From: Georgina Hamilton
To: Plan Hearings
Cc: Glenire Farm; "Andrew Mockford"; Julia Crossman; Greg Ryder; Richard Measures; Keri Johnston; Tim Ensor
Subject: Plan Change 7: Opuha Water Limited - Evidence
Date: Friday, 17 July 2020 5:22:45 pm
Attachments: Evidence in chief of Ryan O"Sullivan (OWL) 17.7.20.pdf
Evidence in Chief of Andrew Mockford (OWL) 17.7.20.pdf
Evidence in Chief of Julia Crossman (OWL) 17.7.20.pdf
Quick reference guide (Annexure A to Evidence in Chief of Julia Crossman (OWL)).pdf
Evidence in Chief of Richard Measures (OWL) 17.7.20.pdf
Evidence in Chief of Keri Johnston (OWL) 17.7.20.pdf
Evidence in Chief of Dr Gregory Ryder (AMWG & OWL) 17.7.20.pdf
Evidence in Chief of Tim Ensor (OWL) 17.7.20.pdf

Dear Tavisha

We act for Opuha Water Limited (**OWL**), submitter no. PC7-381.

We **attach** for filing, in relation to the above matter, statements of evidence in chief of the following witnesses on behalf of OWL:

1. Ryan O'Sullivan (OWL Board Chair)
2. Andrew Mockford (OWL CEO)
3. Julia Crossman (OWL Environmental Manager)
4. Dr Greg Ryder (Lake Opuha - water quality) – note this statement of evidence addresses matters also pertaining to the submissions of the Adaptive Management Working Group (AMWG) and has also been filed with other AMWG evidence today.
5. Richard Measures (water quality)
6. Keri Johnston (hydrology/allocation)
7. Tim Ensor (planning)

We note that:

- Annexure A to the evidence of Ms Crossman comprises a "Quick Reference Guide" providing a location map and key information regarding the Opuha Scheme. This is also attached as a separate document for the assistance of the Hearings Commissioners.

- a flyover video of the Opihi catchment accompanies Mr Mockford's evidence. A link is provided within Mr Mockford's evidence by which the video can be accessed (https://youtu.be/Kp6luxCqWsk). The video is also downloadable in mp3 format from the following link, which can then be shared/posted (e.g. on ECan's PC7 webpage): https://we.tl/t-YgyExCMmGF

Kind regards

Georgina Hamilton
Partner

GRESSON DORMAN & CO
EST 1868

Level 1, 24 The Terrace, TIMARU 7910 | PO Box 244, TIMARU 7940
PHONE: 03 687 8004 | DDI: 03 687 8065 | MOBILE: 027 686 9252 | FAX: 03 684 4584
EMAIL: georgina@gressons.co.nz

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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STATEMENT OF EVIDENCE IN CHIEF OF RICHARD JOHN MEASURES ON BEHALF OF OPUHA WATER LIMITED (SUBMITTER NO. 381)

Dated: 17 June 2020

GRESSON DORMAN & CO
Solicitors
PO Box 244, Timaru 7940
Telephone 03 687 8004
Facsimile 03 684 4584
Solicitor acting: G C Hamilton
georgina@gressons.co.nz

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1. INTRODUCTION

1.1 My full name is Richard John Measures. I am currently employed as a hydrodynamics scientist at the National Institute of Water and Atmospheric research (NIWA) in Christchurch, where I have worked for the last 9 years.

Qualifications and experience

1.2 I have a masters degree in Civil Engineering from the University of Sheffield in the UK and am a Chartered Engineer with the Chartered Institute of Water and Environmental Management (CIWEM). I am on the committee of the New Zealand Rivers Group and am a member of the New Zealand Hydrological Society and New Zealand Coastal Society.

1.3 I have 14 years' professional experience of river related consulting and research. I have authored 8 peer reviewed scientific papers and over 50 client reports. I specialise in river hydrodynamics, morphology and sediment transport in gravel bed rivers and their hāpua. Since 2011 I have been involved in research and consulting relating understanding and managing the environmental effects of flow regime change in rivers as part of NIWA's Environmental Flows Research Programme.

