (hereafter referred to as ROTAN-Annual) and calibrated it using OVERSEER version 6.2.0 nitrogen losses, recent stream monitoring data, revised groundwater boundaries, and updated land use information [6, 7, 8]. Its annual time-step makes ROTAN-Annual consistent with OVERSEER and the target annual load for Lake Rotorua, and suitable to support the PC10 process.

9. In the model, water and nitrogen travel to the lake by three pathways: quickflow, slowflow and streamflow. Nitrogen removal along each pathway (termed attenuation)

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[1] Morgenstern, U.; Daughney, C.J.; Leonard, G.; Gordon, D.; Donath, F.M.; Reeves, R. (2015). Using groundwater age and hydrochemistry to understand sources and dynamics of nutrient contamination through the catchment into Lake Rotorua, New Zealand. *Hydrology & Earth Systems Science 19: 803-822.*

[2] White, P.A., Rutherford, J.C. (2009) Groundwater catchment boundaries of Lake Rotorua. *GNS Science report, 2009/75LR for Environment Bay of Plenty.*

[3] Rutherford, J.C.; Tait, A.; Palliser, C.C.; Wadhwa, S.; Rucinski, D. (2008). Water balance modelling in the Lake Rotorua catchment. *NIWA Client Report HAM2008-048*. Hamilton.

[4] Rutherford, J.C.; Palliser, C.C.; Wadhwa, S. (2009). Nitrogen exports from the Lake Rotorua catchment – calibration of the ROTAN model. *NIWA Client Report HAM2009-019.* Hamilton.

[5] Rutherford, J.C.; Palliser, C.C.; Wadhwa, S. (2011). Prediction of nitrogen loads to Lake Rotorua using the ROTAN model. *NIWA Client Report HAM2010-134.* Hamilton.

[6] Rutherford, J.C., MacCormick, A. (2016). Predicting nitrogen inputs to Lake Rotorua using ROTAN-Annual. *NIWA Consultancy Report 2016102HN*. Project BOP16201. October 2016.

[7] MacCormick, A., Rutherford, J.C. (2016) Update of the ROTAN discharge coefficients into OVERSEER 6.2.0. *BoPRC Report.* December 2016.

[8] White, P.A.; Tschritter, C.; Lovett, A.; Cusi, M. (2014). Lake Rotorua catchment boundary relevant to Bay of Plenty Regional Council's water and land management policies, GNS Science Consultancy Report 2014/111. 99 p.

is quantified using three separate coefficients whose values were calibrated to match observed stream concentrations.

10. The model was calibrated using standard methods to identify combinations of the attenuation coefficients that gave a good match between observed and predicted stream total nitrogen concentrations at ten monitoring locations over a 30 year period.

11. Model predictions were insensitive to the quickflow attenuation coefficient because quickflow makes only a small contribution to the total lake inflow.

12. The slowflow and streamflow attenuation coefficients strongly influenced predicted stream concentrations. These coefficients were found to be inversely correlated (viz., if the slowflow coefficient was high, the streamflow coefficient was low). There are insufficient data available to estimate these attenuation coefficients independently, but it was possible to identify several combinations of these coefficients that gave satisfactory predictions of observed concentrations.

13. Assuming spatially uniform attenuation coefficients did not produce a satisfactory match between observed and predicted TN concentrations at all monitoring sites. Allowing attenuation coefficients to vary spatially did not significantly reduce uncertainty in predicted lake loads and resulted in differences between catchments that had no scientific basis.

14. Several different combinations of attenuation coefficients gave a similar good match between observed and predicted concentrations. This does not pose a serious problem when predicting lake loads. The model was run using 1000 combinations of coefficients (termed a Monte Carlo simulation) with the reasonable expectation that, although the predicted lake loads may be variable, they will be unbiased. The statistical distributions of predicted lake loads were then calculated.

15. ROTAN-Annual predicted that the 'most likely' steady state load assuming current land use is 750 t y^{-1} with a 95% confidence interval of 670-840 t y^{-1}. This is not significantly different from the ROTAN-2011 estimate of 725 t y^{-1} which confirms that the results of the 2011 study are still valid even though OVERSEER has changed, new groundwater boundaries have been defined and there are seven years more stream monitoring data.

16. ROTAN-Annual predicted that on average 42% of total nitrogen losses were attenuated (viz., did not reach the lake). This compares favourably with published

estimates of catchment-scale attenuation in other catchments both in New Zealand and overseas. ROTAN-2011 predicted much lower attenuation which was noted at the time as unusual.

17. For the loss reductions specified in PC10, the model predicts the steady-state lake load to be 425 t y^{-1} with a 95% confidence interval of 390-460 t y^{-1}. These lake loads exclude rainfall on the lake of 30 t y^{-1}. Engineering and gorse control targets have not been adjusted following adoption by BoPRC of OVERSEER version 6.2.0. This has contributed to the predicted steady-state lake load being 5% higher than the target but, given the high uncertainty in model predictions, the difference may not be statistically significant.

18. The statistical distributions of uncertainties in OVERSEER losses, stream concentrations and groundwater travel times are unknown. Therefore, the 95% confidence interval of 390-460 t y^{-1} for the steady state lake load under PC10 is only approximate and it is not possible to estimate precisely the probability that the steady state target load of 405 t y^{-1} will be achieved.

19. Making two reasonable assumptions about the statistical distribution of uncertainties (uniform and normal), there is a 13-21% probability that the steady state lake load will be less than, and a 79-87% probability it will be greater than, the target of 405 t y^{-1}.

20. Of interest is the possibility that the steady state lake load will be greater or less than the target by an amount that will have a detectable effect on lake water quality. I do not know what the implications are of exceeding or not attaining the target lake load but I assumed that provided the steady state lake load is within 10% of the target then lake water quality will meet the expectations of PC10.

21. Making two reasonable assumptions about the distributions of uncertainties in steady state lake load (uniform and normal), I estimated that the probability lake load reductions will be more than required is negligibly small, and less than required is 12-20%.

22. In my opinion:

    (a) There is a negligible risk the nitrogen control measures in PC10 will be more than required to meet the lake target.

    (b) There is a risk (c. 12-20%) that nitrogen control measures will be less than required to meet the lake target.

23. ROTAN-Annual predicts that nitrogen reductions specified by BoPRC will reduce lake loads to within 25% of the target (405 t y^{-1}) within 25 years although steady-state may not be reached until after 2100. Aquifers with short residence times (e.g., Ngongotaha 15.5 years) are likely to approach steady state within the term of PC10 but those with long residence times (e.g., Waingaehe 145 years) will take a long time to reach steady state.