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 Proposed Canterbury Land and Water Regional Plan Change 3

EVIDENCE OF DR PHILIPPE GERBEAUX

FOR DIRECTOR-GENERAL OF CONSERVATION

Dated 25 September 2015

Director General of Conservation

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STATEMENT OF EVIDENCE OF PHILIPPE GERBEAUX

INTRODUCTION

1. My full name is Philippe Gerbeaux.

2. I am appearing on behalf of the Director-General of Conservation. I am employed by the Department of Conservation (DOC) as a Freshwater Technical Advisor in the Freshwater Section of the Science & Policy Group. I have held this national role since September 2012; I held a similar role with a different title in a different group prior to that (2009-2012).

3. Of relevance to this evidence, my current role includes a technical and scientific coordination role and a membership of the Technical Advisory Group in the Living Water programme (a DOC/Fonterra partnership). I am also co-leading a project with NIWA and University of Canterbury on the classification of coastal hydrosystems (a project funded by MfE).

4. I hold the following qualifications: D.E.A. ("Diplôme d'Etudes Approfondies", eq. M.Sc.) in Ecology, Ethology and Planning (1982) from the University of Toulouse (France); D.E.P.T.N. ("Diplôme d'Expert en Prévention et Traitement des Nuisances") a post graduate diploma in Prevention and Treatment of Pollution (1982) from the University of Savoie and; PhD in Resource Management and Ecology (1989) from the University of Canterbury and Lincoln College (New Zealand).

5. I have worked in the field of freshwater and wetland ecology and management for the last 30 years, in New Zealand and overseas, working both in a research and management capacity.

6. Between 1995 and 2006, I was employed by DOC as a Technical Support Officer on the West Coast and regularly provided advice on relevant matters of wetland identification, delineation and assessment. In that position I also co-ordinated

conservation, survey and monitoring programmes related to indigenous freshwater fish and fisheries. I was seconded during the last part of that period to the Research and Development Division of the Department to lead the wetland component of the Waters of National Importance ("WONI") project.

7. In 2005 I was appointed by the Oceania Government members of the Ramsar Convention (an International Convention on Wetlands), as their Regional Networker on the Scientific and Technical Review Panel (the "STRP") of the Convention. I have done two terms (till 2011) with the STRP and in that capacity used to liaise with and support all Ramsar National Focal Points from the Oceania region. I also participated annually in the STRP meeting held with other wetland experts from around the world. The meetings aim to provide advice to the Secretary-General of the Convention and help progress and improve the implementation of the Triennium programme adopted at the Ramsar Conferences of Parties which is held every three years.

8. Since completing my PhD I have also worked as a scientist with the Department of Scientific and Industrial Research on the ecology of benthic algae in river ecosystems (1990-1992) and as a scientist and planner for "Station Biologique de la Tour du Valat" (1992-1994), a Research Institute dedicated to the Conservation of Mediterranean wetlands. Between 2006 and 2009 I held the position of Chief Technical Advisor and contributed to establish the Regional Office for Oceania of the International Union for the Conservation of Nature (the "IUCN"), based in Suva (Fiji).

9. I have written over 50 reports and publications including 20 refereed scientific articles, a chapter on wetlands (as co-author) in the 2004 *Freshwaters of New Zealand* and two books (also as co-author): *Wetland types in New Zealand* (2004), and one published two years ago on the conservation and management of freshwater fish and crustaceans in Polynesian countries of the South Pacific (in collaboration with the French National History Museum). I am a co-author of *Wetland ecosystems of national importance for biodiversity: criteria, methods and candidate list of nationally important wetlands* (Ausseil et al.2008). This work was

accepted for publication in a special issue of the *Freshwater Biology* journal in January 2011. This Special Issue is the first major compilation of studies on systematic conservation planning in fresh waters (Turak & Linke, 2011). My most recent scientific contribution, published by the New Zealand Journal of Ecology, reports on recent advances in the identification and assessment of significant habitat in two areas of contrasting biodiversity loss in New Zealand (Maseyk and Gerbeaux 2015).

10. I have refereed articles on wetlands for several scientific journals.

11. I am a member and a past committee member of the New Zealand Freshwater Sciences Society. The Society invited me to give a plenary address at the 2004 conference of the Society held in conjunction with the New Zealand Ecological Society in Nelson. I have been a Trustee of the Waikato-based National Wetland Trust of New Zealand for several years and remain a member.

12. I am familiar with ecological issues associated with wetlands in New Zealand and in the Canterbury region, including Wainono lagoon which I first visited in December 1984, in the course of preparing for my PhD research which I carried out on a similar coastal system (Te Waihora). I have since re-familiarised myself with the site during a recent visit and during several discussions with colleagues over the period I worked in Christchurch.

13. Over my time in New Zealand, I have visited many wetlands, both on public conservation land administered by the Department of Conservation and on private land. My work in the West Coast involved mainly compiling inventories (wetlands and wetland species), site value assessments, vegetation mapping, providing wetland management advice to Department rangers and to Resource Management planners, and coordinating West Coast-based FORST-funded wetland research in collaboration with Crown Research Agencies like NIWA and Landcare Research. I was able to present my work, directly or through hearings, to stakeholders of the West Coast region including Councils, Mining companies, Federated Farmers, farmers themselves, Westland Milk Products, Landcare Trust, QEII 2 Trust, as well as

community groups (through World Wetland Day activities) but also to the national research community at various conferences and various stakeholders of other regions (including Northland, Bay of Plenty, Auckland, Canterbury, Tasman, Southland).

14. I have read the Code of Conduct for Expert Witnesses (Rule 330A, High Court Rules and Environment Court Practice Note) and agree to comply with it. I have complied with the Code in the preparation of this evidence.