1.4 Since 2012 I have led various studies relating to the Opuha Dam and rivers downstream of it. This work has included: reviewing data on water quality, nutrients and the role of aeration in Lake Opuha, recommending protocols for aerator operation, and coordinating installation/operation of upgraded instrumentation for monitoring water quality in Lake Opuha.

Background

1.5 I am familiar with the provisions of PC7 to which these proceedings relate. In preparing my evidence, I have reviewed the relevant parts of the section 32 Report and the section 42A Report. In preparing my evidence, I have also reviewed:

(a) Davies-Colley R.J., Franklin P., Wilcock B., Clearwater S., Hickey C. (2013) National Objectives Framework - Temperature, Dissolved Oxygen & pH. Proposed thresholds for discussion. *NIWA Client report HAM2013-056 for the Ministry for the Environment*.

(b) Gibbs M., Hickey C. (2012) Guidelines for Artificial Lakes, NIWA Client report HAM2011-045 Prepared for Ministry for the Environment.

(c) Gibbs M., Measures R.J. (2017) Lake Opuha: In lake processes and aeration - a review, *NIWA Client Report 2017024HN*.

(d) Hamilton D.P., Collier K.J., Quinn J.M., Howard-Williams C. (Eds) (2018) *Lake restoration handbook: A New Zealand perspective*. Springer.

(e) Hawes I., Spigel B. (1999) Report on water quality in the Opuha Dam, *NIWA Client Report: CHC99/12, prepared for Opuha Dam Company*.

(f) Ministry for the Environment (2019) Draft National Policy Statement for Freshwater Management.

(g) Meredith A.S. (1999) Water Quality of Lake Opuha: Limnological Issues of a Newly Formed Lake, *Canterbury Regional Council Report*.

(h) Science and Technical Advisory Group (2019) Freshwater science and technical advisory group report to the Minister for the Environment.

Code of Conduct

1.6 I confirm that I have read the Code of Conduct for expert witnesses contained in the Environment Court's Practice Note as updated in 2014. My evidence has been prepared in compliance with that Code. In particular, unless I state otherwise, this evidence is within my area of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

2. SCOPE OF EVIDENCE

2.1 I have been engaged by Opuha Water Limited (OWL) to provide evidence in relation to the dissolved oxygen and temperature outcomes proposed for Lake Opuha in section 14.6.1, Table 14(b) of Plan Change 7 (PC7) to the Canterbury Land and Water Regional Plan (CLWRP).

2.2 My evidence is structured as follows:

(a) Background to water quality in Lake Opuha;

(b) Dissolved oxygen and temperature parameters; and

(c) Definitions of lake water quality parameters.

3. EXECUTIVE SUMMARY

3.1 Following commissioning of the Opuha Dam in 1998 Lake Opuha suffered from thermal stratification in the summer and early autumn, resulting in low or zero dissolved oxygen in the hypolimnion. This caused the release of dissolved metals and nutrients from the lakebed sediment into the water, having a range of adverse effects. An aeration system was installed in the lake in 2003 and has operated as required since then to induce mixing currents in the lake, preventing thermal stratification and the associated low dissolved oxygen conditions. The aeration system is a point of difference between Lake Opuha and other lakes in Canterbury. It provides a way to directly manipulate the lake, meaning that dissolved oxygen outcomes set for Lake Opuha have day-to-day management implications which are not present for other Canterbury lakes.

3.2 Specifying thresholds in terms of absolute dissolved oxygen concentration (i.e. mg/l) rather than percentage saturation is more consistent with thresholds relevant to outcomes for fish and water chemistry that are recommended in scientific analysis and guidance documents. Thresholds set in terms of percentage saturation do not equate to a consistent concentration because of the effect of temperature and pressure on oxygen solubility.

