BEFORE CANTERBURY REGIONAL COUNCIL
AT CHRISTCHURCH

In the matter of	the Resource Management Act 1991
And	
In the matter of	Proposed Variation 2 to the Proposed Canterbury Land and Water Plan
And	
In the matter of	a submission by Te Rūnanga o Ngāi Tahu

EVIDENCE OF GREGORY PETER BURRELL
ON BEHALF OF TE RŪNANGA O NGĀI TAHU
DATED 18 MAY 2015

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QUALIFICATIONS AND EXPERIENCE

1. My full name is Gregory Peter Burrell.

2. I have a Bachelor of Science, a Post Graduate Diploma in Science, and a Doctor of Philosophy (PhD), all majoring in Zoology and all obtained from the University of Canterbury. My specialty area is freshwater ecology, which is the study of how living things in freshwater interact with each other and their environment. My PhD studied ecological aspects of river-groundwater interactions, but my professional experience is broad and includes experience working in rivers, lakes, wetlands, groundwater, estuaries, and terrestrial environments.

3. I have over 15 years of work experience as a freshwater ecologist. I currently hold the position of Director and Senior Scientist at Instream Consulting Ltd, a company I set up in August 2014. Prior to that I worked for ten years as an ecologist and senior shareholder at Golder Associates, including two years in British Columbia, Canada. Previous professional experience includes positions held with several other consultancies. I also worked at the National Institute of Water and Atmospheric Research (NIWA) in the 1990s, where I was involved with a large research programme focussed on impacts of landuse change on river ecosystems (eg riparian shading experiments, leaf decay studies, and sedimentation impacts).

4. Of particular relevance to this hearing, I undertook fieldwork in the Hinds-Valetta area in 2007 and provided evidence for the applicant group at the Valetta-Ashburton Groundwater Zone hearing in 2008. As part of that work my Golder colleagues and I made notes on ecology and habitat at approximately 40 drain and river sites, sampled water quality and invertebrates at 14 sites, sampled fish at 18 sites, and made detailed instream habitat measurements and undertook subsequent flow-habitat modelling at ten sites, including the Hinds River and various drains. I visited some of the drains and the Hinds River again on 24 April 2015; that fieldtrip included visiting drains where the University of Canterbury is researching the effectiveness of different mitigations on improving water quality and ecology.

SCOPE OF EVIDENCE

5. I have been asked by Te Rūnanga o Ngāi Tahu and Te Rūnanga o Arowhenua to present evidence in relation to aquatic ecology for the hearing

of Variation 2 (Hekeao/Hinds Plains) to the proposed Canterbury Land and Water Regional Plan (LWRP). In particular, I have been asked to:

(a) Provide an ecological overview, highlighting key factors that influence aquatic ecology and describing the current state and trends in aquatic ecology.

(b) Discuss the Variation 2 water quality-related issues.

(c) Discuss Variation 2 water quantity-related issues.

6. In preparing this evidence I have reviewed the following hearing-related documents (including relevant references cited within):

- Proposed Variation 2 to the LWRP, and the s32 and s42A reports.
- Zone Implementation Plan (ZIP) addendum.
- Technical Overview report (Bower 2014).
- Hydrology report (Durney & Ritson 2014).
- Water quality modelling report (Scott 2013).
- Ecology reports (Meredith & Lessard 2014a, b).
- Cultural values report (Tipa & Associates 2014).

7. I confirm that I have read and agree to comply with the Code of Conduct for expert witnesses contained within the Environment Court of New Zealand Practice note 2014. I confirm that the opinions I express are within my area of expertise except where I state I am relying on the opinions of other experts. I have not omitted any facts known to me that may be material in influencing my evidence.

ECOLOGICAL OVERVIEW

8. The two ECan ecology reports supporting Variation 2 (Meredith & Lessard 2014a, b) provide a good overview of the water quality and ecology of the Hekeao/Hinds Plains area, including discussion of the factors that affect aquatic ecosystems. I will therefore provide a brief summary of what I consider the key issues are.

Factors Affecting Freshwater Biota

9. The plants and animals, or biota, of freshwaters are strongly affected by the amount of water present, water quality, and habitat conditions. A healthy freshwater ecosystem is therefore one that provides the correct mix of water quality, quantity and habitat to support the range and abundance of species you would naturally expect to be present with little human disturbance. The freshwater biota includes: algae, bacteria, and fungi that grow on the riverbed and are collectively called “periphyton”; aquatic plants or “macrophytes” that grow from the banks, bed and float on the water surface; invertebrates that graze on periphyton and organic matter, and prey on each other; and fish that feed on invertebrates and other fish.

10. The obvious fundamental requirement for freshwater biota is the presence of water. However, the presence of water on its own is insufficient to support healthy and diverse freshwater communities, as species differ in their flow-related habitat requirements. Flood disturbance and low flows are particularly important factors affecting the biota.

11. Regular floods in hill-fed rivers scour the bed of periphyton, macrophytes and fine sediments, maintaining clean stony substrates preferred for many fish and invertebrates. While spring-fed streams may also have stony bed sediments, they are more prone to build up of periphyton, macrophytes and fine sediments, due to the lack of floods. Hence, spring-fed streams are more susceptible to nuisance growths and sedimentation than hill-fed streams.

12. Low flows and water levels also affect aquatic communities, with different species affected differently depending on their flow preferences. For example, adult eels (*Anguilla* spp.) and brown trout (*Salmo trutta*) favour deeper water and pools, small native fish such as bluegill bullies (*Gobiomorphus hubbsi*) favour shallow, swift velocities, and inanga (*Galaxias maculatus,* the main component of the whitebait catch), prefer slower velocities. While lower flows occur naturally over summer, water abstraction and drought can reduce flows and water levels, limiting the diversity of aquatic habitats present for the biota, with impacts felt most strongly by species that favour the deeper and swifter water.

13. Key water quality parameters that influence freshwater biota in agricultural catchments include nutrients (especially nitrogen and phosphorus), temperature, dissolved oxygen, and clarity/turbidity. The presence of faecal

contaminants is also of concern to recreational water users and gatherers of mahinga kai. However, my focus here is on aquatic ecosystems, which are more strongly affected by nutrients, temperature, dissolved oxygen and turbidity.

14. While nitrogen and phosphorus are basic requirements for plant growth, in excess they can stimulate nuisance growths of periphyton and macrophytes, and ammonia and nitrate-nitrogen can become toxic at high concentrations. It is generally acknowledged that the primary route of nitrate-nitrogen into freshwaters is via groundwater, while phosphorus is primarily sourced from overland flowpaths and bank erosion. Streams running through intensive agricultural landuse are typically associated with elevated concentrations of nitrate-nitrogen, due to groundwater sources high in nitrate, and elevated phosphorus, sourced from overland runoff and bank erosion. I discuss nutrient guidelines later in my evidence (paragraphs 20-27).