15. My qualifications as an expert are set out above. I confirm that the issues addressed in this brief of evidence are within my area of expertise.

16. I have not omitted to consider material facts known to me that might alter or detract from the opinions expressed.

SCOPE OF EVIDENCE

17. My evidence provides an ecological freshwater perspective on the matters raised in the Director-General's submission on Variation 3 of the Proposed Canterbury Land and Water Plan. Specifically, my evidence will address the following matters:

- What type of hydrosystem is Wainono lagoon
- Key ecological features of Wainono Lagoon
- Effects of Augmentation and any issues with the Aquatic Analytics Ltd modelling
- Benefits of constructed wetlands

WHAT TYPE OF HYDROSYSTEM IS WAINONO LAGOON

18. I am proposing first to review the terminology used to describe Wainono lagoon.

19. Classifications and typologies enable the use and sharing of common terms and are therefore very important to be understood and used in policy, research and management issues (Gerbeaux et al in press).

20. Wainono Lagoon has been described as a Waituna type lagoon (Kirk and Lauder 2000), which can be further defined as a barrier- or 'barrier beach-enclosed freshwater-dominated lagoon' (Hume et al *in prep*), more usually closed from the sea than opened to it. For those lagoons more usually opened than closed, an appropriate term is 'tidal lagoon' (Hume et al *in prep*).

21. A key feature of such coastal barrier- or barrier beach-enclosed system relates to their lacustrine hydrosytem characteristics which may allow some to call them coastal shallow lakes (e.g. Schallenberg and Saulnier-Talbot 2014).

22. Schallenberg (2013) has suggested that since the installation of the Waihao box, the hydrology of the system behaves like a coastal lake which receives inputs of sea water (through high seas/waves and tidal inflows through the box; Mabin 2011), causing its salinity to vary over time.

23. Based on my expertise in wetland classification, I also regard Wainono as one example of coastal hydrosystem dominated by lacustrine types of processes. However, I strongly acknowledge that brackishness, shallowness, a strong influence of flood inflow events (Mabin 2011) and a particular regime of water level and salinity fluctuations characteristics are dominant features of Wainono that make it, like other similar coastal lagoons, different from other inland shallow lakes (Gerbeaux 1987).

24. It is worth noting that coastal hydrosystems may include different types of hydrosystems ranging from riverine - dominated (e.g river mouths), estuarine - dominated (e.g. tidal lagoons – or 'estuaries') and marine - dominated (e.g. semi-enclosed embayments) systems.

25. Like marsh, swamp, fen and bog classes can be distinguished within inland palustrine, riverine and lacustrine hydrosystems (see Johnson and Gerbeaux 2004), each coastal hydrosytem type may itself be further sub-divided into several other geomorphic types. Within lacustrine-dominated coastal system, two geomorphic types can be recognised: damp sand plain lakes that are never connected to the sea

but the result of coastal processes; and barrier- or barrier beach-enclosed (Waituna) types that are sometimes connected to the sea) (Hume et al in prep.).

26. Wainono was shown to have had a history of saline, freshwater and brackish phases starting probably some 6000 thousand years ago as a tidal inlet or embayment, and evolving first through build up and closure of a beach barrier into a freshwater lake, until artificial opening to the sea (building of Waihao Box) lowered lake levels and increased salinity (Schallenberg and Saulnier-Talbot 2014). Additional cores taken by the Canterbury University Department of Geography from Wainono lagoon in 2015 indicate that Wainono would have been tidal and strongly influenced by a marine phase prior to European arrival – possibly as a result of breach though the barrier (Norman pers.com.; evidence of this is based on a foraminifera analysis 1m down in the sediment); an event which probably occurred two or three hundred years ago.

27. In the face of climate change and sea-level rise, it may well return to that more marine-dominated hydrosystem state in the future. Although out of scope for this evidence, I wish to draw attention to the scenarios currently proposed in relation to climate change and consequences it may have on the South Canterbury coastal environment (see http://www.mfe.govt.nz/climate-change/how-climate-change-affects-nz/climate-change-impacts and http://www.mfe.govt.nz/climate-change/how-climate-change-affects-nz/how-might-climate-change-affect-my-region/canterbury).

28. I also wish to draw attention to the use of another name for the barrier- or barrier beach-enclosed lagoon systems: intermittently closed and opened lakes/lagoons (ICOLLs). My opinion is that the term ICOLL, which was first defined in Australia and has been subsequently introduced to New Zealand, has a specific meaning that does not apply to all intermittently closed and opened coastal systems in New Zealand, especially Waituna-type lagoons which have coarser (mixed sand-gravel) barriers separating them from the sea than ICOLLs in Australia (mostly sandy). Such difference makes them more permeable than their Australian counterparts,

therefore allowing them to drain/permeate through the barrier and probably reduce the frequency of natural breaching.

THE CENTRAL ROLE OF MACROPHYTES IN PROTECTING WAINONO ECOLOGICAL VALUES AND MAINTAINING WATER QUALITY

29. The more recent environmental history of the lagoon has been well reported on by Schallenberg and Saulnier-Talbot (2014). Their study highlights in particular (see inset p.6 of the report) the major role and ecological value of macrophytes[1] (including *Ruppia* – which was the focus of my PhD research mentioned in paragraph 11) which will be central to my evidence throughout.

30. The study also describes how and why it has changed in recent times with regard to the effects of land use (conversions to pasture) and hydrological modification (artificial connection to the sea through the Waihao box as already mentioned).

31. The ecological values of Wainono Lagoon have been highlighted in a number of reports and publications other than Schallenberg and Saulnier-Talbot (2014) (e.g. Benn 2011, Tipa & Associates 2012) and those values are the reason for a restoration proposal to have been given substantial financial support over a period of five years (from 2012): together, the presence of an extensive wetland area around the margins of the lagoons (the most extensive wetland area in South Canterbury) and the presence of numerous important species for conservation (birds, fish, native vegetation –aquatic, wetland and terrestrial) and mahinga kai (food) or raranga (weaving), make Wainono Lagoon a South Canterbury treasure (ECan 2012a).