3.3 In my opinion an appropriate threshold for hypolimnion dissolved oxygen in Lake Opuha would be 5.0 mg/l, based on the band B threshold for hypolimnetic dissolved oxygen in the draft NPS-FM. This threshold is more stringent than the current consent requirements governing aerator operation and is consistent with the current protocol for aerator operation in Lake Opuha (developed by NIWA following a review of available data relating to the lake).

3.4 Dissolved oxygen (and temperature) are continuously monitored in Lake Opuha and data shows variations over time and with depth. Accurately defining the timescales and depths which the PC7 dissolved oxygen and temperature outcomes relate to is important if they are to be used for management. In my opinion a 1-day average would be appropriate for hypolimnetic dissolved oxygen.

4. BACKGROUND TO WATER QUALITY IN LAKE OPUHA

4.1 The approximately 50 m high Opuha Dam impounds Lake Opuha, an on-river artificial lake with a volume (when full) of 77 million m^3. The lake has a maximum depth of approximately 40 m, and an operating range of 22.2 m. The dam discharges through a power station with its intake located 32 m below the lake full level. The power station operates intermittently with a flow rate of approximately 16 m^3/s.

4.2 Following commissioning of the dam in 1998 the dam experienced severe water quality problems. During warm summer months the lake thermally stratified and the deeper water became anoxic. Thermal stratification occurs when surface waters heat up faster than conduction and mixing can transfer heat down to the bottom waters of the lake. Warm water is less dense which means warming causes the surface water to become buoyant, opposing mixing. Eventually a sharp temperature gradient (thermocline) develops between the warm surface water (epilimnion) and the colder deeper water (hypolimnion). There is very little mixing across the thermocline making it a barrier to the transfer of heat, oxygen and nutrients. Sediment oxygen demand, due to the decay of organic material on the lakebed, removes oxygen from the water column. When the lake is stratified oxygen in the hypolimnion is not replenished, leading to low dissolved oxygen (hypoxic conditions) or even the complete absence of oxygen (anoxic conditions). In lake Opuha the thermocline typically forms at around 10 to 15 m below the lake surface.

4.3 In 2003 a bubble plume aeration system was installed in the lake to mix the lake and prevent the water quality issues associated with stratification. The system consists of a compressor which drives pressurised air through a submerged pipe extending down the face of the dam into a 250 m long diffuser pipe (sparge line) along the lakebed in the deepest part of the lake. The diffuser releases fine bubbles which rise through the lake, entraining a column of water above the diffuser and mixing the lake, preventing or breaking down stratification.

4.4 The aerator has been largely successful in preventing prolonged stratification, with associated low dissolved oxygen in the hypolimnion. However, during extended periods of high temperatures and low winds (wind helps to mix the lake) the aerator can struggle to mix the lake allowing stratification to develop and dissolved oxygen levels to start reducing. Once these weather conditions end the aerator does break down any stratification which has developed, and oxygen levels increase again.

4.5 Continuous data on hypolimnion dissolved oxygen concentration for the period since April 2018 (when upgraded sensors were installed in the lake) is shown in Figure 1. The data shows strong seasonal variability, as well as short term variability (related to night/day cycles and intermittent power station operation). The aerator was used for several extended periods during both the 2018-19 and 2019-20 summers.