15. High water temperatures can be lethal to fish and invertebrates, as can low dissolved oxygen concentrations. High macrophyte cover is associated with large daily swings in dissolved oxygen, as plants produce oxygen in excess during the day but only respire overnight, sometimes driving dissolved oxygen down to levels that are lethal to invertebrates and fish. High levels of stream shade by riparian vegetation – in the order of 70% shade – are needed to keep water temperatures relatively cool and to control macrophyte cover to levels that dissolved oxygen swings are less of an issue (Collier et al., 1995). Agricultural and urban landscapes with minimal riparian shading are often associated with high water temperatures and low daily minimum dissolved oxygen concentrations, which impact negatively on the biota. Both temperature and dissolved oxygen are further affected by flow, with greater extremes in temperature and dissolved oxygen occurring during low flow and in standing water.

16. Optically clear water is both aesthetically appealing and is a requirement for many freshwater species. The impacts of fine sediment on aquatic biota are well understood, and include reduced algal production, gill abrasion, disruption of spawning migrations, and smothering of habitat, invertebrates, and fish (Ryan 1991; Davies-Colley & Smith 2001; Clapcott et al. 2011). Pugging of exposed soils, overland flowpaths, drain maintenance, and bank erosion caused by stock access, can all contribute to elevated turbidity and fine sediment deposition in agricultural streams.

17. Riparian (bankside) and instream (lake and river bed) habitat conditions also strongly affect the biota. Riparian vegetation provides habitat for birds and invertebrates, gives shade (regulating temperatures and instream plant growths), can intercept and filter out sediment, nutrients and faecal material before entering the waterway, stabilises banks, provides fish cover, and the fall of leaf litter and wood provides habitat and food to stream invertebrates. While pasture grass may provide a useful filtering function in the riparian zone, shrubs and trees are required to provide riparian habitat, shade, bank stability, cover, and leaf litter to the stream ecosystem (Collier et al. 1995). Urban and agricultural waterways often lack trees and shrubs in the riparian zone, which greatly limits the quality of aquatic habitat present, and is associated with degraded aquatic and riparian biodiversity (Collier et al. 1995).

18. Instream habitat includes the range and diversity of physical habitats present. Stony bed sediments are favoured habitats for pollution-sensitive invertebrate species and many fish species, while silt-dominated bed sediments are often less favoured. Similarly, winding stream channels that provide a range of shallow and deep habitats also support a wider diversity of species than straight channels with minimal instream habitat diversity. Drains and streams in both urban and agricultural environments are often deepened and straightened to improve drainage functions, which impacts negatively on instream habitats and the biota they support.

Key Message

19. Freshwater ecosystems are affected by a range of factors that can be broadly categorized as water quantity, water quality, and habitat. If any one of these factors is unfavourable, it will impact on the biota present. The first order of priority is having sufficient water to support aquatic life. However, a healthy aquatic community can only be present if all the environmental factors are favourable. For example, improving flows and reducing nutrient concentrations alone will not restore a degraded aquatic community dominated by pollution-tolerant species if it remains impacted by a lack of riparian shade, stock access, and deposited fine sediment.

Nutrient and Periphyton Guidelines

20. As indicated above, nutrients are essential for growth of periphyton and macrophytes, but excessive nutrient concentrations can lead to nuisance growths. The New Zealand Periphyton Guideline (Biggs 2000) gives

periphyton limits for protection of different instream values, as well as corresponding nutrient concentrations to achieve those limits. The Periphyton Guideline suggests an annual maximum biomass limit of 50 mg/m² of chlorophyll *a* for protection of benthic biodiversity (measured as invertebrate community health). For protection of aesthetics and trout habitat and angling, the Periphyton Guideline suggests a maximum bed cover with filamentous algae of 30%, which is equivalent to 120 mg/m² of chlorophyll *a*, or a maximum bed cover with thick mats of 60%, or 200 mg/m² of chlorophyll *a* (Biggs 2000).

21. The periphyton Attribute Table of the National Objectives Framework within the 2014 New Zealand Freshwater Policy Statement for Freshwater Management (NPS) is based on the New Zealand Periphyton Guideline. The NPS "Attribute States" range from Class A rivers, with chlorophyll *a* values of <50 mg/m², through to a National Bottom Line limit of 200 mg/m².

22. The Periphyton Guideline recommends nutrient concentrations for preventing nuisance growths at unshaded sites. The guideline nutrients are dissolved reactive phosphorus (DRP) and dissolved inorganic nitrogen (DIN), which is comprised of nitrate-N, nitrite-N, and ammoniacal-N. For protection of benthic biodiversity, the Periphyton Guideline recommends DIN concentrations <0.02 mg/L and DRP concentrations <0.001 mg/L. For protection of aesthetics and trout habitat/angling the Periphyton Guideline recommends DIN concentrations from <0.01 to <0.3 mg/L and DRP from <0.01 to <0.03 mg/L, with inter-flood accrual intervals ranging from 20-100 days. The Periphyton Guideline recognises that rivers that are frequently flood disturbed can have higher nutrient concentrations than more stable rivers to maintain the same level of periphyton biomass, hence the range of nutrient limits given above.

23. At high concentrations, nitrate can become toxic. The New Zealand nitrate toxicity guidelines include consideration of both chronic (long term) and acute (short term) effects, with lower nitrate limits for avoiding chronic effects (Hickey 2013). The chronic toxicity guidelines range from an annual median of 1.0 mg/L of nitrate-N for 99% protection of species at high conservation systems, through to 6.9 mg/L for 80% protection at highly disturbed systems (Table 1).

24. The nitrate toxicity guidelines were based on a statistical analysis of the results of 22 studies, including six species found in New Zealand. The New

Zealand species include introduced lake trout (*Salvelinus namaycush*), Chinook salmon (*Oncorhynchus tshawytscha*), rainbow trout (*O. mykiss*), and the common water flea (*Cereodaphnia dubia*). The only two native species included were inanga and the common mayfly *Deleatidium*.

25. The nitrate toxicity guidelines follow the risk-based approach of the Australian and New Zealand Environment and Conservation Council (ANZECC 2000) guidelines, whereby an exceedance of a guideline value triggers further site-specific investigation. There is currently insufficient toxicity data for New Zealand native species to derive site-specific criteria based on laboratory toxicity testing. The toxicity guidelines recommended that a wider range of native species should be tested for nitrate toxicity, as well as field studies across a range of nitrate concentrations to validate the laboratory tests.

Table 1: New Zealand nitrate toxicity guidelines (from Hickey 2013).

Guideline Protection Level	Median Nitrate Concentration (mg/L)	95th Percentile Nitrate Concentration (mg/L)	Description of Management Class
99%	1.0	1.5	Pristine environment with high biodiversity and conservation values.
95%	2.4	3.5	Environments subject to a range of disturbances from human activities, but with minor effects.
90%	3.8	5.6	Environments with naturally seasonally elevated concentrations for significant periods of the year (1-3 months).
80%	6.9	9.8	Environments which are measurably degraded and which have seasonally elevated concentrations for significant periods of the year (1-3 months).

