Tabled at Hearing on 16 November 2015

BEFORE THE CANTERBURY REGIONAL COUNCIL

IN THE MATTER OF: the Resource Management Act 1991

AND

IN THE MATTER OF: a submission on the Partially Operative Canterbury Land and Water Regional Plan; Plan Change 3

STATEMENT OF EVIDENCE OF DR MARC SCHALLENBERG

FOR THE DIRECTOR-GENERAL OF CONSERVATION

Dated 25 September 2015

Director-General of Conservation

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STATEMENT OF EVIDENCE OF MARC SCHALLENBERG

BACKGROUND

1 My full name is Marc Schallenberg.

2 I am an environmental consultant trading under the name Hydrosphere Research Limited and I'm also a Research Fellow in aquatic ecology at the University of Otago.

3 I have run my own consultancy for three years and I've held my current position of Research Fellow at the University of Otago for 21 years. Previously I was a post-doctoral researcher at the National Institute of Water and Atmospheric Research (NIWA).

4 I hold a BSc in ecology, evolution and behaviour as well as a PhD in Limnology from McGill University, Montreal, Canada.

5 I have authored or co-authored 39 peer-reviewed articles published scientific journals, seven book chapters, and around 40 technical reports dealing with freshwater and estuarine science. According to Google Scholar Citations, to date my work has been cited 1546 times in the scientific literature.

6 I have carried out scientific and policy work for numerous Regional Councils, the Ministry for the Environment, the Department of Conservation and various NGOs and community groups. I have been an expert witness at numerous hearings, including at the Environment Court.

7 I am the current president of the New Zealand Freshwater Sciences Society.

8 To date, I have conducted research, including field work, on around 80 New Zealand lakes and lagoons. I have personally sampled Wainono Lagoon three times and published two peer-reviewed articles on Wainono Lagoon (Drake et al. 2010; Schallenberg & Saulnier-Talbot 2015), a report for the Department of Conservation (Drake et al. 2009) and I've written two reports for Environment Canterbury on the Lagoon (Schallenberg 2013; Schallenberg & Saulnier Talbot 2014).

9 Since 2006, I have been studying, assisting with policy development, and publishing on intermittently closed and open lakes and lagoons (ICOLLs). I have carried out research on eight such systems within New Zealand and was on an expert group convened by the Ministry for the Environment to set ecological targets for New Zealand ICOLLs.

10 The Department of Conservation has asked me to examine the report of Abell et al. (2015; Hydrodynamic-ecological modelling to support assessment of water quality management options for Wainono Lagoon) and to comment on the scientific robustness of the modelling exercise as well as on the conclusions reached with regard to the proposed use of augmentation water to mitigate the impacts of agricultural intensification in the catchment of Wainono Lagoon.

BODY OF EVIDENCE

11 I have some experience with deterministic modelling of lakes and have published two papers which have involved such modelling (Thomas & Schallenberg 2009; Bayer et al. 2013). The latter study used the physical lake model DYRESM, which was used in the Abell et al. (2015) study.

12 I was a participant in Environment Southland's Lagoon Technical Group, which established nutrient loading limits to safeguard the health of Waituna Lagoon (Environment Southland, 2013). During that process, Environment Southland funded the development of a Waituna Lagoon deterministic model, which was adapted for use to model Wainono Lagoon by Abell et al. (2015). The Waituna model contributed one of three independent strands of evidence which Environment Southland sought to help define nutrient load limits to the lagoon. The other approaches used were: 1) a broad scale literature review of nutrient loads in relation to seagrass health in similar types of ecosystems worldwide (Schallenberg & Schallenberg 2012) and 2) an analysis of the Waituna situation by an Australian coastal lagoon expert (Peter Scanes, NSW Office of Environment and Heritage), who relied on his extensive experience and on data from numerous Australian coastal lagoons (Scanes 2013). In the case of Waituna Lagoon, the findings from the three independent studies supported one another and, therefore,

robust nutrient load limits for Waituna Lagoon could be identified (Environment Southland 2013).

13 ECAN has commissioned the Abell et al. (2015) modelling study to identify mitigation scenarios involving water augmentation, which could maintain the trophic level index (TLI) of Wainono Lagoon below 6 (specified as a 3-year TLI3 value for the lake).