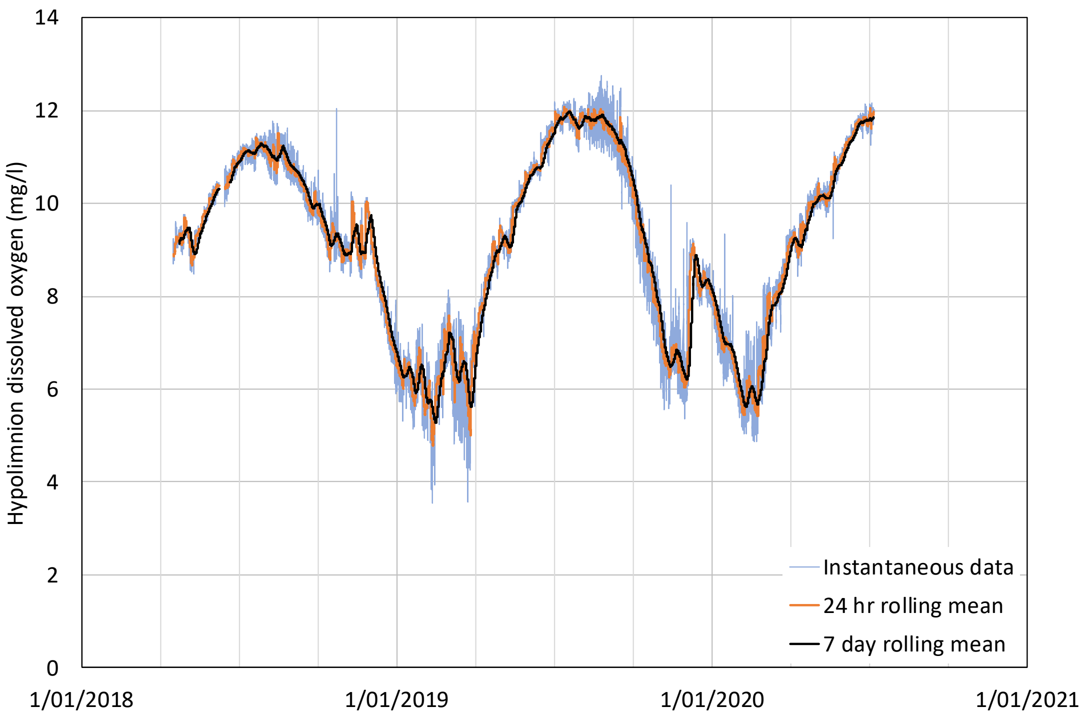

Figure 1: Dissolved oxygen monitoring data from the hypolimnion of Lake Opuha April 2018 to June 2020.

5. DISSOLVED OXYGEN AND TEMPERATURE OUTCOMES FOR LAKE OPUHA

5.1 Table 14(b) of PC7 contains freshwater outcomes for Lake Opuha including minimum dissolved oxygen saturation of 70% for the hypolimnion and 90% for the epilimnion.

5.2 There are two main reasons to include dissolved oxygen requirements for lakes:

(a) Fish – fish (and macro-invertebrates) require dissolved oxygen to respirate. Low dissolved oxygen stresses fish and extreme low dissolved oxygen causes fish kills.

(b) Water chemistry – low dissolved oxygen triggers chemical reactions in lake sediments which release dissolved nutrients and metals into the water column. Nutrients can trigger phytoplankton blooms within lakes or accelerated growth of nuisance periphyton in downstream rivers.

5.3 Setting appropriate dissolved oxygen targets requires consideration of both fish and water chemistry requirements.

5.4 My concern regarding the PC7 outcomes for dissolved oxygen is that they are specified in terms of percentage saturation (oxygen concentration relative to the solubility of oxygen) whereas the impacts of dissolved oxygen on fish or water chemistry are generally linked to the absolute concentration of oxygen (i.e. in mg/l). The conversion between percentage saturation and absolute concentration is strongly influenced by temperature and to a lesser extent pressure. This means that the impact on fish and water chemistry of a specified percentage saturation is not consistent. Specifying dissolved oxygen outcomes in terms of absolute concentrations is consistent with current guidance (such as the draft NPS-FM and the Lake Restoration Handbook) and is consistent with dissolved oxygen sensor technology.