32. In their report on Wainono lagoon, Schallenberg and Saulnier-Talbot (2014) have stated that in shallow lakes "aquatic plants confer many ecological benefits. For example, they absorb plant nutrients such as nitrogen and phosphorus from the water and lake bed, thereby reducing available nutrients which would otherwise fuel nuisance phytoplankton blooms. Macrophytes reduce currents and waves, reducing

[1] Macrophytes is a term used thereafter as a synonym of submerged aquatic plants

the stirring up of bottom sediments into the water column, resulting in improved water clarity.../...the presence of macrophytes in shallow lakes is a key indicator of their health...".

33. Robertson and Funnell (2012) draw a similar conclusion for Waituna lagoon in Southland: "A change in the ecological character of Waituna lagoon resulting from the decline of aquatic macrophytes is a primary concern for the managers".

34. The importance of macrophytes in shallow lakes was the topic of my Ph.D research (Gerbeaux 1989) and I am therefore well placed to endorse the comments made by Schallenberg and Saulnier-Talbot (2014) or Robertson and Funnell (2012) reported in the previous paragraphs. I also convened a workshop on shallow lakes with members of the then 'New Zealand Limnological Society' (now 'New Zealand Freshwater Sciences Society') from all around New Zealand in 1987 which had come to similar conclusions (Gerbeaux 1987).

35. Unlike Waituna lagoon which still supports a submerged macrophyte community dominated by *Ruppia* (Robertson and Funnell 2012), no macrophytes were observed over the past few years in Wainono lagoon until recently, when Schallenberg and Saulnier-Talbot (2014) observed seedlings of Ruppia-like plants in the summer of 2012-2013. They concluded that the lagoon was "clinging to an ecological threshold or tipping point and that successful restoration to a state and healthy macrophyte beds, clearer waters and a diverse and productive aquatic food web could still be achievable".

36. I witnessed a similar situation in Te Waihora in the late 1980s: when, despite reports of their total disappearance, I observed seedlings floating along the shoreline. Such events indicate that there is a still a good seed bank present but the seedlings do not have the ability to re-establish properly. This is often because the level of light penetration on the bottom of the lagoon is so reduced that the rhizomes cannot expand and anchor themselves in the sediment, leaving the plants exposed to wave action – accentuated by artificially lowered water levels - and being uprooted (Gerbeaux 1989, 1993; Gerbeaux and Ward 1991).

37. I reported above (paragraph 12) that I had visited Wainono lagoon in December 1984 (see photo below). As I had been there to check on the presence of *Ruppia* propagules that I could bring back to Lincoln for my experiments, I remember being able to see those plants on a calm day through a relatively clear water column; and I was able to collect specimen in a plastic bag. When I visited the site again recently (11.09.2015), also on a calm day, the water was so loaded with fine suspended solids and phytoplankton[2] that the bottom could not be seen; not even near the edge of the lagoon, in very shallow depth. I became aware then of the degree of degradation in water quality the lagoon must have been under over the past decades.

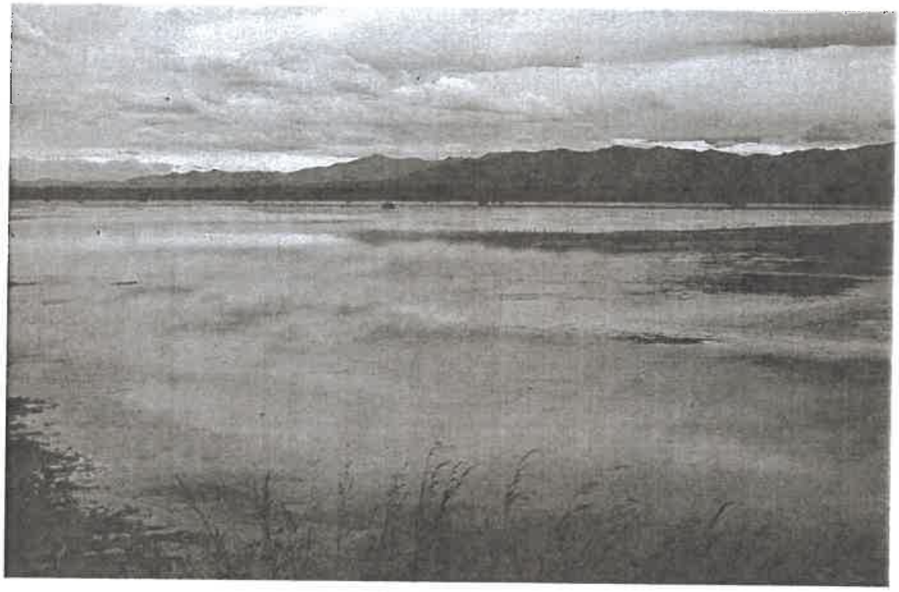

Plate 1: A photo taken in December 1984 indicates the presence of macrophytes

38. I note that a Wainono restoration project – "likely to cost nearly 2.5 million over 5 years (Ecan 2012a)" is now under way. I have checked the list of projects proposed

[2] Phytoplankton are photosynthesizing microscopic organisms that inhabit the actively upper water layers of almost all oceans and bodies of fresh water; they range in morphology from single-celled forms to multi-cellular colonies and filaments. In most water bodies, they function as the primary producers in the food chain, producing organic material from sunlight, carbon dioxide water and inorganic nutrients (e.g. nitrogen, phosphorus). In large concentrations they can decrease the clarity of the water, alter the colour of the water, be toxic to stock and wildlife, produce unpleasant tastes and odours, alter the pH of the water, deplete oxygen, clog water intake filters and therefore determine the aesthetic appeal of a lake and its suitability for many different uses. They are otherwise a major factor in ecosystem maintenance and protection and phytoplankton abundance is often measured as chlorophyll a (in g/l).