26. The nitrate Attribute Table of the NPS is based on the Hickey (2013) nitrate toxicity guidelines. The NPS nitrate Attribute States range from Class A rivers, with median nitrate-N concentrations <1.0 mg/L (equivalent to the 99% protection level), through to a National Bottom Line median concentration of 6.9 mg/L (equivalent to 80% protection).

Key Message

27. In summary, the following points should be considered when applying nutrient guidelines to New Zealand freshwaters:

- Both nitrogen and phosphorus concentrations affect plant growth, and excessive amounts of either can cause nuisance growths.
- Adverse effects of nitrate on freshwater ecosystems occur at concentrations well below the toxicity guidelines, by stimulating nuisance periphyton growths.
- New Zealand nitrate toxicity guidelines are based on a review of international literature that included two New Zealand native species.
- New Zealand nitrate toxicity guidelines are default “trigger values” and their exceedance should stimulate site-specific investigations.

Ecological State and Trends in the Hekeao/Hinds Plains

Upper Hekeao/Hinds River

28. The upper Hekeao/Hinds River (upstream of State Highway 1) is in a relatively good ecological state for a hill-fed Canterbury river. In particular, the combination of relatively low nutrient concentrations and frequent flood disturbance mean that nuisance periphyton growths and macrophytes are uncommon (Meredith & Lessard 2014a), and the broad stony bed has low cover with fine sediment. However, median DIN and DRP concentrations are around limits for prevention of nuisance algal growths (Meredith & Lessard 2014a), which means an increase in either DIN or DRP could increase the likelihood of nuisance growths occurring.

29. Recent sampling of the Hekeao/Hinds River and its tributaries caught Canterbury galaxias (*Galaxias vulgaris*), shortfin eel (*Anguilla australis*), longfin eel (*A. dieffenbachii*), upland bully (*Gobiomorphus breviceps*), and brown trout (Lessard 2013). This is a typical fish fauna for a Canterbury hill-fed stream. However, two of the species recorded – longfin eel and Canterbury galaxias – are considered threatened species (Goodman et al. 2014).

30. There is insufficient monitoring data of water quality, invertebrates, or fish to assess any trends in ecological state in the upper Hekeao/Hinds River catchment. In my opinion, recent water quality data monitoring in the upper

catchment should continue and it should be supplemented with invertebrate and fish monitoring data, to assess any trends in ecological state over time.

Lower Hekeao/Hinds Plains Waterways

31. The waterways downstream of State Highway 1 are spring-fed and historically formed part of an extensive swamp that was drained for agriculture over 100 years ago. Based on historical observations and survey maps from the mid-1800s, the Ashburton and Rangitata Rivers are the only waterways in the area that have maintained a near natural course to the sea over time (Small & Blee 1999). While a number of defined watercourses existed to the west of where State Highway 1 is today, their channels became ill-defined upon entering the Longbeach swamp. There were a number of well-defined outlet channels to the coast (associated with deeply eroded gullies commonly called "dongas").

32. It is uncertain how many watercourses historically had perennial flow to the coast. Waterways that did appear to have both perennial flow and a perennial opening to the sea were the wetlands now called Hekeao/Hinds River, Parakanoi Drain, and Blees Drain. Others exited at ponds and wetlands behind the beach. While most of these waterways now have a very artificial appearance some, such as Parakanoi Drain, are shown on early survey maps and appear to follow their original course (Mitchell 1980).

33. The Hekeao/Hinds River historically had an ill-defined channel downstream of the present location of State Highway 1 and it discharged directly into Longbeach swamp. In the late 1800s works were undertaken to artificially straighten and constrain the Hekeao/Hinds River downstream of the Surveyors Road area down to an opening to the sea. The lower reaches of the river have been maintained for flood protection (eg addition of stopbanks and willow removal) since then. At the same time, Taylors Drain was cut, following an existing line of drainage to the Hinds River, to further drain swampland and alleviate flooding in the area (Small & Blee 1999).

34. Like most lowland Canterbury streams, those of the Hekeao/Hinds Plains are currently in a degraded ecological state. Streams and drains[1] are impacted by abstraction from surface water and groundwater (Durney & Ritson 2014),

[1] I note here that with a few exceptions, nearly all lowland waterways in the Hekeao/Hinds Plains area are named as drains, as all of the waterways have been artificially modified to some extent to drain the land. However, the term "drain" often has negative connotations, implying that the only value a waterway provides is drainage, when in fact a wide variety of instream values may be provided. For this reason, I use the term "drain" to refer specifically to waterway names (eg Boundary Drain), but use the term "stream" when referring to flowing waterways in a generic sense.

most are steep-sided, straight, have minimal native riparian vegetation or shade, they have very high nitrate concentrations, and consequently many have high macrophyte cover, and poor habitat for invertebrates and fish.

35. ECan water quality monitoring data from 2001 and 2014[2] show a substantial increase in nitrate concentrations at all sites in 2014, and substantial declines in DRP concentrations at all sites in 2014 (Figure 1). Suspended solids concentrations also declined at four of the six monitoring sites (Figure 1). I have inspected long term monitoring data from Blees and Boundary Drains (data collected from monthly to quarterly from 2001-2014), and based on data from these two long term monitoring sites, the trends shown in Figure 1 are representative of a steady change in water quality over the 2001-2014 period.

36. Increasing nitrate concentrations could be caused by landuse intensification and increasing discharge of nitrate-rich groundwater. Given that flows have been declining in the lowland Hekeao/Hinds Plains, increased nitrate concentrations have more likely been caused by landuse intensification than increasing flow.

37. Likely causes of declining DRP and suspended solids concentrations include declining flows and improved land management. Low flows are associated with reduced runoff and erosion, so reduced flows are a likely cause of declining DRP and suspended solids concentrations in lowland streams of the Hekeao/Hinds Plains. Improved land management could also be contributing to declining levels of DRP and suspended solids, but I strongly doubt there has been sufficient change in land management to be responsible for the observed improvement in these two water quality parameters.

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[2] Monitoring data are patchy throughout the zone, but there was a mixture of monthly and quarterly monitoring data collected within a two year period around 2001 and 2014 for six lowland sites, namely Blees, Boundary, Flemington, Parakanoi, Stormy, and Windermere Drains.