5.5 The solubility of oxygen in water is a function of temperature and pressure. Figure 2 shows how oxygen solubility varies with temperature and Figure 3 shows the conversion between absolute dissolved oxygen concentrations and percentage saturation. Hypolimnion temperatures in Lake Opuha typically range from approximately 5°C to 19°C. For this range of temperature, the dissolved oxygen concentration corresponding to 70% saturation varies from approximately 6.5 to 9.0 mg/l. Variations in air pressure due to weather and altitude do impact oxygen solubility. The surface of Lake Opuha is at 392 m above sea level (when full), corresponding to a 4.6 % reduction in oxygen solubility due to the reduction in air pressure with altitude. Dissolved oxygen sensors measure the absolute concentration of dissolved oxygen (modern sensors generally use an optode which responds to the partial pressure of oxygen). Most sensors also report percentage saturation by performing an onboard conversion accounting for water temperature. However, this conversion typically does not account for pressure, so corresponds to a standardised sea level pressure of 1013 mb. The need to correct percentage saturation data for altitude provides an additional complexity (a step which is often omitted resulting in a small but significant measurement bias). Absolute concentration data needs no such correction.

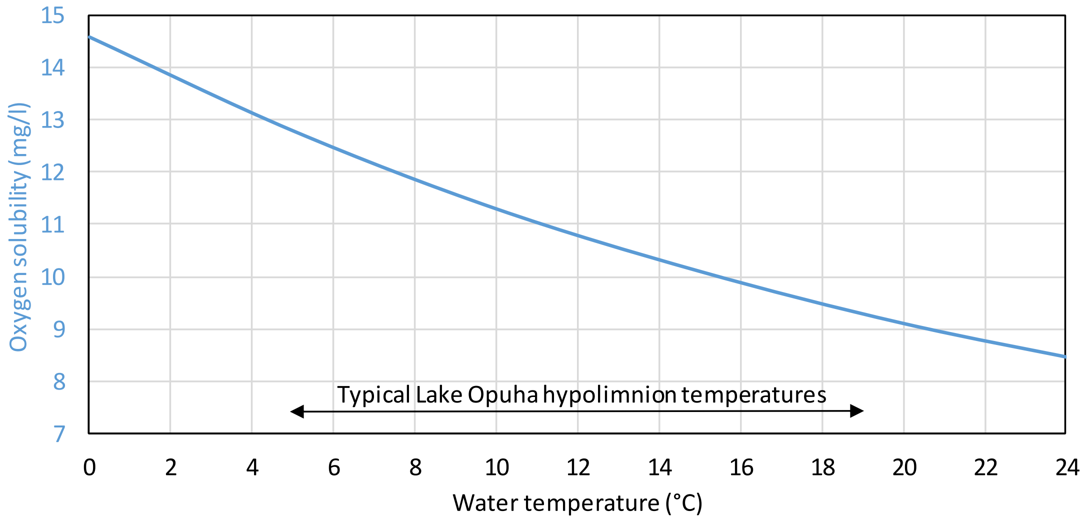

Figure 2: Variation in oxygen solubility with temperature in freshwater at sea level.

