Prepared for: Barkers Creek Catchment Group (through Access to Experts)
Date: 10/04/2024

Barkers Creek nutrient review: Sources, mitigation and achievability of targets

Quality Assurance (Status: Final)			
Role	Responsibility	Date	Signature
Prepared by	Michael Greer	10/04/2024	[signature]
Approved for issue by:			

Executive Summary

In 2013/14 Environment Canterbury (ECan) implemented an investigation into the potential source of nutrients in the Barkers Creek catchment. That investigation concluded that the creek is a significant source of nutrient, sediment and microbial contaminant loads to the Waihi River, and that intensified land use is the source of water quality contamination.

Torlesse Environmental Limited (Torlesse) has been engaged by the Access to Experts (A2E) service to help the Barkers Creek Catchment Group (the Group) better understand the source and impact of nutrients (nitrogen and phosphorus) in Barkers Creek. The purpose of this report is to draw upon the available science to describe:

- The extent to which seemingly high nutrients in the Barkers Creek catchment are due to naturally occurring processes; and
- The achievability of the nutrient related Freshwater Outcomes and Water Quality Limits in Plan Change 7 (PC7) to the Canterbury Land and Water Regional Plan (LWRP).

The available water quality data for Barkers Creek indicates that:

- The catchments of the Rokonui Drain and the water race[1] to the east of Middlemiss Road are key contributors to dissolved reactive phosphorus concentrations (DRP) concentrations in the lower reaches of Barkers Creek. The water race is also a a major contributor to nitrate (NO_3-N) concentrations.
    - It is not possible to explain exactly why the Rokonui Drain is such an important phosphorus contributor. Confusingly, relative (compared to other sub-catchments) DRP loads from that catchment are commensurate with its catchment size. However, actual DRP concentrations in that waterbody are unexplainably high (2 – 30 times higher than elsewhere in the catchment).
    - The water race to the east of Middlemiss Road contribution to NO_3-N and loads is not necessarily the result of the intensity of land use in this sub-catchment. Rather, it may be the result of:
        - Higher DRP and NO_3-N leaching rates in this area due to the presence of much freer draining soils than in the rest of the catchment (well drained vs poorly drained in S-Map); and
        - The presence of springs discharging leached nutrients to surface water.
- Targeting mitigations to Rokonui Drain and the water race to the east of Middlemiss Road is likely to result in the largest improvement in water quality. On the other hand, mitigations are likely to be least effective upstream of McKeowns Road where DRP and to a lesser extent NO_3-N concentrations are not significantly elevated above natural state. However, that is not to say that mitigations should not be implemented throughout the entire catchment
- The LWRP Water Quality Limits for NO_3-N and DRP appear to be achievable. However, the level of mitigation required is likely significant and may need to involve:
    - Land use change over ~10% of the catchment;
    - A reduction of winter dairy grazing across most of the catchment.

  There will be financial costs associated with these mitigations, and it is my understanding that for some landowners (especially those with farms used for winter grazing) these costs may be

[1] Referred to as a water race in Graham (2019). Unclear whether it is actually a race (Danette McKeown pers. comm.)

high. However, I am unable to comment on whether such costs are justified as the extent to which freshwater quality outcomes should be balanced against the financial impacts on farmers is subjective.

Given the potential challenges in meeting the LWRP Water Quality Limits for NO_3-N and DRP, possible next steps for the Group is to use this report to engage with ECan to:

- Determine how they intend to interpret and enforce the water quality limits through the Freshwater Farm Plan process; and
- Highlight the need for further studies aimed at:
  - Developing relevant catchment specific water quality targets for inclusion in future plan changes; and
  - Quantifying the actions necessary to meet such targets.

1 Introduction

Barkers Creek is a fourth-order tributary of the Waihi, Hae Hae te Moana, Temuka and Opihi Rivers. Most (91%) of the 3,225 ha catchment is in high or low producing grassland[2] with the predominant land use being sheep and beef farming. There are around 17 farms in the catchment, and most farmers belong to the Barkers Creek Catchment Group (the Group).