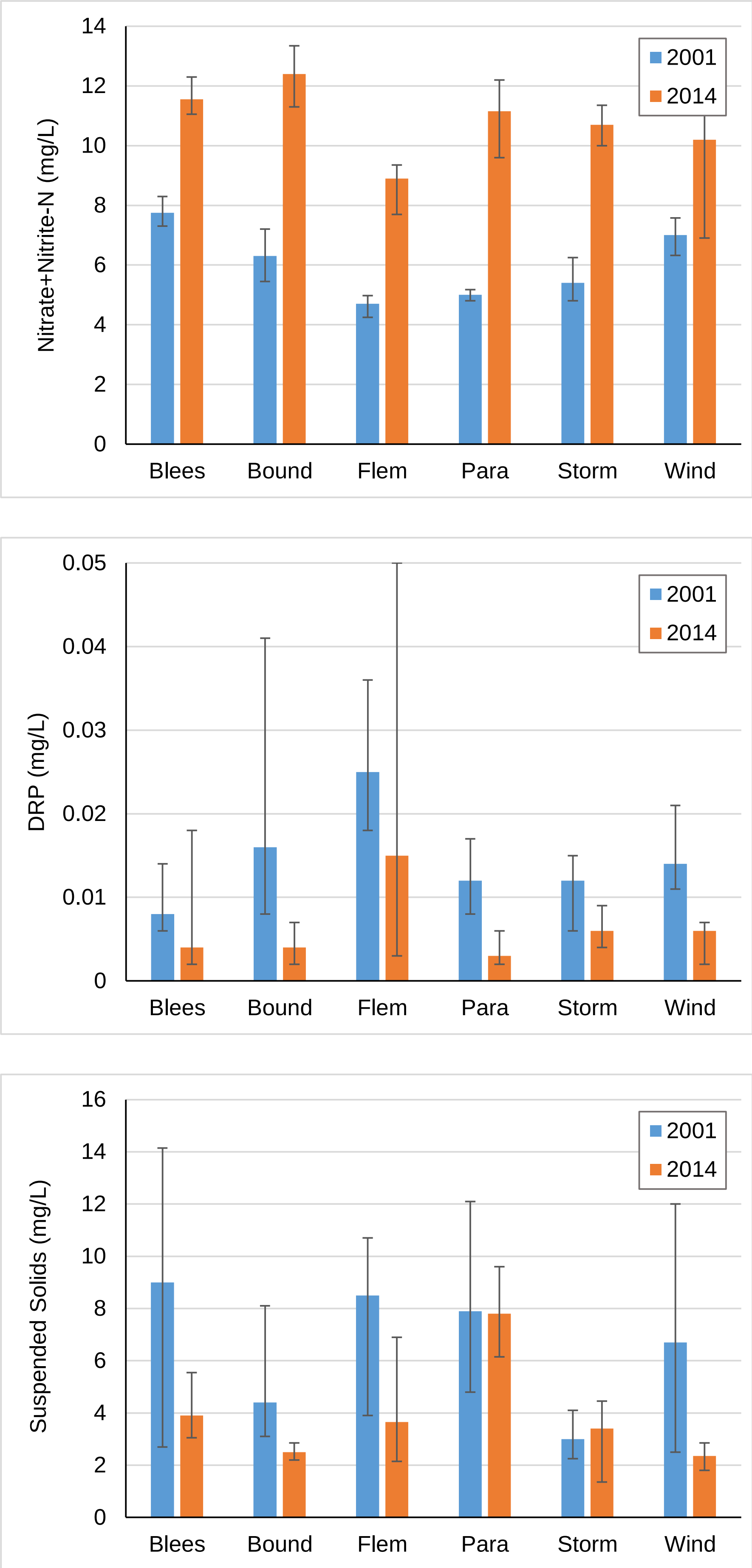

Figure 1: Median (± interquartile range) ECan water quality data from 2001 and 2014.

38. The lower reaches of the Hekeao/Hinds River are susceptible to nuisance algal blooms, due to the combination of high nutrient concentrations and more stable flows than the upper reaches. These blooms include the blue-green alga *Phormidium* (Figure 2), which is toxic to dogs and can be harmful to humans.

Figure 2: The Hekeao/Hinds River at Poplar Road, April 2015. Black mats of the toxic algae *Phormidium* are visible on the riverbed.

39. The impact of low flows was very apparent during my recent site visit in April 2015. All of the lowland waterways I visited between the Hekeao/Hinds River and the Ashburton River were dry (Figure 3, Figure 4). The only exceptions were several streams receiving water from the Eiffelton irrigation scheme to keep them flowing. This was in stark contrast to the fieldwork I conducted at a similar time of year in 2007, when all of the lowland streams were flowing. Lowland streams south of the Hekeao/Hinds River were still flowing during my April 2015 visit, and consequently looked to be in better health (Figure 5, Figure 6). I acknowledge that exceptionally low rainfall very likely contributed to the low stream flows in 2015, but my observations showed that the northern Valetta area streams are clearly more susceptible to low flows and drying than the southern streams.

Figure 3: Parakanoi Drain dry at Lower Beach Road, April 2015.

Figure 4: Flemington Drain dry at Grahams Road, April 2015.

Figure 5: Twenty One Drain flowing at Twenty One Drain Road, April 2015.

Figure 6: Boundary Drain flowing at Trig Pole Road, April 2015.

40. Notwithstanding their overall degraded state, lowland streams of the Hekeao/Hinds Plains support a diverse range of fish species, including longfin eel (declining threat status), critically threatened Canterbury mudfish (*Neochanna burrowsius*), and good numbers of bluegill bully (*Gobiomorphus hubbsi*), which are swift-water specialists that are also in a state of decline nationally (Goodman et al. 2014).

41. An important feature of the Hekeao/Hinds River and some of the lowland streams is that they have intermittent flow, meaning they go dry over summer. For the mid reaches of the Hekeao/Hinds River, this means that aquatic habitat dries up over summer, with the greatest impact on fish and invertebrate species occurring at sites that dry the most frequently and for the longest duration. River drying also blocks the path of migratory fish species such as eels and lamprey (*Geotria australis*). Declining flow in the Hekeao/Hinds River (Durney & Ritson 2014) has likely negatively impacted the fish fauna, although there has been no long term monitoring of fish in the Hekeao/Hinds area (or the Canterbury region for that matter).

42. Another important feature of the lower Hekeao/Hinds Plains streams is that their mouths are often blocked by gravel bars. This can result in a river mouth lagoon, or hapua, which has its own inherent ecological value. However, river mouth closure limits the opportunity for migratory fish to travel between the ocean and stream environment. Thus, the abundance and population structure of migratory species such as eel, lamprey, and bluegill bullies can be affected by prolonged periods of river mouth closure. River mouth closure is affected by ocean conditions and river flows, and reduced

flows could increase the duration of mouth closure, adversely affecting migratory fish species (Jowett et al., 2005).

43. Invertebrate communities of the lower Hekeao/Hinds Plains were sampled by ECan in 2001, 2006, and 2012 (Meredith et al. 2006; Meredith & Lessard 2014a). These invertebrate data provide a good indication of changes in ecological health over time in the area, because invertebrates are affected by water quality, quantity, and habitat. A widely used indicator of invertebrate community health in Canterbury is the Quantitative Macroinvertebrate Community Index (QMCI), with values over 6 indicating “excellent” conditions, and values below 4 indicating “poor” conditions.

44. In 2001, average QMCI scores for the lower Hekeao/Hinds Plains streams were above 5, and indicative of “good” conditions. Streams to the south of the Hekeao/Hinds River had higher QMCI scores and flows on average than those to the north. Overall, invertebrate health scores were higher than average for Canterbury lowland rivers, which typically have QMCI scores below 5, and indicative of “fair” conditions. The relatively high abundance of pollution-sensitive invertebrates in 2001 was likely because many of the streams had gravel beds with low silt cover, which is uncommon for Canterbury lowland streams (Meredith et al. 2006).