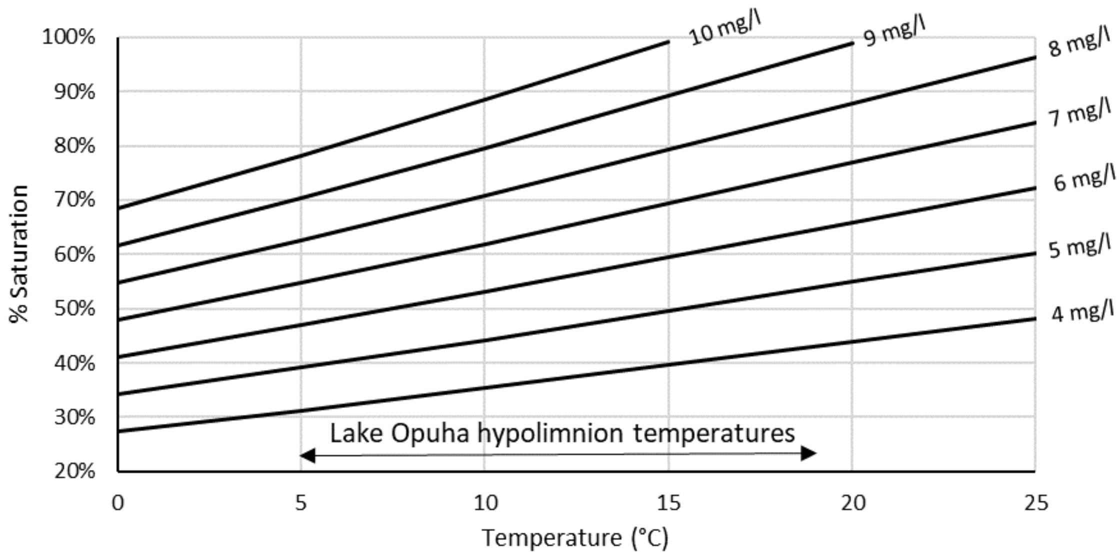

Figure 3: Relationship between absolute and relative dissolved oxygen for freshwater at temperatures between 0 and 25 degrees (at sea level).

5.6 Thresholds for dissolved oxygen in lakes were proposed in the Draft National Policy Statement for Freshwater Management (NPS-FM)[1] released for consultation in September 2019. Tables 20 and 21 of the NPS-FM specify thresholds for lake bottom and mid-hypolimnetic dissolved oxygen. These tables are reproduced below as my Table 1 and Table 2. The NPS-FM lake

[1] Ministry for the Environment (2019) Draft National Policy Statement for Freshwater Management. https://www.mfe.govt.nz/publications/fresh-water/draft-national-policy-statement-freshwater-management.

dissolved oxygen bands are derived from recommendations in the Freshwater science and technical advisory group report to the Minister for the Environment (STAG report)[2]. No changes to the NPS-FM lake dissolved oxygen tables were recommended by the Freshwater Independent Advisory Panel[3] following their review of the draft NPS-FM and relevant consultation responses (except to move them into a new 'must consider for use where relevant' class of attributes).

Table 1: Draft NPS-FM thresholds for measured or estimated annual minimum lake-bottom dissolved oxygen concentration (from Table 20 MfE 2019). The thresholds relate to dissolved oxygen measured 1 m above the lakebed in the deepest part of the lake.

Band	DO (mg/l)	Description
A	DO ≥ 7.5	No risk from bottom DO of biogeochemical conditions causing nutrient release from sediments.
B	2.0 ≤ DO < 7.5	Minimal risk from bottom DO of biogeochemical conditions causing nutrient release from sediments.
C	0.5 ≤ DO < 2.0	Risk from bottom DO of biogeochemical conditions causing nutrient release from sediments.
Bottom Line	0.5	National 'bottom line'
D	DO < 0.5	Likelihood from bottom DO of biogeochemical conditions resulting in nutrient release from sediments.

Table 2: Draft NPS-FM thresholds for measured or estimated annual minimum mid-hypolimnetic dissolved oxygen concentration (from Table 21 MfE 2019).

Band	DO (mg/l)	Description
A	DO ≥ 7.5	No stress caused to any fish species by low dissolved oxygen.
B	5.0 ≤ DO < 7.5	Minor stress on sensitive fish seeking thermal refuge in the hypolimnion. Minor risk of reduced abundance of sensitive fish and macro-invertebrate species.
C	4.0 ≤ DO < 5.0	Moderate stress on sensitive fish seeking thermal refuge in the hypolimnion. Risk of sensitive fish species being lost.
Bottom Line	4.0	National 'bottom line'
D	DO < 4.0	Significant stress on a range of fish species seeking thermal refuge in the hypolimnion. Likelihood of local extinctions of fish species and loss of ecological integrity.