(ECan 2012b). I support those projects, and the proposal to restore the macrophyte beds in the lagoon as indicated in Table 15 (b) of the proposed variation 3 to the proposed CLWRP.

39. It may be that the water quality improvements resulting from the Wainono Restoration project, as well as the proposed flow augmentation, will have the effect of enhancing the light climate of the lagoon and enable the natural regrowth of macrophytes but it is questionable whether or not this will be possible without a specific focus on factors affecting their growth. Water clarity and Chlorophyll a are two measurements (of the four - with total nitrogen and total phosphorous – used to calculate the TLI - or trophic lake index) that have a direct influence on the underwater light climate that I am proposing to focus our attention on.

40. The water clarity appears to be constantly poor these days and reducing the TLI through diluting nutrients in the water column, as currently proposed, will in my view be insufficient to restore water clarity levels that can enable a regrowth of macrophyte beds and therefore restore the ecological health of the lagoon.

41. Schallenberg and Saulnier-Talbot (2014) did state that the successful restoration of macrophytes into a degraded lake is usually a very onerous and expansive undertaking. Such a proposal has been made for Te Waihora (http://ecan.govt.nz/news-and-notices/news/Pages/te-waihora-restoration-project.aspx) at an approximate cost of one million dollars.

42. The decision to implement that macrophyte restoration project in Te Waihora, even at that cost, may be used as evidence of how important it is to restore submerged aquatic plants. This is because restoration of macrophytes would assist with a more meaningful reduction in the TLI than reducing nutrients through not only stabilisation of the lagoon bed and reduction of bottom sediment resuspension, but also through the reduction of phytoplankton and therefore chlorophyll a, another key measurement integrated in the calculation of the TLI.

43. Numerous studies carried out in the 1990s have highlighted that the presence of macrophytes is beneficial in shallow lakes and clearly has a negative effect on phytoplankton biomass (Sondergaard and Moss 1998). I will quote thereafter Sondergaard and Moss (1998) on some points that are in my view very relevant to the modelling and management of Wainono Lagoon, especially as they relate to the lowering of phytoplankton biomass (measured in the TLI calculation as chlorophyll a).

44. "Several mechanisms contribute to maintenance of low phytoplankton growth in association with macrophyte beds. These include direct mechanisms associated with the plants themselves, including creation of a still water environment, poor light climate near the sediment, and secretion of allelopathic substances as well as mechanisms indirectly linked with the plants, such as provision of refuges or habitat for grazers on algae, and modification of the ambient nutrient regime by the metabolic activity of the plants. In turn, these mechanisms are affected by a second level of influences – predation by fish on the grazers, imposition of nutrient loads from the catchment, and hydrodynamic conditions that determine the degree of water movement through the plant beds. All these mechanisms interact. The hydrodynamics must determine the extent to which anoxic gradients that promote denitrification can be established; excretion by grazers modifies the nutrient regime. Furthermore, the influence of specific composition of the macrophyte community is likely to be important. There are metabolic as well as structural differences among different species of submerged plants" - let alone those between for instance *Ruppia* and Charophytes as reported by Schallenberg and Saulnier-Talbot 2014. "The degree of grazing on algae will also be affected by the composition of the grazer community, which in turn, is determined by the size structure and composition of the fish community. The macrophyte growth will also be subject to grazing by vertebrates so that the structure and composition of the beds will vary".

45. Sondergaard and Moss (1998) make an important additional comment: "the importance of different mechanisms and processes will, to some extent, be lake

specific". In my opinion this comment is important in the context of reviewing the proposed planning regime for flow augmentation.

THE PROPOSED FLOW AUGMENTATION AND SUPPORTING MODEL

46. The potential benefits of flow augmentation have been reviewed by Sutherland and Norton (2011) and include (i) dilution of contaminants in the lagoon; (ii) the ability to manage lagoon water quality and nuisance phytoplankton blooms by replacing lagoon water volume over a relatively short period of a few days; and (iii) potentially enhancing habitat and fish passage. They based their assessment on several assumptions (see first paragraph p.8 of their report), including flow augmentation of 31.5 million m3/year water from the Waitaki River into Wainono lagoon.

47. Abell et al (2015) suggest (p.3) that in systems like Te Waihora where light is a more important controlling factor than in Waituna, phytoplankton biomass is less sensitive to dilution of nutrient-rich water. This statement applies to Wainono as well.

48. The brackish characteristic of Wainono lagoon is problematic for any modelling and certainly is for the coupling of physical models (DYRESM and ELCOM) to the CAEDYM ecological model proposed by Abell et al (2015). Abell et al (2015) acknowledged this issue in their report (e.g. see last box of their Table 16).

49. Schallenberg (2015) reinforces this point when he says (p.5): "CAEDYM is a freshwater lake ecological model and may not capture important biogeochemical differences between freshwater lakes and brackish lakes/lagoons". Nitrogen, which is the main nutrient targeted for dilution under the proposed flow augmentation (see next section on flow augmentation) is not the only key plant nutrient in Wainono lagoon. Phosphorus also is important. And Schallenberg (2015) concludes: "CAEDYM, being a freshwater model, does not incorporate important processes which influence P dynamics in brackish lakes and lagoons". I concur with him.

50. A U.S.A National estuarine Experts Workgroup has highlighted similar issues. Their report (Gilbert et al 2010) characterises the biogeochemical complexities inherent in 'estuaries' (defined in a broad sense including coastal lagoons) and in turn, the

complexities associated with developing numeric nutrient criteria protective of designated uses. Their document emphasises methods, models and data that facilitate in either characterising or constraining complexity, or it identifies characteristics of data useful for criteria development.

