BEFORE INDEPENDANT HEARING COMMISSIONERS
APPOINTED BY THE CANTERBURY REGIONAL COUNCIL

UNDER:	the Resource Management Act 1991
IN THE MATTER OF:	Proposed Plan Change 7 to the Canterbury Land and Water Regional Plan – Section 14: Orari-Temuka-Opihi-Pareora

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UPDATE OF THE EVIDENCE IN CHIEF OF
RICHARD JOHN MEASURES ON BEHALF OF
OPUHA WATER LIMITED (SUBMITTER NO. PC7-381)

Dated: 27 October 2020

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1. INTRODUCTION

1.1 My full name is Richard John Measures. My experience and qualifications are set out in my primary statement dated 17 July 2020.

1.2 My evidence for Opuha Water Limited relates to dissolved oxygen and temperature outcomes for Lake Opuha. My primary evidence was prepared prior to the release of NPS-FM 2020, which includes tables for lake dissolved oxygen limits (Tables 18 and 19). However, the content of these tables is unchanged from the Draft NPS-FM 2019 (Tables 20 and 21) so no changes to my evidence are required as a result of the new NPS-FM.

1.3 Dissolved oxygen limits have a greater significance for Lake Opuha than for other lakes in Canterbury because it is an artificial lake with an aeration system installed, allowing direct management intervention to help mix the lake and prevent stratification occurring. The functioning of the aeration system, and the history of water quality issues prior to commissioning of the aeration system, is described in my primary evidence.

1.4 Dissolved oxygen outcomes for Lake Opuha were discussed during the expert conferencing session on freshwater quality/ecology on 18 August. Relevant points of agreement from that conferencing session were:

a) Dissolved oxygen concentration (i.e. expressed in mg/l) is the most appropriate measure of lake dissolved oxygen for setting outcomes for Lake Opuha. This is consistent with OWL’s original submission and my evidence in chief but differs from the Section 42A report.

b) There are merits to setting both lake-bottom and mid-hypolimnetic dissolved oxygen limits for Lake Opuha. Lake bottom limits are most relevant for water chemistry concerns (which are a particular concern in Lake Opuha) but are more difficult to measure.

c) Limits within the range of NPS-FM band B are appropriate for lakebed and mid-hypolimnetic dissolved oxygen.

d) The measurement frequency and averaging period for continuously monitored dissolved oxygen is important as it has a significant impact on interpretation of results.

1.5 Two points regarding dissolved oxygen limits for Lake Opuha were not agreed upon:

a) There was disagreement over the limits for lake-bottom and mid-hypolimnion dissolved oxygen within the range specified for band B in the NPS-FM.

b) There was no agreed averaging period for interpreting continuously monitored dissolved oxygen data against the targets.

1.6 On 13 October Shirley Hayward provided additional written evidence for Environment Canterbury in response to questions raised during the hearing[1]. She proposes lake-bottom and mid-hypolimnetic dissolved oxygen limits of 5.0 and 6.0 mg/l respectively and an averaging period of 1-hour to be used when comparing continuously monitored dissolved oxygen against these limits.

1.7 This update to my evidence in chief provides a response to Ms Hayward's proposals in that regard with additional explanation/reasoning for my recommended lake-bottom and mid-hypolimnetic dissolved oxygen limits of 2.0 and 5.0 mg/l respectively. It also summarises and expands on the reasoning for my recommendation that a 24-hour averaging period is used to interpret continuously monitored dissolved oxygen data.

2. LAKE-BOTTOM DISSOLVED OXYGEN LIMITS

2.1 Microbial decomposition processes in lake bed sediments consume oxygen (sediment oxygen demand) causing the sediment, and the lake bottom waters adjacent to it, to become oxygen depleted. Lake-bottom dissolved oxygen concentration is important because it influences the REDOX potential, which in turn causes metals and phosphorus to change between soluble and insoluble forms. As the dissolved oxygen concentration falls towards zero, REDOX potential becomes less positive and insoluble metal oxides dissolve. At dissolved oxygen concentrations below about 5 mg/l manganese oxide begins

[1] Environment Canterbury (13 October 2020) Second set of responses to questions of hearing commissioners from the first hearing day.

to change to soluble Mn2+, and below about 2 mg/l the dissolution of iron oxide to soluble Fe2+ begins (Gibbs and Hickey, 2012)[2].

2.2 As insoluble metal oxides dissolve, any phosphorus that was bound to their oxide form is released as dissolved reactive phosphorus (DRP). Whilst both manganese and iron oxides can have phosphorus bound to them, the dissolution of manganese generally causes negligible increases in DRP whereas the dissolution of iron causes much more significant increases. This is thought to be because phosphorus released from the dissolution of manganese is often bound to iron oxides before it can be released into the water column (Chen et al 2019)[3].