45. Average QMCI scores for the lower Hekeao/Hinds Plains streams declined below 4 into the “poor” category in 2006, and were slightly lower again in 2012 (see Figure 7). Thus, lowland stream health in the Hekeao/Hinds Plains has declined from good to poor over the last decade.

Figure 7: Mean Quantitative Macroinvertebrate Community Index (QMCI) scores of lowland streams in the Hekeao/Hinds Plains area. Reproduced from Meredith & Lessard (2014a).

Likely Causes of the Current State of the lower Hekeao/Hinds Plains Streams

46. Several intensive studies of lowland streams throughout Canterbury (including some in the Hekeao/Hinds Plains area) found that the strongest determinants of invertebrate community structure were measures of habitat quality and stream discharge or flow (Greenwood et al. 2012; Burdon et al. 2013; Moore 2014). Fine sediment deposition and low water velocities impacted negatively on the biota, with smaller waterways more impacted than larger waterways (Greenwood et al. 2012). These studies included streams with nitrate-nitrogen concentrations ranging from 0.004 mg/L to 13.14 mg/L, yet there was no strong correlation between nitrate and invertebrate community health, despite the wide range of nitrate concentrations.

47. Similarly, QMCI scores tend to be higher in lowland streams with higher flow in the Hekeao/Hinds Plains area, but there is no clear pattern of QMCI score with DIN, DRP, or suspended solids concentration (Figure 8).

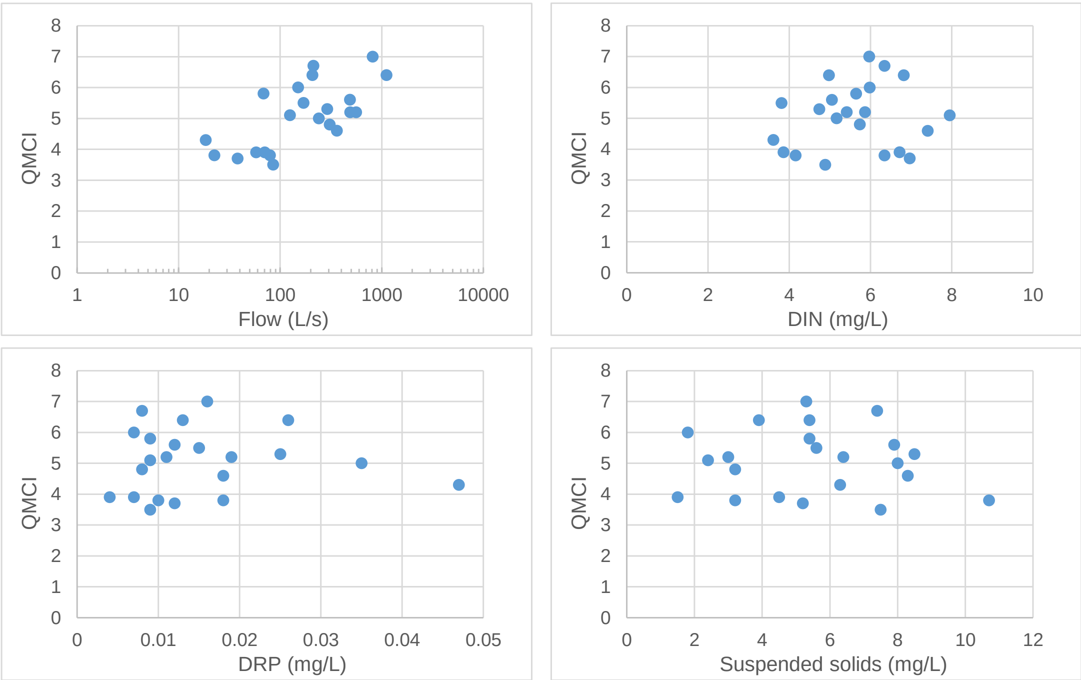

Figure 8: Relationship between invertebrate QMCI scores and flow, dissolved inorganic nitrogen (DIN), dissolved reactive phosphorus (DRP), and suspended solids in lowland streams of the Hekeao/Hinds Plains. Data are from 2001-2002, and are from Meredith et al. (2006).

48. Based on the studies summarised above, it is my opinion that poor quality instream habitat and low flows are likely causes of the present degraded ecological state of lowland streams of the Hekeao/Hinds Plains. I do not

mean that nutrient concentrations are unimportant, but rather that the range of elevated nitrate concentrations in these streams likely have a lesser influence on the biota than physical habitat and flow.

49. The recent decline in invertebrate community health may have been caused by a variety of factors. In my opinion, declining groundwater levels and flows in lowland streams (Durney & Ritson 2014) are a likely cause. Although nitrate concentrations have also increased during this time period, I consider nitrates are not as likely to have caused the decline, because there is a weak link between nitrate concentration and QMCI scores in lowland Canterbury rivers (Moore 2014).

50. It is unclear to me whether declining physical habitat was also the cause of declining ecosystem health, as ECan's habitat monitoring data was not available for me to review. However, declining flows could indirectly affect physical habitat and water quality, with reduced flow facilitating fine sediment deposition, macrophyte growth, and reducing habitat diversity.

VARIATION 2 WATER QUALITY ISSUES

51. I note that Variation 2 seeks to improve water quality in lowland waterways and maintain water quality in the upper catchment, as stated in Policies 13.4.9 and 13.4.10. It is encouraging to see reductions in nitrogen, phosphorus, microbial pathogens, and sediment laid out at the policy level of a plan. My principal concern is whether there is sufficient detail in the rules to deliver the freshwater outcomes sought in Table 13(a) of Variation 2. The plan anticipates that the freshwater outcomes will be achieved by a combination of implementing rules in Variation 2 and implementation of recommendations in the ZIP addendum.

52. In the following paragraphs I comment on elements of Variation 2 that I consider are either at odds with the overall goal of improved ecosystem health, or could simply do with some refinement.

Impacts of Further Landuse Intensification

53. In my opinion, the key uncertainty with Variation 2 is whether the effects of further landuse intensification (as proposed in the plan) can be offset to mitigate ecological effects. My concern here particularly relates to the lower catchment, where streams are in a degraded state. Variation 2 seeks to improve water quality and ecology in these lowland streams, but also anticipates further landuse intensification in the area.

54. Proposed mitigation measures for Hekeao/Hinds Plains streams include improved riparian management and fencing, improved drain management, protection of spring heads, instream habitat enhancement, and improved fish passage (Meredith & Lessard 2014b). I consider that the proposed range of mitigation measures are appropriate and should help improve aquatic habitat and water quality, although the magnitude of improvement is difficult to predict.