[2] Science and Technical Advisory Group (2019) Freshwater science and technical advisory group report to the Minister for the Environment. https://www.mfe.govt.nz/sites/default/files/media/Fresh water/freshwater-science-and-technical-advisory-group-report.pdf

[3] Essential Freshwater: Report of the Freshwater Independent Advisory Panel (February 2020) https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/essential-freshwater-report-of-freshwater-independent-advisory-panel.pdf

5.7 I recommend that the NPS-FM thresholds for mid-hypolimnetic dissolved oxygen would be a logical source for thresholds in the Canterbury Land and Water Regional Plan. For lake Opuha I suggest a threshold of 5.0 mg/l would be appropriate for the hypolimnion, corresponding to band B of the draft NPS-FM. No guidance on epilimnion dissolved oxygen is given in NPS-FM but the band A threshold of 7.5 mg/l is described as "no stress caused to any fish species by low dissolved oxygen" and would seem appropriate for the epilimnion of Lake Opuha.

5.8 A hypolimnion dissolved oxygen threshold of 5.0 mg/l is more stringent than the current 40% saturation 'trigger level' in OWL's consent[4] (roughly corresponding to 4 mg/l at typical summer lake temperatures). The current protocols used by OWL for aerator operation recommend that the aerator is turned on if the hypolimnion dissolved oxygen concentration drops below 7.0 mg/l. This is generally effective at preventing dissolved oxygen dropping below 5.0 mg/l. These protocols where developed after a review of available data from Lake Opuha (Gibbs and Measures 2018)[5] and are consistent with subsequent guidance on aerator operation published in the Lake Restoration Handbook (Hamilton et al 2018)[6].

5.9 Preventing nutrient release from sediments is a particular concern in Lake Opuha given the history of issues related to stratification prior to installation of the aeration system in 2003 (see paragraph 4.2). Ongoing investigations funded by Opuha Water are investigating lakebed dissolved oxygen dynamics in the deepest part of the lake but are complicated by the temporal and spatial variability in dissolved oxygen and the difficulties of regularly monitoring near bed dissolved oxygen. Temporary loggers installed in deepest part of the lake from late-February to May 2020 show minimum dissolved oxygen concentrations near the lakebed of approximately 4.3 mg/l.

5.10 I can find little supporting evidence for the Lake Opuha dissolved oxygen concentrations specified in PC7 table 14(b) (70% and 90% for the hypolimnion and epilimnion respectively). These concentrations are consistent with the

[4] Environment Canterbury (2004) Consent to dam the Opuha River with a dam of dimensions described in CRC950567, *Consent Number: CRC950579.3*.
[5] Gibbs M., Measures R.J. (2017) Lake Opuha: In lake processes and aeration - a review, *NIWA Client Report 2017024HN*.
[6] Hamilton D.P., Collier K.J., Quinn J.M., Howard-Williams C. (Eds) (2018) *Lake restoration handbook: A New Zealand perspective*. Springer.

regional guidance contained in the Canterbury Land and Water Regional Plan (Table 1(b)), which appears to have been carried over from the CLWRP's predecessor, the Natural Resources Regional Plan (notified 2004), but there is little explanation of its basis in the supporting Section 32 documents (or elsewhere) for either plan. The section 42A report[7] identifies that setting appropriate thresholds for dissolved oxygen in Lake Opuha is important because of the historical issues related to low dissolved oxygen (I agree), but it provides little justification for the thresholds selected.

5.11 Setting an appropriate threshold for hypolimnion dissolved oxygen and using the aerator to maintain water quality above this threshold is important to prevent adverse impacts. However, an unnecessarily high dissolved oxygen threshold for the Lake Opuha hypolimnion would require running the aerator for longer durations (with associated costs and energy usage), or possibly upgrading the aeration system (i.e. bigger compressor and longer diffuser). It would also tend to increase lake temperature (by increasing mixing of warm surface water down into the lake).