2.3 The description in NPS-FM (2020) for band B lake-bottom dissolved oxygen is "*Minimal risk from bottom DO of biogeochemical conditions causing nutrient release from sediments*". This corresponds to a minimum dissolved oxygen concentration of 2.0 to 7.5 mg/l measured 1 m above the lake bed in the deepest part of the lake. Band C (0.5 to 2.0 mg/l) is described as "*Risk from bottom DO of biogeochemical conditions causing nutrient release from sediments*". The implication is that 2.0 mg/l is the threshold where the risk of nutrient release becomes more than "*minimal*". 2.0 mg/l is consistent with the threshold for the dissolution of iron oxides and associated release of sediment bound phosphorus.

2.4 In my opinion 2.0 mg/l is the appropriate threshold for minimum lake-bottom dissolved oxygen in Lake Opuha to prevent the release of sediment bound nutrients. This is consistent with the NPS-FM and with scientific understanding of the threshold dissolved oxygen which triggers significant DRP release from sediment.

2.5 Currently there are no limits for lake-bottom dissolved oxygen in the LWRP or the relevant consents for Lake Opuha. There is little data available to know how this proposed limit corresponds to minimum lake bottom-dissolved

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[2] Gibbs M., Hickey C. (2012) Guidelines for Artificial Lakes, *NIWA Client report HAM2011-045 Prepared for Ministry for the Environment*. https://www.envirolink.govt.nz/assets/Envirolink/Guidelines-for-artificial-lakes.pdf

[3] Chen M., Ding S., Wu Y., Fan X., Jin Z., Tsang D.C.W., Wang Y., Zhang C. (2019) Phosphorus mobilization in lake sediments: Experimental evidence of strong control by iron and negligible influences of manganese redox reactions. *Environmental Pollution* 246:472–481. https://doi.org/10.1016/j.envpol.2018.12.031.

oxygen under the current aeration regime. Temporary loggers installed in the deepest part of the lake from late-February to May 2020 (by NIWA on behalf of OWL) show minimum dissolved oxygen concentrations near the lakebed of approximately 4.3 mg/l. However, aeration had been operating for several weeks prior to the installation of the temporary loggers and it is likely that concentrations were lower than this in the weeks prior to installation (based on patterns observed in mid-hypolimnetic oxygen).

3. MID-HYPOLIMNETIC DISSOLVED OXYGEN LIMITS

3.1 The main purpose of a limit for mid-hypolimnetic dissolved oxygen is to protect fish and other aquatic organisms. Band B of the NPS-FM (5.0 to 7.5 mg/l) is described as "*Minor stress on sensitive fish seeking thermal refuge in the hypolimnion. Minor risk of reduced abundance of sensitive fish and macro-invertebrate species.*"

3.2 Mid hypolimnetic dissolved oxygen is currently monitored continuously in Lake Opuha to inform operational management of the aeration system and as part of consent requirements[4]. Monitoring data shows that minimum dissolved oxygen concentrations over the 2018-19 and 2019-20 summers were in the range 3.5 to 5.6 mg/l (depending on the averaging period). As far as I am aware, no concerns were raised in either of these summers over adverse effects on fish, nor has effects on fish due to low dissolved oxygen been a major concern since the aeration system was commissioned.

3.3 My recommended 5.0 mg/l limit for mid-hypolimnetic dissolved oxygen is higher than the current limit of 40% saturation specified in the dam consent[4] (roughly corresponding to 4 mg/l at typical summer lake temperatures) and would have required more pro-active use of aeration by the operator, Opuha Water, in the summer of 2018-19 to prevent dissolved oxygen dropping below my recommended 5.0 mg/l limit.

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[4] Environment Canterbury (2004) Consent to dam the Opuha River with a dam of dimensions described in CRC950567, *Consent Number: CRC950579.3*

4. AVERAGING PERIOD FOR MEASUREMENT OF DISSOLVED OXYGEN

4.1 The averaging period used for comparing continuous dissolved oxygen monitoring data against limits has a significant impact on what those limits 'mean' in the real world. This is clearly illustrated in table 3 of my Evidence in Chief, reproduced below as table 1.

Table 1 The effect of different averaging periods on minimum hypolimnion dissolved oxygen

	2018-19	**2019-20**
Minimum **instantaneous** dissolved oxygen (mg/l)	3.54	4.86
Minimum **1-hour mean** dissolved oxygen (mg/l)	3.87	5.01
Minimum **6-hour mean** dissolved oxygen (mg/l)	4.44	5.22
Minimum **1-day mean** dissolved oxygen (mg/l)	4.78	5.41
Minimum **7-day mean** dissolved oxygen (mg/l)	5.28	5.62

4.2 My evidence in chief clearly sets out the reasoning that an averaging period of some kind is necessary to avoid issues with 'noise' present in instantaneous data. It also explains the basis for my recommended 1-day averaging period.

4.3 Using a 1-hour averaging period, as suggested by Environment Canterbury, would mean that compliance with a limit would be strongly influenced by short duration variability in the data caused by factors such as currents introduced by intermittent power station operation and aeration, as well as diurnal temperature variations. These short-term variations are hard to predict, and aeration takes several days to be effective. Trying to manage to a limit defined in terms of a 1-hour average would be highly impractical.

4.4 For these reasons, I remain of the view that an averaging period for measurement of dissolved oxygen of 1-day is more appropriate.

Richard John Measures

27 October 2020