55. There is considerable literature showing the negative relationship between agricultural landuse and ecological health (Quinn et al. 1997; Allan 2004; Greenwood et al. 2012), but there is less data quantifying the effectiveness of different mitigation measures (Anastasiadis et al. 2012). It is therefore my opinion that Variation 2 would provide a more certain positive outcome for degraded lowland streams if it focussed on mitigating the effects of existing landuse activities before allowing further intensification.

Variation 2 Focus on Nitrate

56. Variation 2 has a strong focus on managing nitrate leaching, with less stringent controls on discharges of other water quality parameters such as phosphorus and sediment. I appreciate that this emphasis reflects concerns over very high nitrate concentrations. While I agree that nitrate concentrations need to be reduced to protect aquatic biota, in my opinion other contaminants such as sediment and phosphorus also need to be managed to improve aquatic health in lowland streams.

57. Variation 2 provides clear limits on nitrate concentrations for surface waters, based on nitrate toxicity limits (which I discuss further below). Median nitrate concentrations are currently in the order of 9-10 mg/L for many of the lowland streams in the area (Meredith & Lessard 2014a), so the proposed median limit of 6.9 mg/L for Spring-fed Plains streams in Variation 2 represents a substantial improvement. However I note that 6.9 mg/L of nitrate-N is still very high, and well above any limits that would prevent excessive plant and periphyton growth.

58. Concentrations of DRP are relatively low in the Hekeao/Hinds Plains area, with median values of 0.004-0.019 mg/L in the upper catchment and 0.005-0.008 mg/L in the lower catchment (Meredith & Lessard 2014a). As Dr Dudley observes in his evidence, low DRP concentrations likely result in seasonal nutrient limitation of periphyton. This is a view shared by Meredith et al. (2006), who stated that all streams in the Hekeao/Hinds Plains area

were phosphorus limited. This means that increasing phosphorus concentrations could lead to greater likelihood and frequency of nuisance algal growths occurring. Therefore, from an aquatic ecology perspective, I consider it prudent to include a phosphorus limit in Variation 2 that represents a cap on current DRP concentrations, and that the cap would take effect immediately, rather than the 2035 target for surface water nitrate concentrations.

59. Based on the median of ECan monitoring data from 2011-2013 (Meredith & Lessard 2014a), in my opinion the following annual median DRP limits for protecting ecosystem health in the Hekeao/Hinds Plains area are appropriate:

- Hill-fed Upland: 0.02 mg/L
- Hill-fed Lower, and Spring-fed Plains: 0.008 mg/L

As stated above, these limits place a cap on existing DRP concentrations.

Freshwater Outcomes

60. I generally agree with the proposed outcomes in Table 13(a) of Variation 2, as they are generally consistent with existing water quality guidelines, and they anticipate marked improvements in water quality and habitat quality.

Adequacy of Mitigations Provided in Variation 2

61. Variation 2 states that losses of nutrients, microbes and sediments to streams will be achieved by: excluding intensively farmed stock from drains and streams (excluding ephemeral waterways), setting nitrogen load and leaching limits, and implementing the farm practices in Schedule 24a or implementing Farm Environment Plans (FEPs). Overall, I consider these to be appropriate measures for improving water quality and ecological outcomes. However, I do consider that the mitigations outlined in Schedule 24a and the FEP template need more detail, to increase certainty that they will deliver the desired environmental outcomes.

62. Intensive farming activities can introduce phosphorus, sediment and faecal matter into streams via stock accessing waterways and trampling the bed and banks, or via overland flow paths. Variation 2 appears to rely heavily on stock exclusion from permanent waterways to reduce discharges of phosphorus, sediment and faecal material, but stock exclusion only tackles

part of the problem. This is because Variation 2 does not restrict stock access to temporary drainages that feed into permanent waterways.

63. Figure 9 below illustrates my point. Stock have trampled the ground that the ephemeral waterway flows over, exposing the flowing water to sediment and other contaminants. Although this ephemeral waterway drains into a fenced permanently flowing stream, fencing does not prevent the discharge of contaminants from the ephemeral waterway into the fenced stream. In my opinion, Schedule 24a and FEPs should give specific guidance to avoid loss of sediment, phosphorus, faecal matter and other contaminants into streams; avoiding the sort of situation illustrated by Figure 9.

Figure 9: Heavy pugging in an ephemeral watercourse in Canterbury (outside the Hekeao/Hinds Plains area).

64. I note that additional work is anticipated by the Ashburton Zone Committee around minimum flows and other matters to protect aquatic habitat. This work is to be undertaken by the Hinds Drains Working Party, with recommendations due to the zone committee by 1 December 2015.

Appropriateness of the Nitrate Toxicity Limit in Lowland Streams

65. As I stated in paragraph 27, the adverse effects of nitrate on freshwater ecosystems occur at concentrations well below toxicity guidelines, by

stimulating growth of periphyton to excessive levels. It therefore makes sense that nitrate limits should first aim to protect against nuisance periphyton before focussing on toxicity. However, it is an unfortunate fact that nitrate concentrations well exceed Periphyton Guideline limits in the lowland streams of the Hekeao/Hinds Plains, and therefore ECan has used nitrate toxicity guidelines as limits in Variation 2.

66. The nitrate limits in Table 13(j) of Variation 2 are a median of 3.8 mg/L for Hill-fed Lower streams (the lower Hekeao/Hinds River) and 6.9 mg/L for Spring-fed Plains streams. I note that the median nitrate plus nitrite[3] concentration from 2011-2013 was 5.2 mg/L for the lower Hekeao/Hinds River and its tributaries (Meredith & Lessard 2014a), so the Variation 2 nitrate limit of 3.8 mg/L represents an approximately 25% reduction in nitrate concentrations compared to current levels. Median nitrate plus nitrite concentrations from 2011-2013 were 9.3 mg/L for lowland streams in the southern Mayfield area and 9.6 in lowland streams in the northern Valetta area (Meredith & Lessard 2014a). Thus, the proposed Variation 2 nitrate limit of 6.9 mg/L also represents an approximately 25% nitrate reduction in these streams.

67. Nitrate concentrations naturally vary amongst streams, so the percent reduction in nitrate will also vary from stream to stream. The lowest median nitrate plus nitrite concentration from 2011-2013 for a lowland stream reported in Meredith & Lessard (2014a) was 7.4 mg/L for Flemington Drain, so a limit of 6.9 mg/L would represent a small (~7%) improvement in this stream. The highest median concentration was 10.9 mg/L in a Boundary Drain tributary, so the 6.9 mg/L limit would be a large (~37%) improvement in this stream.

68. Overall, I believe that the proposed Variation 2 nitrate limits represent a significant improvement in the current state for Hill-fed Lower and Spring-fed Plains streams. I consider that the proposed nitrate limits give effect to the NPS, as they will require nitrate concentrations to decline to at least meet the National Bottom Line of 6.9 mg/L.