5.12 Hypolimnion temperatures measured in Lake Opuha currently peak at approximately 19°C in late summer (24-hour average hypolimnion temperature peaked at 19.22°C and 19.00°C in 2018-19 and 2019-20 respectively). PC7 Table 14(b) specifies 19°C as the outcome for maximum lake temperature. This threshold comes from the LWRP water quality outcomes Table 1b and appears to have been carried forward from the Natural Resources Regional Plan (notified 2004), but there is little explanation of its basis in the supporting Section 32 documents (or elsewhere) for either plan. The draft NPF-FM does not contain guidance on attributes for water temperature but there is some guidance (for rivers rather than lakes) given in the National Objectives Framework (NOF) for temperature, dissolved oxygen and pH[8]. A maximum temperature of 19°C corresponds to the NOF band A "*No thermal stress on any aquatic organisms that are present at matched reference (near-pristine) sites*"[9]. I do not have a strong opinion on whether this threshold is appropriate for Lake Opuha,

[7] Part 4, at 3.36, page 243.
[8] Davies-Colley R.J., Franklin P., Wilcock B., Clearwater S., Hickey C. (2013) National Objectives Framework - Temperature, Dissolved Oxygen & pH. Proposed thresholds for discussion. *NIWA Client Rep No HAM2013-056 for the Ministry for the Environment*.
[9] Table 2-3: Proposed NOF for temperature regime in rivers and streams in 'Eastern Dry' regions of New Zealand, page 29 of the NOF.

however, given that the maximum hypolimnion lake temperature is generally around this threshold, additional aeration to increase dissolved oxygen will likely increase hypolimnion temperatures above 19°C.

6. DEFINITIONS FOR LAKE WATER QUALITY PARAMETERS

6.1 Another concern I have regarding the PC7 dissolved oxygen and temperature outcomes for Lake Opuha is that the neither PC7 Table 14(b), or Table 1b of the CLWRP have any definitions for these parameters.

6.2 Unlike most other Canterbury lakes, temperature and dissolved oxygen are measured continuously in Lake Opuha at multiple depths. This data is used to inform aerator operation, so definitions of how the PC7 outcomes relate to measurements will be important.

6.3 Data from Lake Opuha shows significant variations in dissolved oxygen and temperature with both depth and time. For example, as shown in Figure 1 and Table 3, minimum hypolimnion dissolved oxygen is quite different depending on the time frame it is averaged over. Without specification of how data is quantified the specified minimum dissolved oxygen and maximum temperature in Lake Opuha are somewhat ambiguous.

Table 3 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

6.4 The currently installed lake monitoring instrumentation records instantaneous measurements at 15-minute intervals. Noise is often present in this instantaneous data and I would not recommend setting dissolved oxygen or temperature limits for instantaneous data. Daily fluctuations and fluctuations associated with intermittent power station operation are also visible in the temperature and dissolved oxygen data.

6.5 There is little guidance available on appropriate time-averaging periods for lake dissolved oxygen targets. For lake-bottom and mid-hypolimnetic dissolved oxygen the draft NPS-FM refers to "*measured or estimated annual minimum*" but provides no guidance on the appropriate time-averaging period for instantaneous data. The STAG report[2] provides a little more detail: "*Rapid DO changes in lakes are not expected. Monthly sampling may be adequate in most cases and we recognise that continuous sensor-enabled monitoring is always advantageous.*"[10] However, as mentioned previously, Lake Opuha can experience relatively rapid changes in DO during the summer. Monthly sampling would be insufficient to capture minima in Lake Opuha but the continuous sensor data can be noisy, so an averaging period of some kind is required.

6.6 The draft NPS-FM provides separate thresholds for 1-day and 7-day mean dissolved oxygen in rivers (Table 9 in the draft NPS-FM[1]), recognising that the duration of low-dissolved oxygen concentrations is important for aquatic organisms. This importance of duration, magnitude and frequency of low-dissolved oxygen is described in more detail in the NOF[8] and the bases for the separate 1-day and 7-day river dissolved oxygen bands are explained. The draft NPS-FM bands for mid-hypolimnetic dissolved oxygen match the bands for 1-day mean river dissolved oxygen. I suggest specifying a 1-day mean for hypolimnetic dissolved oxygen would be appropriate. Existing consent thresholds for triggering enhanced monitoring and aeration relate to 7-day average dissolved oxygen and temperature[4].

Richard John Measures
17 July 2020

[10] Table footnote 1, page 21 of the STAG report.