In 2013/14 Environment Canterbury (ECan) implemented an investigation into the potential source of nutrients in the Barkers Creek catchment in response to increasing dissolved inorganic nitrogen (DIN) concentrations in the Waihi River. That investigation concluded that the creek "*is a significant source of DIN, phosphorus, sediment and microbial contaminant loads to the Waihi River*", and that "[i]*ntensified landuse* [] *is a source of water quality contamination*" (Kelly, 2015). This was also the prevailing narrative narrative during the Orari, Temuka, Opihi and Pareora (OTOP) sub-regional limit setting process (Hayward *et al.*, 2019).

Torlesse Environmental Limited (Torlesse) has been engaged by the Access to Experts (A2E) service to help the Group better understand the source and impact of nutrients (nitrogen and phosphorus) in Barkers Creek. The purpose of this report is to draw upon the best available science to describe:

- The extent to which seemingly high nutrients in the catchment are due to naturally occurring processes; and
- The implications of naturally high nutrient concentrations on the achievability of the nutrient related Freshwater Outcomes and Water Quality Limits set in Tables 14(a) and 14(c) of Plan Change 7 (PC7) to the Canterbury Land and Water Regional Plan (LWRP).

2 Approach used to identify nutrient sources

2.1 Water quality parameters considered

This report is focused solely on nitrate (NO_3-N) and dissolved reactive phosphorus (DRP).

- NO_3-N makes up the majority of DIN in New Zealand rivers, which is the plant available component of nitrogen. As concentrations of DIN increase so too does the risk of nuisance periphyton (algae) growths in hill-fed systems and nuisance macrophyte (weed) growths in spring-fed systems. NO_3-N is also toxic to invertebrates and fish in high concentrations
- DRP is the plant available component of phosphorous and as with DIN the higher the DRP concentration the greater the risk of nuisance periphyton and macrophyte growths.

Note: DIN also includes ammoniacal nitrogen (NH_4-N) and nitrite (NO_2-N). However, the loads of these contaminants in Barkers Creek have not been quantified. Thus, it was necessary to limit the scope of this assessment to NO_3-N.

2.2 Describing the source and impact of NO_3-N and DRP

ECan do not routinely monitor water quality in Barkers Creek and have only directly collected data for the 2013-14 investigation described in Section 0 (Kelly, 2015). However, they did part-fund a masters project

[2] As defined by the Land Cover Database (LCDB) version 5.0.

by Mr Hamish Graham (an ECan officer) which aimed to identify nutrients sources in the Barkers Creek catchment (Graham, 2019). The data collected for that thesis provides useful insight into nutrient transport in the Barkers Creek catchment. Consequently, the raw data collected by Mr Graham was interrogated to:

- Summarise the state of nutrient concentrations at various points in the Barkers Creek catchment;
- Delineate joint surface-groundwater sub-catchments (through rasterisation and geospatial analysis of the surface water catchments and ground water contours in Figures 6-1 and Figures 5-1 in Graham (2019) respectively);
- Quantify NO_3-N and DRP loads from each sub-catchment; and
- Quantify the relative nutrient loss rates from the different sub-catchments (i.e., whether a sub-catchment contributes a greater or lesser percentage of the total nutrient load than would be expected based on sub-catchment size).

The outputs described above were then considered alongside information contained in the wider scientific literature to describe:

1. The extent to which 'high' nutrient concentrations in Barker's Creek are the result of naturally occurring process (based on reference (natural) state estimates in McDowell *et al*. (2013)[3]);
2. The potential to reduce nutrient concentrations through mitigations (based on the findings of McDowell *et al*. (2021) and Monaghan (2021) and the mitigation effectiveness WebApp[4] developed through the Our Land and Water (OLW) National Science Challenge); and
3. The achievability of the nutrient related Freshwater Outcomes and Water Quality Limits set in Tables 14(a) and 14(c) of PC7 to the LWRP (based on the outputs described in Points 1 and 2 above and the nutrient criteria in Snelder & Kilroy (2023))

2.3 Scope and limitations

While the data presented in Graham (2019) are robust, they were collected some time ago (> 6 years) over a short period (<1 year). Furthermore, much of the additional analysis presented in this report is based on national water quality models. While useful tools when used across large spatial scales, the performance of these models reduces as spatial resolution increases. Consequently, it is not possible to provide categorical conclusion regarding the:

- The current state and source of nutrients in Barkers Creek;
- The extent to which nutrient concentrations are driven by natural processes;
- The effectiveness of recently implemented or potential future mitigations.