69. I am sceptical as to whether achieving the 3.8 mg/L or 6.9 mg/L nitrate target will result in improved ecological health, as outlined in paragraphs 46-49 above. However, the limit represents a substantial reduction in nitrate

[3] Meredith & Lessard (2014a) did not report nitrate-N and nitrite-N results separately. However, it is my experience that the nitrite-N component in samples is typically small in lowland Canterbury rivers, so it is reasonable to compare combined nitrate plus nitrite data against nitrate toxicity guidelines.

concentrations, and at the very least it will be associated with an overall reduction in nitrogen load to the coastal environment. I consider nitrate concentrations will need to decline even further – to at least below around 1.0 mg/L – before aquatic ecosystems would benefit, due to stimulation of nuisance growths at higher concentrations (see paragraph 22 above). If it is impractical to further reduce nitrate concentrations in lowland streams, then I consider the focus should be on improving stream shading, to reduce the risk of periphyton and macrophyte proliferations.

Protection of Upper Catchment Water Quality

70. The upper Hekeao/Hinds River and its tributaries are currently in a good ecological state. However, the proposed 1.0 mg/L nitrate limit in the upper catchment will not maintain the current water quality state. Median DIN concentrations for the North and South Branches of the Hekeao/Hinds River are currently around 0.018-0.585 mg/L (Meredith et al. 2014a), which is nearly half the proposed nitrate limit of 1.0 mg/L.

71. In my opinion, Variation 2 should include limits on both DIN and DRP to maintain existing water quality and to achieve the freshwater outcomes in Table 13(a). I note that Table 13(a) includes a periphyton chlorophyll *a* limit of 50 mg/m² for Hill-fed Upland streams, which is based on the "benthic biodiversity" limit in the New Zealand Periphyton Guideline (Biggs 2000). Using the DIN and DRP formulae provided in the Periphyton Guideline (page 43) and assuming an average inter-flood accrual time of 22 days for the South Branch recorder site[4], nutrient concentrations would need to be <0.002 mg/L of DRP and/or <0.02 mg/L of DIN to achieve the proposed periphyton outcome of 50 mg/m² of chlorophyll a. With median DIN concentrations currently around 0.018-0.585 mg/L, and median DRP concentrations around 0.004-0.019 mg/L (Meredith & Lessard 2014a), it is likely that the chlorophyll *a* concentrations already exceed the 50 mg/m² limit and that any further nutrient increases could increase the likelihood and frequency of nuisance growths occurring.

72. Meredith & Lessard (2014a) proposed a DIN limit of 0.8 mg/L for protection of "healthy stream communities" in the upper Hekeao/Hinds Plains. The 0.8 mg/L DIN limit was taken from a recommendation of Dr Death during the Tukituki Environmental Protection Agency (EPA) hearing. In his evidence in

[4] Median flow from the ECan South Branch recorder (1 July 2007 to 30 June 2013) was 131 L/s. The mean annual accrual length (number of days between flows exceed three times median flow) was 22 days, and varied between 15 and 34 days for the six years of record.

chief, Dr Death stated that one of the reasons the 0.8 mg/L nitrate limit was more suitable for the Tukituki catchment than a target based on the New Zealand Periphyton Guideline, was because his number was based on a relationship between measured nitrate concentrations and invertebrate community health (measured as the MCI score) in local streams, whereas local streams were under-represented in the studies underpinning the Periphyton Guideline. In my opinion the New Zealand Periphyton Guideline is appropriate for nutrient limit-setting in Canterbury, because much of the research underpinning the Periphyton Guideline was conducted in Canterbury Rivers.

73. Given that DIN and DRP concentrations already exceed Periphyton Guideline limits for protecting biodiversity in the upper Hekeao/Hinds Plains, I recommend capping current DIN and DRP concentrations to maintain existing water quality and ecosystem health. That would equate to a median DIN limit of approximately 0.6 mg/L and a median DRP limit of 0.02 mg/L.

74. In summary, I consider that the nitrate toxicity guideline of 1.0 mg/L provides inadequate protection of aquatic ecosystems of the upper Hekeao/Hinds Plains. Instead, I recommend an annual median DIN limit of 0.6 mg/L and an annual median DRP limit of 0.02 mg/L. My proposed limits would place a cap on existing nutrient concentrations, which would help with maintaining current water quality and achieving the proposed freshwater outcomes in the upper Hekeao/Hinds Plains streams.

VARIATION 2 WATER QUANTITY ISSUES

Background to Environmental Flows

75. The term “environmental flow” refers to the range of flows required to sustain a healthy river ecosystem. Environmental flow management includes consideration of minimum flow requirements, the need for flushing flows, and the timing of different flow needs within a given river. Two common methods for protecting freshwater ecosystems from the adverse effects of water abstraction is by setting minimum flows and allocation limits.

76. A minimum flow is the flow below which water takes must cease. Minimum flows can be established to protect a variety of ecological values, including: minimum passage depths for migratory trout and salmon; provision of aquatic habitat for a diversity of species or key species of concern; protection of water quality (especially dissolved oxygen and temperature); provision of

continuous flow from headwaters to the sea for migratory fish species; and provision of breeding habitat for threatened birds.

77. An allocation limit is the total rate of water that can be withdrawn from a stream, taking into account all consented water takes. Allocation includes consideration of both the effects of surface water takes and the cumulative effects of hydraulically connected groundwater takes. High allocation results in rivers sitting at or below the minimum flow for a long period. This is particularly of concern when minimum flows are set too low to adequately protect the biota.

78. There are a variety of ways of assessing minimum flow and allocation requirements for aquatic biota, although none are without controversy. The proposed National Environmental Standard on Ecological Flows (NES) and its companion, the draft New Zealand guidelines for assessing ecological flows recommend a risk-based approach to setting environmental flows, with the level of investigation commensurate with both the level of pressure on the freshwater resource and the ecological values present (Beca 2008; MfE 2008). Assessment methods range from analysis of historical flows and expert opinion through to detailed hydraulic habitat models and coupled water quality models. I agree with the draft NES risk-based approach to setting environmental flows.

79. The draft NES includes default minimum flow and allocation limits for rivers with no existing limits, as follows:

Rivers with mean flow less than or equal to 5 m^3/s:

- Minimum flow of 90% of the mean annual low flow (MALF), and allocation of 30% of MALF

Rivers with mean flow greater than 5 m^3/s:

- Minimum flow of 80% of MALF and allocation of 50% of MALF

These default limits were based on expert opinion and review of studies that showed greater likelihood of adverse ecological effects occurring at lower minimum flows and higher allocation limits (MfE 2008).

80. I have previously used a mixture of expert panel and hydraulic habitat modelling methods to review environmental flows in numerous streams throughout Canterbury, including streams in the Hekeao/Hinds Plains area. I

have found that for smaller rivers and streams, such as those in the Hekeao/Hinds Plains area, there is good scientific justification for referencing minimum flows to MALF. This is because I have found aquatic habitat and water quality (especially temperature and dissolved oxygen) can become limiting at or around MALF. However, in my opinion a "rule of thumb" minimum flow method needs to be scientifically defensible in each situation it is applied, preferably by comparison with other methods (eg modelling and expert panel), especially if the water resource is in high demand for abstraction.