51. Those complexities are reflected and acknowledged in Table 16 of Abell et al (2015), with the non-inclusion or approximation of key factors such as grazers (not included), use of wind data (data from Timaru only - remote from the site), nutrient concentrations in lagoon bed sediments (estimated and not based on measurements) and sea-water intrusion due to wave overtopping (not represented).

52. Coastal hydrosystems, as I have highlighted above, are not necessarily functioning like inland shallow lake hydrosystems and even if Wainono is one example of coastal hydrosystems dominated by lacustrine types of processes, its brackishness, shallowness and particular regime of water level and salinity fluctuations combine to produce characteristics tending to indicate a different type of functioning than that of a normal lake. A reference in the proposed model to the new 'CLUES' estuary tool developed by NIWA (Plew et al 2015) may be desirable (see also https://www.niwa.co.nz/freshwater-and-estuaries/research-projects/estuarine-water-quality-the-clues-estuary-tool). I am also aware that an Estuarine Trophic Index (ETI) is currently being developed by NIWA under Envirolink funding (John Zeldis pers.com.). ETI may be, for systems like Wainono, a more appropriate index to use in the future than the LTI. I understand that it will not be ready for another 2 years and thefore the timeframe required for this Plan Change 3 to the Canterbury Land and Water Plan, may not allow its use. It is however important in my opinion to rely on tools that are not well adapted to provide sufficiently accurate predictions.

53. As alluded to in my paragraph 40 above, I have in any case some concerns related to the focus on nutrients (N in particular) to manage the TLI. I must add that I am also not convinced that the TLI , as a number used to indicate the health of Wainono lagoon, is the most appropriate tool to do this or to monitor ecological improvements.

54. Another important consideration is proposed by Sutherland and Norton (2011), page 31 of their report (bottom paragraph). They state: "As discussed in section 3.1[3], the predicted increased nutrient loads are likely to increase phytoplankton biomass. This will, in turn, reduce the light available in the water column. However, the very weak relationship between the phytoplankton biomass and turbidity indicates that suspended solids are the main cause of light attenuation in Wainono Lagoon. On this basis it is unlikely that the re-establishment of macrophytes in Wainono lagoon will be inhibited due to the large number of other major barriers preventing macrophyte re-establishment, that are independent of nutrient loads (see their figure 3.5 where they include in priority order: light attenuation barrier, wave or biotic disturbance, absence of plant propagules and unsuitable conditions for germination and growth as possible barriers).

55. This statement, even if not substantiated with data (Figure 3.1 only shows the poor correlation between Chlorophyll a and turbidity – no data is provided in relation to the potential barriers) , is probably correct and similar to those reported by Gerbeaux (1993) and Gerbeaux and Ward (191991) for Te Waihora/Lake Ellesmere (Figure 1).

56. The numerical relationship between optical parameters varies according to the changes in the optical properties of water, especially in transitional coastal waters. Gerbeaux and Ward (1991) have evaluated the relative effects of the main water clarity determinants on optical properties in Te Waihora/Lake Ellesmere, described temporal fluctuations in these, and discussed factors that control light attenuation. They found that the dominant cause of light attenuation was scattering. Clarity was found therefore to be indeed more dependent on very high levels of inorganic suspensoids than on phytoplankton biomass as suggested by Sutherland and Norton (2011) for Wainono. The diagram in figure 1 below illustrates the relationship between factors contributing to a loss of macrophytes.

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[3] It is a section on primary productivity (phytoplankton biomass)

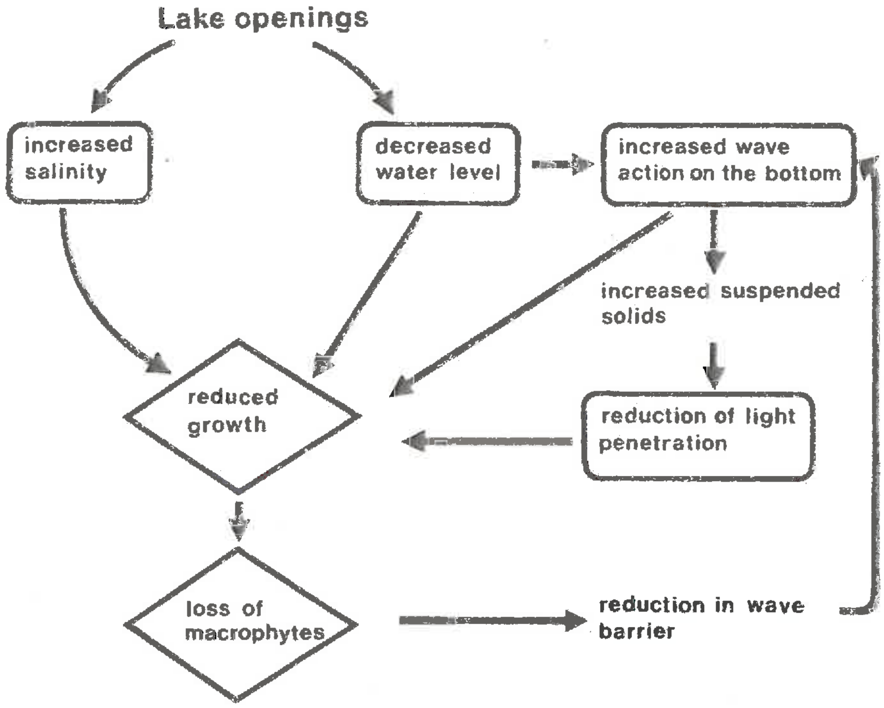

Fig. 1. Possible factors preventing the regeneration of aquatic plants in Lake Ellesmere.