Rather, this report simply provides a general indication of the achievability of the nutrient related Freshwater Outcomes and Water Quality Limits set in Tables 14(a) and 14(c) of Plan Change 7 (PC7) and the potential mitigation required to achieve them.

It is my understanding that the Group may use this information:

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[3] Distribution of references state calculated from reported median concentrations, confidence intervals and sample sizes and derived standard deviations. Percentile = $Median_{log} + Z \times Standard\ deviation_{log}$ **where** $Standard\ deviation_{log} = CI_{log} / 3.92 \times \sqrt{n}$ **and** $Z = x_{log} - median_{log} / Standard\ deviation_{log}$

[4] https://www.monitoringfreshwater.co.nz/

- To identify the possible extent of the mitigations that are needed in Freshwater Farm Plans (FFPs) (assuming that the catchment context of Barkers Creek will necessitate the achievement of the Freshwater Outcomes and Water Quality Limits in PC7 through FFPs[5]);
- Ensure those mitigations are targeted towards the parts of the catchment where they will be most effective; and/or
- To aid in conversations with ECan regarding the potential for any further work in the catchment needed to develop relevant catchment specific water quality targets for inclusion in future plan changes.

This report alone should not be tabled as evidence in Council or Environment Court Hearings without significant additional technical work.

3 Results and discussion

3.1 Where are the nutrients coming from?

Through geospatial analysis of the groundwater contours in Graham (2019) the joint surface-groundwater catchments of each of the major sub-catchments of Barkers Creek catchment were delineated. These surface-groundwater catchments were then paired with the nutrient load estimates cited in Graham (2019) to map:

- The percentage each sub-catchment contributes to total DRP and NO_3-N loads;
- The relative nutrient losses in each sub-catchment calculated as the percentage of total nutrient loads contributed by the sub-catchment divided by its land area (as a percentage of total (Barkers Creek) catchment area).

The naming of the different sub-catchments used in this report has been pulled directly from Graham (2019) and is described below in Table 1. The downstream end of each sub-catchments is also mapped in Figure 1.

Table 1: Sub-catchment considered in this report and the abbreviated naming used in this report. Naming has been drawn from Graham (2019).

Sub-catchment (upstream to downstream) and site location	Abbreviated name
[Upper] Barkers Creek at McKeown Road	UBC
Drain at downstream McKeown Road	D2
Drain at downstream Saywell Ford	D4
Rokonui Drain at upstream Barkers confluence	D6
Middlemiss Drain at upstream Barkers confluence	D8
Water Race at upstream Barkers confluence	D10
Morning Glory at upstream Barkers confluence	D11
Drain at upstream Sercombe	D12
Sercombe North Drain at upstream Barkers	D14
Sercombe South Drain at upstream Barkers	D15
Drain at upstream Barkers/Waihi confluence	D16

[5] Note this is an assumption and should not be considered legal or policy advice. I am unable to comment on whether ECan will require farmers to demonstrate that their FFPs will result in the achievement of the PC7 Freshwater Outcomes and Water Quality Limits.