81. With increasing demand for water in Canterbury, there has been a trend towards taking water for storage outside of the irrigation season. A minimum flow based on some percentage retention of MALF may protect aquatic ecosystems during summer low flows (when MALF typically occurs), but may be too low when applied at other times. For example, spawning trout and salmon rely on adequate depths and velocities for upstream passage and spawning in autumn-winter, and a minimum flow based on summer low flows may provide inadequate depths and habitat. Therefore, I consider it prudent to consider having higher minimum flows outside the irrigation season, or at least clearly stating that the minimum flow applies only to the irrigation season, if a single minimum flow is to be used.

Adequacy of Current Environmental Flows in the Hekeao/Hinds Plains

82. I understand from the Variation 2 hydrology report that there is minimal flow allocated in the upper catchment (Durney & Ritson 2014). Variation 2 proposes capping the existing allocation, so I consider the current and proposed allocation for the upper catchment adequately protect the aquatic ecosystems present.

83. The flow record is very short for the lower Hekeao/Hinds River and other lowland streams, which makes it difficult to assess the adequacy of existing minimum flows and allocation limits. A total of 1,522 L/s of flow is allocated for abstraction from the Hekeao/Hinds River above the Poplar Road measuring site, where the lowest recorded flow is 244 L/s and the minimum flow is approximately 700 L/s, based on correlation with the Boundary Road minimum flow of 150 L/s (Durney & Ritson 2014).

84. Based on the results of hydraulic habitat modelling at the Poplar Road site, Meredith & Lessard (2014a) recommended that the minimum flow in the lower Hekeao/Hinds River should be maintained at 700-800 L/s to optimize

existing aquatic habitat. They also concluded that the reach generally provided poor habitat for larger fish (eels and trout) and threatened swift-water species (torrentfish and bluegill bullies). Meredith & Lessard (2014a) noted that *"…managing the river to improve the diversity of habitat may be more effective than just increasing flows."*

85. I concur with Meredith & Lessard's (2014a) minimum flow recommendations. I also agree with their suggestion of improving habitat diversity in the lower river to improve fish habitat. In my opinion, fish habitat could be enhanced by instream works that increase the amount of pool and steep riffle habitat available.

86. Although no naturalised MALF is given for the Hekeao/Hinds River, the total allocation is around six times the lowest recorded flow and double the minimum flow. Streams with such high allocation are typically subjected to prolonged periods of low flow (MfE 2008), which impacts negatively on the biota. I therefore consider that the current level of allocation is too high.

87. Based on my review of data in Tables 9.4, 10.11, and 10.12 of the hydrology report (Durney & Ritson 2014), it is my opinion that minimum flows are likely too low and allocation far too high to sustain healthy aquatic ecosystems in lowland streams of the Hekeao/Hinds Plains. Minimum flows are on average around 20% of the naturalised seven day MALF (7DMALF) and allocation is on average 1.3 times greater than the naturalised 7DMALF.

88. Flows in streams in the northern Valetta area are generally much lower than in the southern Mayfield area. Table 9.4 of Durney & Ritson (2014) shows that Valetta streams have an average residual 7DMALF of approximately 30 L/s compared to 160 L/s in Mayfield streams (residual 7DMALF is the mean annual low flow calculated after all takes have been withdrawn). Similarly, total allocation is much higher in the Valetta streams, with total allocation on average 12 times higher than residual 7DMALF, compared to the Mayfield streams where total allocation is on average 3 times higher than residual 7DMALF. Flow allocation impacts will therefore be greater in the Valetta area, both due to the relative size of the allocation compared to the low flows, but also because smaller streams are more susceptible to the effects of high allocation (MfE 2008). This is supported in part by ECan invertebrate monitoring data, which shows that while QMCI scores have declined in lowland streams throughout the Hekeao/Hinds Plains zone, scores have

always been higher in the Mayfield area than in the Valetta area, which has lower flows (Meredith et al. 2006; Meredith & Lessard 2014a).

89. I understand that there has been a decline in groundwater levels and spring-fed stream flows since the early to mid-2000s (Durney & Ritson 2014). The cause for this decline is attributed to reduced groundwater recharge (due to a shift from border-dyke to spray irrigation) and increased groundwater abstraction (Durney & Ritson 2014). I therefore consider it very likely that the combination of high allocation and declining flows has negatively impacted aquatic ecosystems, and they are a likely reason for the observed decline in invertebrate community health from 2001 to 2012 (see paragraphs 44 to 49 above).

Adequacy of Proposed Default Minimum Flows and Allocation

90. Variation 2 proposes to maintain current minimum flows and cap allocation in the lowland streams until 2020. After 2020, there will be new default minimum flows of 50% of 7DMALF and an allocation limit of 20% of 7DMALF.

91. I note that the default limits are taken directly from Rule 5.123 of the LWRP. Importantly, Rule 5.123 requires that 7DMALF is calculated by ECan, but it does not stipulate that it shall be the naturalised 7DMALF. If ECan determines that naturalised 7DMALF should be used (which I consider would be more appropriate than residual 7DMALF), then 50% 7DMALF is on average approximately four times higher than the current minimum flows. Hence, the proposed default minimum flow will result in a large increase in current minimum flows, which I consider would be very beneficial to aquatic ecosystems. Benefits would be greatest in the Valetta area, where the streams are smaller and current minimum flows are on average only 16% of naturalised 7DMALF.

92. The proposed default allocation limit of 20% of 7DMALF represents a large reduction in allocation compared to the current situation and I consider it will greatly benefit lowland stream ecosystems. Benefits of reduced allocation would be greatest in the Valetta area, where current allocation is approximately 1.6 times greater than naturalised 7DMALF.

93. The alternative to the default minimum flows and allocation limits in Variation 2 is for catchment-specific limits to be developed. I understand that the Hinds Drains Working Party is tasked with developing plans to deliver new minimum flows and allocation limits. The Working Party includes

representatives from the community, farmers, the zone committee, Fish and Game, Department of Conservation, and local rūnanga (Arowhenua/Ngāi Tūāhuriri), and has the support of relevant technical experts.

94. I note that Te Rūnanga o Arowhenua have recommended a minimum water depth of 30 cm for protection of eel (tuna) habitat in the Hekeao/Hinds Plains (Tipa & Associates 2013). Similarly, Meredith & Lessard (2014a) suggested a depth of 40 cm would adequately protect eel habitat, based on habitat preference curves. Clearly, not all streams will be able to provide a minimum or average depth of 30 or 40 cm, due to differences in catchment size and channel form. Therefore, minimum flows based on maintaining a preferred depth for eels (or any species) should be undertaken on a stream by stream basis.

95. I consider the 2020 deadline to be appropriate for developing new environmental flows. It will allow some time to gather the additional flow and environmental data needed to underpin the limits, as well as providing time to develop and evaluate the environmental, economic, social, and cultural impacts of alternative minimum flow and allocation limits. While it means that lowland streams will remain in a degraded state for another five years, I do not see the point in proposing limits any earlier, if they are based on poor information and are unrealistic.

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