57. Some of the reports I have read (Hall 2003, Mabin 2011, Sutherland and Norton 2011, Golder Associates 2012) indicate to me large fluctuations in the underwater light environment, salinity and water level fluctuations. Like for Te Waihora/Lake Ellesmere, turbidity caused by wind re-suspension of inorganic suspensoids is likely to be responsible for most of the fluctuations in the underwater light environment while phytoplankton may be comparatively less important; although any reduction will still contribute to improved water clarity. I note in table 16 of Abell et al (2015) that the nutrient concentrations assigned to lagoon bed sediments were estimated and not based on measurements. This (as well as the lack of information about the macrophyte component), is likely to affect the predictive capacity of the model. Chlorophyll a levels however also depend on the frequency of floods or nutrient flushes in the inflows and good management of riparian margins in the catchment appear to me as being potentially more crucial than reducing nutrient in the lagoon through flow augmentation. The nutrients carried with the inflows may be accumulated in the lagoon sediments and then released through resuspension

depending on wind speed and on water levels. In my opinion managing the legacy of the past decades is unlikely to be solved through flow augmentation.

58. My review of the literature associated with the proposed variation 3 of the proposed CLWRP has not revealed any attempt, beyond those made by Sutherland and Norton (2011), to fully understand the relationships between the factors controlling light attenuation in the water column. Yet those could be further adequately monitored relatively cheaply, using wind data from the nearest weather station (Oamaru may be more appropriate than Timaru) and turbidity or clarity measurements[4] (currently and apparently not included in the monitoring associated with the Wainono restoration project). Monitoring on continuing basis seasonal fluctuations of light attenuation is very important for macrophyte management, but also for implementing effective measures to achieve water quality improvements and the overall health of the lagoon and its productivity (including grazers).

59. Sutherland and Norton (2011) have excluded Secchi depth (SD - water clarity) from the predicted TLI calculations primarily due to sparse data. They added that SD is not necessarily crucial for the TLI. SD is however a visual measure of water transparency and a coarse way to evaluate the fluctuations of underwater light penetration and seasonal light attenuation so important for submerged plants.

60. Augmentation can certainly contribute to an improvement in the lagoon and although not in scope, has the potential to help sustain the life supporting capacity of freshwater ecosystems throughout the catchment, particularly those containing threatened species such as Canterbury mudfish (see my colleague's – Dr Nicholas Dunn – evidence); for as long as this augmentation is not only used for the irrigation of pastures but also for the re-creation of wetland habitats along major waterways. Such wetlands, especially if located along riparian margins of waterways with critical high sedimentation hotspots, would not only sustain threatened species habitat but

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[4] I have noted the proposed use of a SHMAK tube method to measure clarity (in Table 15 (b) of the proposed variation 3. See Kilroy and Biggs 2002.

also contribute to decreased sediment inflows into the lagoon. They would restore habitat of cultural value as well.

61. I have already mentioned the possible role of climate change and sea level rise in returning the lagoon into a more marine or estuarine phase in the longer term. Climate change is also relevant when assessing the inflows, wind direction and wind intensity. Wind data can assist in understanding better the water level fluctuations around the margins of the lagoon (through the seiche effect associated to wind surges in this type of shallow environment – see Gerbeaux 1989). Those fluctuations are crucial to maintain adequate habitat for some birds (see my colleague Andy Grant's evidence – para 25). An indication of such possible trends in those factors may assist refining the ecological outcome of scenarios currently being proposed.

62. Finally, of relevance to the proposed flow augmentation on the ecology of Wainono, is the quality of the water that may be redirected into the lagoon.

63. As indicated (p.5) in the Director General's submission (DOC 2015), the effects of large amounts of fine glacial silt and didymo from the Waitaki River present potential risks, including the risk of increasing turbidity in the lagoon. While augmentation may assist maintaining a TLI of 6 of less (noting my reservations about the use of TLI as a suitable index for this type of coastal hydrosystem), I reiterate that the health of the lagoon is largely dependent on the presence of macrophytes and its restoration may be therefore more impeded by high inorganic suspensoids (the fine glacial silt carried in the Waitaki River water could add to the problem in that respect))and high water turbidity than by high chlorophyll a levels or high nutrient levels.

64. This will be influenced by the water level regime in the lagoon (see Figure 2 in Gerbeaux 1993). In 1993 I assessed lake-level duration curves for Te Waihora/Lake Ellesmere and found that an optimal regime was to maintain the lake levels stable and high (median depth of 0.9m – see type 3 in Figure 2), from mid-Spring to late Summer. Such regime was accepted as adequate when the Conservation Order for the lake was re-discussed and subsequently amended.

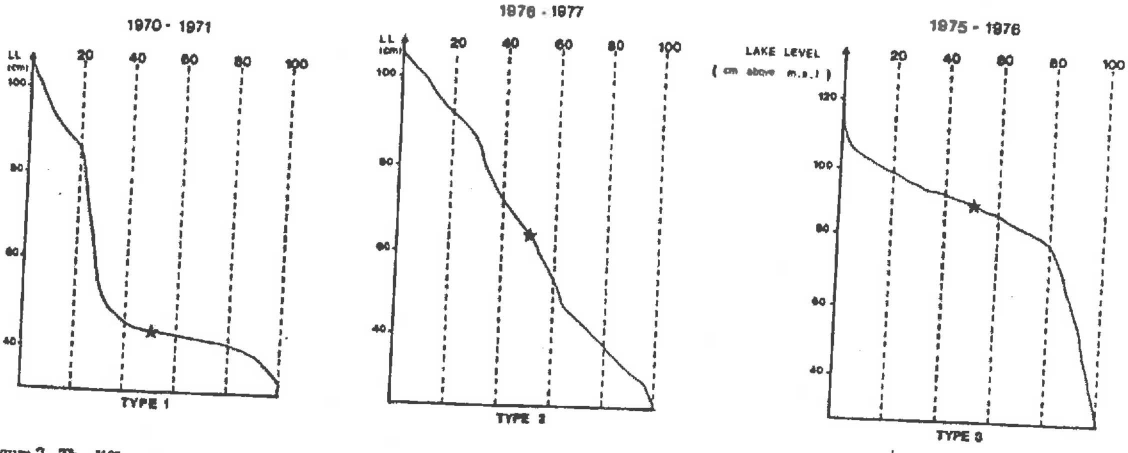

Figure 2. The different types of lake-level duration curves. The star indicates the median value.