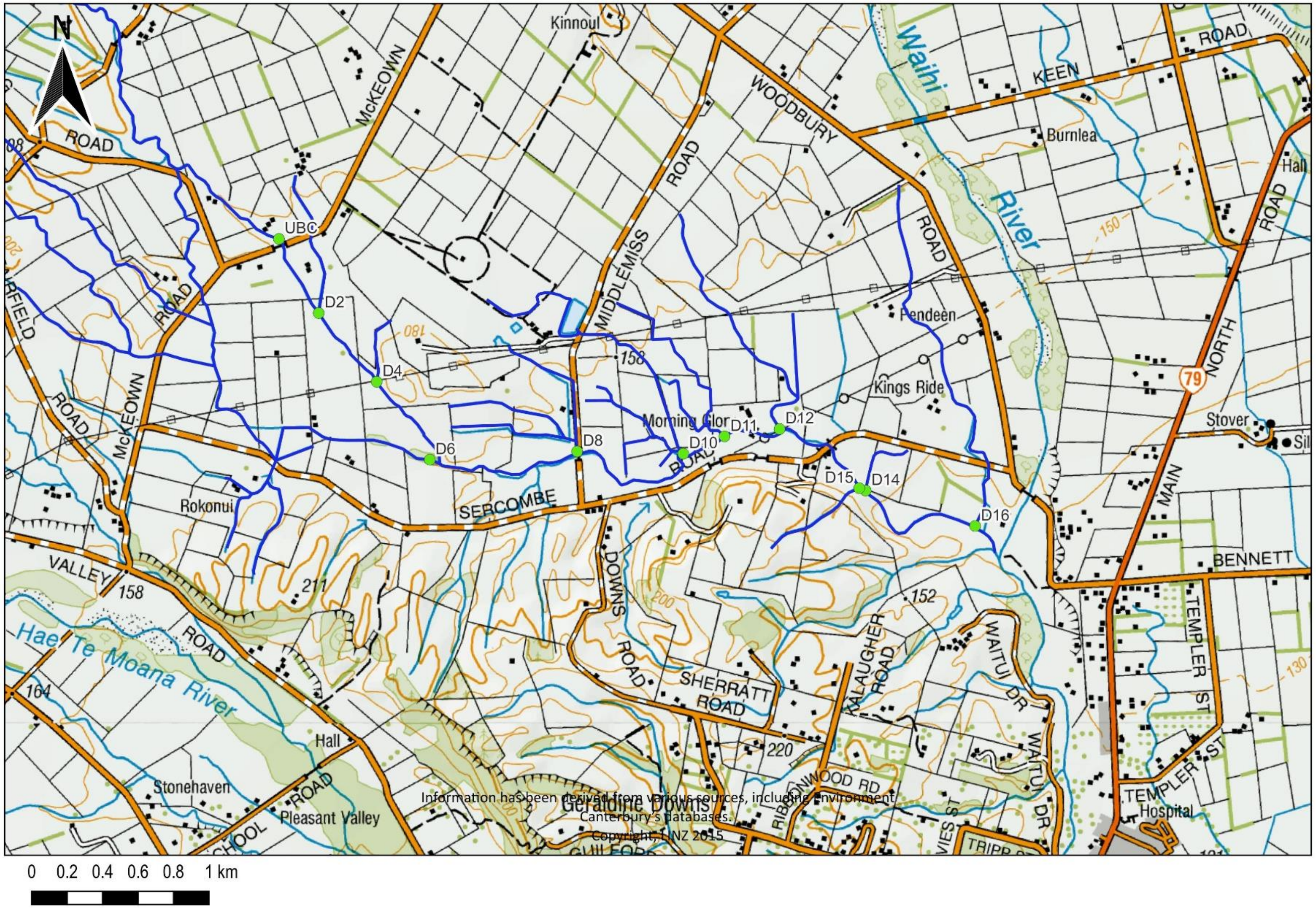

Figure 1: Downstream end of each sub-catchment considered in this report. Naming has been drawn from Graham (2019) and is described in Table 1.

Analysis of the available water quality data suggests that between 2016 and 2017 the catchment of the water race[1] to the east of Middlemiss Road (D10) had higher DRP and NO_3-N loss rates than most of the rest of the Barkers catchment (Figure 4 and Figure 6) and contributed a significant portion of the loads of these nutrients in Barkers Creek (Figure 3 and Figure 6). As a result, inputs from this sub-catchment significantly increased median DRP and NO_3-N concentrations in the creek (Figure 2 and Figure 5). This is not necessarily the result of the intensity of land use in this catchment (which does not appear to differ markedly in D10 from in the other sub-catchments) or the practices employed on the included farms. Rather, it may be the result of:

- Higher DRP and NO_3-N leaching rates in this area due to the presence of much freer draining soils than in the rest of the catchment (well drained vs poorly drained in S-Map); and
- The presence of springs discharging leached nutrients to surface water.

  Note: Graham (2019) attributed DRP loads in the other drains to sediment input (followed by phosphorus release in river).