14 To do this, Abell et al. (2015) adapted the DYRESM-CAEDYM and DYRESM-ELCOM models developed for Waituna Lagoon, substituting input data more specific to Wainono Lagoon, collected from various sources. Unfortunately, few data on the ecology of Wainono Lagoon exist, so many assumptions were made to run the complex CAEDYM ecological model for Wainono Lagoon. For example, sediment nutrient data for Wainono Lagoon were unavailable and so data from Te Waihora/Lake Ellesmere were used instead (with some modification), zooplankton and macrophyte data were unavailable for Wainono Lagoon, etc. (see Table 16 in the Abell et al. 2015 report for its list of assumptions). These types of assumptions are fairly typical of CAEDYM modelling efforts where detailed data on the ecological structure and functioning of the system being modelled are sparse or lacking. Despite such assumptions, sometimes the resulting models can describe lake dynamics fairly well.

Deterministic lake modelling

15 Constructing and running the 1-D model (DYRESM-CAEDYM) and 3-D model (ELCOM-CAEDYM) are major technical feats requiring substantial knowledge of lake functioning, as well as how to:

- estimate input data satisfactorily when direct measurements are not available,
- adjust the model using sensible parameters values selected from the literature,
- adjust the model when information about components of the ecosystem are lacking (i.e., components which are often omitted from lake models, include macrophytes, lake bed sediments, zooplankton, fish, etc.),
- carry out sensible model calibration,
- robustly test the model (validation) to see if it is fit for purpose,
- sensibly extrapolate the model to scenarios outside the model's domain,
- perform sensitivity and uncertainty analyses to help focus interpretations
- interpret the model outputs in terms of the desired information about the system, and
- provide results that account for various types of error that all models contain.

16 If adequate input data are available, enough quantitative knowledge is available about the ecological structure and functioning of the system, and the modellers perform the above steps well, then such models can usefully integrate large amounts of data and can be useful for generating hypotheses about lake ecological responses to future environmental scenarios. If it turns out that the model describes the key dynamics of the lake well, then it can be cautiously applied to test the response of the lake ecosystem to various scenarios. Abell et al. (2015) stated that the Waituna model could be satisfactorily adapted for Wainono Lagoon. I believe that the main finding of the modelling report regarding the influence of augmentation flow on TLI is probably roughly correct, but I have some concerns that the model doesn't accurately capture the ecological dynamics of Wainono Lagoon, bringing into question the certainty with which the model can predict lake responses. Below, I address two separate aspects of the Abel et al. (2015) report: 1) the implications of the model's finding concerning TLI mitigation using augmentation flows and, 2) the scientific robustness of the model as applied to Wainono Lagoon.

Implications of the model results for TLI mitigation using augmentation flows

17 In the case of Waituna Lagoon (Environment Southland 2013), the deterministic model supported management targets that were predicted by two other independent assessments, clarifying management decisions. Similarly, for Wainono Lagoon, the deterministic modelling supported the analysis of Sutherland and Norton (2011), who found that flow augmentation of 1.0 m^3/s should keep the 3-year TLI of the lake below 6.

18 However, the Sutherland and Norton (2011) assessment was based solely on the dilution potential of the augmentation flow on the water quality of the lake and did not account for any ecological processes in the lake. In contrast, the approach of Abell et al. (2015) was to couple complex physical models (DYRESM and ELCOM) to a complex ecological model (CAEDYM). The fact that the conclusions of the two reports are very similar appears to confirm that the mitigation will achieve the TLI goal. However, that the same conclusion was reached both by a simple dilution model and a complex hydrodynamic-ecological model either suggests that the overall influence of the ecology of the lagoon

on the TLI is negligible (and dilution would be only driver of the TLI offset) or that the deterministic model doesn't adequately simulate the lake's ecology. The following section addresses the latter possibility.

Robustness of the Abell et al. (2015) model of Wainono Lagoon

19 A model is "a simplified picture of reality" (Jørgensen 1994). From a scientific perspective, the utility of a model lies in its ability to distil the key processes and structures of a natural system so that the model's behaviour closely mimics the dynamics, structure and function of the system that it models. Therefore, "It is... of great importance that the observations reflect the dynamics of the system." (Jørgensen 1994). Some aspects of the 1D and 3D models of Wainono Lagoon indicate to me that the models are not yet sufficiently developed or scientifically robust. Table 16 of the report lists a number of assumptions that had to be made to run the models and many of these could compromise the ability of the models to simulate Wainono Lagoon. I have also identified some other issues that cast doubts on whether the models should be relied upon to make management decisions. Three of these issues are detailed below.

20 ***A. The lack of adequate calibration and validation time series:*** The main goal of the Abell et al. (2015) report is to use ecosystem modelling to determine how the different mitigation scenarios would specifically affect the 3-year TLI for Wainono Lagoon. Environment Canterbury use a 3-year TLI to account for inter-annual variation within the lake, which can be quite large in such systems. Within the context of this task, to test the goodness of fit of the model for this purpose, it is necessary to validate the model over a number of 3-year TLI periods and to show that the modelled 3-year TLI fits with the 3-year TLI calculated from real monitoring data. In other words, to see if the model is fit for purpose, it needs to be tested/validated against 3-year TLI assessment periods. However, the model was validated only over a 1-year period and so the goodness of fit between of the model to the relevant lake data has not been tested. In other words, the ability of the model to accurately simulate 3-year TLI assessments has not been confirmed.