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J. Aquat. Plant Manage. 31: 1993.

65. Hall (2003) recorded a type 3 lake-level duration curve for Wainono between 1986 and 2001. I have not been able to find any analysis of data since then. Hall (2003) also mentioned a trend towards higher lake level over the same period and suggested clogging of the landward face of the barrier beach below the water line by lake fines as one of the possible causes. This phenomenon could be accentuated by the fines contained in the Waitaki River.

THE BENEFITS OF CONSTRUCTED WETLANDS

66. Suitable artificially constructed wetlands can take up nutrients from inflows and have the potential to reduce the amount of nitrogen entering the lagoon. Thus between 25-30% and up to 50-60% N removal are predicted (Tanner et al 2010) when a created wetland represents 5% of the drained catchment (for tile drain flows from grazed pastures). Size obviously matters and a minimum size representing 1% of the drained catchment can still remove between 15 and 30% of nitrogen.

67. Constructed wetlands attempt to mimic natural wetlands with a view to create an ability to store, assimilate and transform contaminants lost from the land. Their overall performance for nitrogen will be substantially better when flows are steady or show low variability . This tends to happen in lower reaches of streams where flow regimes tend to be more buffered than when they are at the top of catchments.

However a range of other considerations may influence the costs and benefits of top and bottom of the catchment wetlands including: targeting of critical source areas, equitable spread of costs across landowners and biodiversity benefits.

68. Such wetlands should be planted with locally sourced wetland plants.

69. As a general rule, it is preferable in the first place to protect from grazing remaining wetlands in the catchment as they provide a number of ecosystem services other than nutrient retention, as already mentioned in paragraph 55 above. A map of historic wetlands in the catchment is provided in Dr Nicholas Dunn's evidence.

70. I am unclear on whether or not such wetlands will be sufficient to filter the glacial flour contained in the water of the Waitaki River. As already mentioned those inorganic suspensoids would potentially exacerbate the scattering of light in the lagoon and contribute further to the increase of light attenuation in the lagoon. Some attention will need to be given to this potential issue.

71. A recent study of optical properties in glacial lakes (Rose et al 2014), including New Zealand lakes from the Waitaki catchment, showed that variation in attenuation across lakes was related to turbidity, which was used as a proxy for the concentration of glacial flour. Turbidity-specific diffuse attenuation coefficients increased with decreasing wavelength and distance from glaciers and glacial flour contributed about two thirds of attenuation coefficients across ultra violet radiation (UVR) and Photosynthetic active radiation (PAR). Understanding the optical characteristics of substances that regulate light attenuation in glacially-fed lakes and rivers will incidentally help elucidate the signals that these systems provide of broader environmental changes and forecast the effects of climate change on these aquatic ecosystems.

72. Schallenberg and Saulnier-Talbot (2014) highlighted in their study the existence of quaking (floating) wetlands prior to and during the early phase of European settlement. Floating treatment wetlands employing emergent aquatic plants growing on a buoyant mat are innovative tools becoming more and more popular for nutrient

management in ponds, lakes and slow flowing waters (Tanner et al 2011). Plant roots grow through the floating mat and into the water beneath providing a large surface area for nutrient assimilation, growth of biofilms and trapping of fine suspended sediment. By shading the surface and buffering water turbulence they can also promote the settling of suspended algae and solids beneath the mats. They appear to equal or exceed those reported under comparable conditions for conventional surface-flow wetlands as described above and may be an option as well.

CONCLUSIONS

73. Wainono is a coastal barrier-beach enclosed lagoon (Waituna type) which through its shallowness, brackishness and salinity and water level regimes functions differently from deeper and freshwater lakes.

74. I stated in my introduction my involvement in the Living Water programme. The vision of the programme is "A sustainable dairy industry is part of healthy functioning ecosystems that together enrich the lives of all New Zealanders". Throughout, my evidence has attempted to define what a healthy functioning Wainono ecosystem means.

75. I have in particular insisted on the central role that submerged macrophytes used to and could (if restored) play in the healthy functioning of the lagoon. Their quasi-disappearance (only casual observations have been reported in the recent times) means that Wainono is currently in a very poor state and that a return to a healthy state is likely to be associated to the regrowth of macrophytes.

76. My evidence further highlights that a focus on reduction of nutrients through augmentation of flow from the Waitaki River is unlikely to provide sufficient suitable conditions for the regrowth of macrophytes in the lagoon.

77. Introduction of Waitaki River water into the Wainono system may not necessarily lead to improved water quality in the lagoon due to the silty nature of the lagoon bed and the probability of wind resuspension of those fine bed sediments.

78. One better option than diluting nutrients might be to identify means to reduce such resuspension of sediments and other means of reducing light attenuation in the water column of the lagoon.

79. The idea of creating wetlands or a large wetland to filter the Waitaki River water before it enters the lagoon is supported in principle. It should however be complemented by the re-creation of riparian wetlands along inflows, where sedimentation hotspots have been recorded.