21 ***B. Poor model performance with regard to the daily dynamics of the three TLI components:*** The 1-D model was calibrated over a 2-year period and validated over a 1-year period. Standard tests of model goodness of fit were performed using sampled data from Wainono Lagoon over the validation period (Table 14). The tests were performed to see how well the model could predict ECAN's monitoring data for the lake – in effect, a test of the model's ability to reflect the daily dynamics of the parameters of interest in the lake. The correlation coefficient (r) between the modelled prediction and the actual sampled data is a measure of the goodness of fit of the model to the data. The square of the correlation coefficient (r2) describes the proportion of the variance in the measured lake data that is explained by the model. Focusing on the goodness of fit for the TLI components (total nitrogen, total phosphorus and chlorophyll a) in Table 14, the r-values for total nitrogen, total phosphorus and chlorophyll *a* during the validation period were -0.37, 0.10 and -0.10, respectively. This means that 14%, 1% and 1%, of the variance in the measured total nitrogen, total phosphorus and chlorophyll a data, respectively, could be explained by the model. In other words, the model can't predict the dynamics of any of the TLI components in the lake. In fact, the r-values show that a negative relationship exists (albeit very weak) between observed vs modelled total nitrogen, indicating that generally when levels of total nitrogen in the lake were high, the model tended to predict that levels were low. This can be clearly seen in the data (Figs 18 A and D; Figs 19 A and B).

22 The model may be more successful at predicting the states of the TLI attributes if integrated over longer time scales (e.g., 3 years), but we are not presented with information to assess whether the model can satisfactorily do this. To test how the model simulates the 3-year TLI, a longer time period for model validation would be required.

23 ***C. CAEDYM is a freshwater lake ecological model and may not capture important biogeochemical differences between freshwater lakes and brackish lakes/lagoons:*** One such difference relates to the availability of phosphorus, a key plant nutrient in Wainono Lagoon. Brackish lakes have variable salinities. Salts are known to cause dissolved inorganic and organic phosphorus to flocculate, or "salt out", of the water column (Lin et al. 2012). In addition, phosphorus immobilisation (availability) in bed sediments differs markedly between freshwater lakes and coastal marine systems (Caraco et al. 1990) and various geochemical mechanisms (e.g., the concentration of sulphur, which is in much higher concentrations in seawater) have been implicated in causing this difference. These are just two ways in which brackish lakes can have different phosphorus dynamics compared to freshwater lakes. I believe that CAEDYM, being a freshwater model, does not incorporate these important processes which influence P dynamics in brackish lakes and lagoons.

CONCLUSIONS

24 There is still much uncertainty as to how Wainono Lagoon would respond to the perturbations being mooted. I would caution against deriving too much confidence from the assessments of the effect of flow augmentation on TLI that have been made so far. In general, I concur with the conclusions of both Sutherland & Norton (2011) and Abell et al. (2015) that flow augmentation is likely to offset to some extent the increase in the trophic state of the lake that is likely to result from higher nutrient and sediment loads to the lake.

25 However, I don't believe that the likely degree of offset has been robustly assessed at this point in time. Therefore, I suggest that both a precautionary approach and adaptive management should be employed to safeguard the lake. A precautionary approach could be to provide the maximum augmentation flow available at all times to the lake. Adaptive management could involve adequate monitoring of lake health with a commitment to making management changes (if necessary limiting allowable nutrient loads) if the lake's health is observed to suffer as a result of the planned agricultural intensification of its catchment.

26 I suggest that lake health monitoring and limit setting for Wainono Lagoon should consider lake attributes that go beyond simple measures of water quality, such as TLI. The health of Wainono Lagoon and other similar coastal lakes is closely related to the abundance and cover of submerged aquatic macrophytes because macrophytes can regulate aspects of water quality such as phytoplankton biomass and suspended sediment concentrations, they stabilise the lake bed, they provide habitat for invertebrates and fish, are food for waterfowl, and play many other important roles in maintaining lake health (Schefffer 2004). Restoring and maintaining macrophyte beds in Wainono Lagoon would go beyond ensuring a TLI target is met. It would also require consideration be given to sediment loads, water level (and variation) and salinity level (and variation). To adequately monitor and restore the health of Wainono Lagoon, these attributes should also be considered.

Marc Schallenberg

25 September 2015

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