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REFERENCES

Abell, J., Jones, H., Hamilton, D. (2015). Hydrodynamic-ecological modelling to support assessment of water quality management options for Wainono Lagoon. Prepared for Environment Canterbury. Aquatic Analytics Ltd. Hamilton, New Zealand. 73p.

Benn, J. 2011. Instream intrinsic values of the Wainono Lagoon-Waihao River catchment. Draft living document. Department of Conservation

Department of Conservation (2015). Director General's submission on the proposed Variation 3 of the proposed Canterbury Land and Water Management Plan

ECan 2012a. Wainono Restoration Newsletter. Issue 1. April 2012.

ECan 2012b. Wainono Restoration Newsletter. Issue 2. October 2012.

Gerbeaux P 1987. Proceedings of Shallow Lakes Management Problems workshop (John Clayton and Philippe Gerbeaux convenors). New Zealand Limnological Newsletter 23 December 1987: 21-23.

Gerbeaux P 1989. Aquatic plant decline in Lake Ellesmere: a case for macrophyte management in a shallow New Zealand lake. *Ph.D. thesis*, University of Canterbury.

Gerbeaux P 1993. Potential for re-establishment of aquatic plants in Lake Ellesmere (New Zealand). *Journal of Aquatic Plant Management 31*: 122-128.

Gerbeaux P and JC Ward 1989. The light climate of Lake Ellesmere. *Verh. Internat.Verein.Limnol. 23*: 1979-1984.

Gerbeaux P and JC Ward 1991. Factors affecting water clarity in Lake Ellesmere. *New Zealand Journal of Marine and Freshwater Research 25*: 309-316.

Gerbeaux P, Finlayson CM, van Dam A, *In Press*. Classifying wetlands: concepts and principles. Encyclopedia of Wetlands: Wetland Methodology (Vol. 3). Editors: C. Max Finlayson and Anne van Dam. Springer Verlaag.

Gilbert P, Madden C, Boynton W, Flemer D, Heil C, Sharp J 2010. Nutrients in Estuaries. A summary report of the national estuarine Experts Workgroup 2005-2007. 188p.

Golder Associates 2012. Ecological flow review: Waihao River and Wainono lagoon catchment. Report for Environment Canterbury. 63p.

Hall RJ 2003. Hydrological implications of a lake-level control weir for Wainono Lagoon, South Canterbury. Report prepared for Department of Conservation, DOC Science Internal Series 127, 13p.

Hume TM, Gerbeaux P, Hart DE, Kettles H. *In Prep*. A typology of coastal hydrosystems for management purposes. Report to MfE.

Johnson P, and Gerbeaux P 2004. *Wetland types in New Zealand*. Field guide published by the Department of Conservation, Te Papa Atawhai, Wellington.

Kilroy C, Biggs BJF 2002. Use of Shmak clarity tube for measuring water clarity: comparison with the black disk method. NZ J. of Marine and Freshwater Research 36: 519-527

Kirk RM, Lauder GA 2000. Significant coastal lagoon systems in the South Island, New Zealand: Coastal processes and lagoon mouth closure. Department of Conservation, Wellington. *Science for Conservation* 146. 47 p.

Mabin M 2011. Water balance and water quality of the Wainono Lagoon, South Canterbury. Report prepared for Meridian Energy Ltd by URS New Zealand Ltd Christchurch. 45p.

Maseyk, F. J. F., & Gerbeaux, P. (2015). Advances in the identification and assessment of ecologically significant habitats in two areas of contrasting biodiversity loss in New Zealand Journal of Ecology 39(1): 116–127.

Plew DR, Zeldis JR, Shankar U, Elliot, S 2015. CLUES Estuary – a tool for predicting estuary water quality. Proceedings of Australasian Coasts & Port Conference 2015, 15-18 Septembre 2015. Auckland, New Zealand.

Robertson HA and Funnell EP 2012. Aquatic plant dynamics of Waituna Lagoon, New Zealand: trade-offs in managing opening event of a Ramsar site. Wetland Ecol Manage 20 (5): 433-445.

Rose KC, Hamilton DP, Williamson CE et al. 2014. Light attenuation characteristics of glacially-fed lakes. Journal of geophysical research 119 (7): 1446–1457.

Schallenberg M 2013. Nutrient loading thresholds relevant to Wainono Lagoon (Canterbury). Report for Environment Canterbury by Hydrosphere Research Ltd Dunedin.

Schallenberg M 2015. Short peer review of Abell et al 2015 Hydrodynamic-ecological modelling to support assessment of water quality management options for Wainono Lagoon. Report for the Department of Conservation 16 September 2015 by Hydrosphere Research Dunedin.

Schallenberg M and Saulnier-Talbot E 2014. Recent environmental history of Wainono Lagoon (South Canterbury New Zealand). University of Otago Limnology report No12, prepared for Environment Canterbury – May 2014.

Sondergaard M and Moss B (1998). Impact of Submerged Macrophytes on Phytoplankton in Shallow Freshwater Lakes. In *The Structuring Role of Submerged Macrophytes in Lakes* Volume 131 of the series *Ecological Studies* pp 115-132.

Sutherland D and Norton N 2011. Assessment of augmentation of water flows in wainono lagoon. Report prepared for Meridian Energy Ltd by NIWA, Chrischurch.

Tanner CC, Sukias JPS, Yates CR 2010. New Zealand guidelines : Constructed Wetland Treatment of Tile Drainage. NIWA Information series No75. National Institute of Water and Atmospheric Research Ltd. 48p. .

Tanner CC, Sukias JPS, Park J et al. 2011. Floating treatment wetlands : a new tool for nutrient management in lakes and waterways. In: *Adding to the knowledge base for the nutrient manager.* (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Tipa & Associates 2012. *WAIHAO / WAINONO* CATCHMENT Cultural associations and their flow and water management. 98p.