DRP concentrations were also unexplainably high in the Rokonui Drain (D6 - Figure 5), and inputs from that waterway appear to have increased concentrations in Barkers Creek despite DRP loads from that catchment being proportional to its area (Figure 2 and Figure 4).

Further detail is provided in Sections 3.1.1 and 3.1.2 and Figure 2 to Figure 7 below.

3.1.1 Dissolved reactive phosphorus

- As shown in Figure 3, the water race to the east of Middlemiss Road (referred to as D10 in Graham (2019) and Figure 3 and Figure 2) contributed 33% of the DRP load in Barkers Creek in 2016/17, with the Rokonui Drain (D6) and the Upper Barkers Creek Catchment (above McKeown Road; UBC) contributing a further 15% and 13% respectively. All other sub-catchment contributed less than 10% of the total catchment load.
- In 2016/17 relative DRP loss rates were highest in the catchment of the downstream drain entering Barkers Creek from the north downstream of Saywell Ford (D4) and were also high (>1) in the catchment of D10 (Figure 4).
- The effect of the nutrient losses and loads illustrated in Figure 3 and Figure 4 on DRP concentrations in Barkers Creek was that median concentrations decreased between Rices and McKeown Roads but tripled downstream of the Rokonui Drain (D6) before doubling once again downstream of D10 (Figure 2)

  Note: This is consistent with the findings of Kelly (2015).

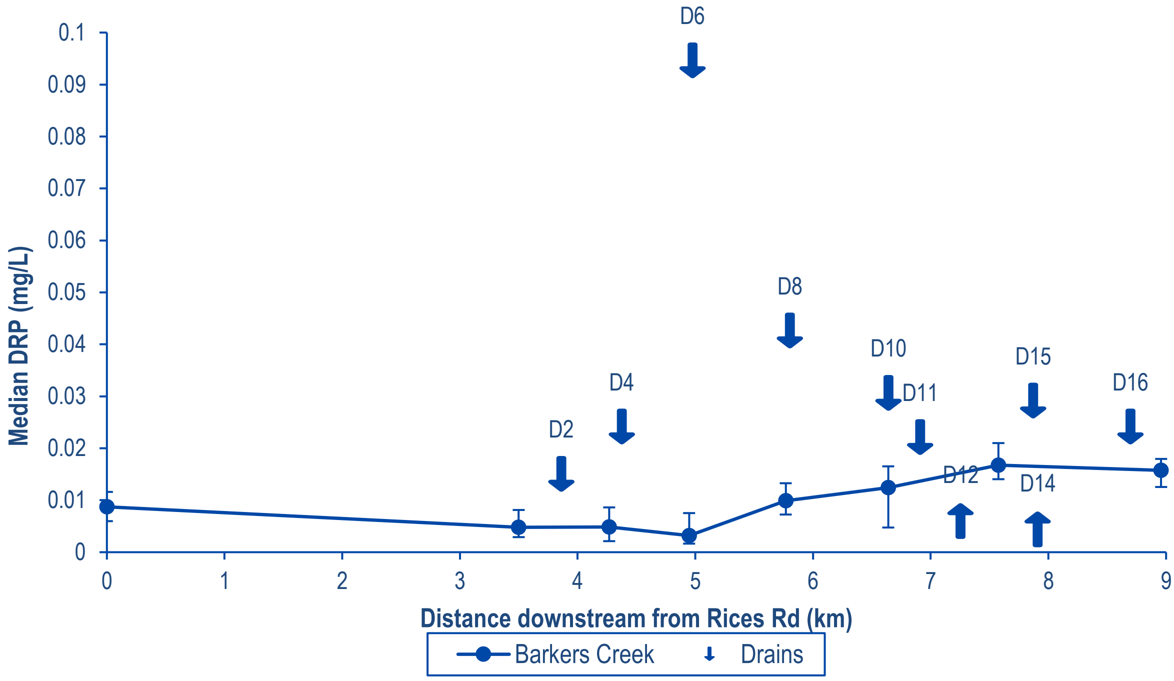

Figure 2: Median DRP concentrations (±S.E.) along Barkers Creek (blue dots and lines) and in the drains entering it (blue arrows) in 2016/17 (as reported by Graham (2019)). See Table 1 and Figure 1 for the locations of each drain sub-catchment.

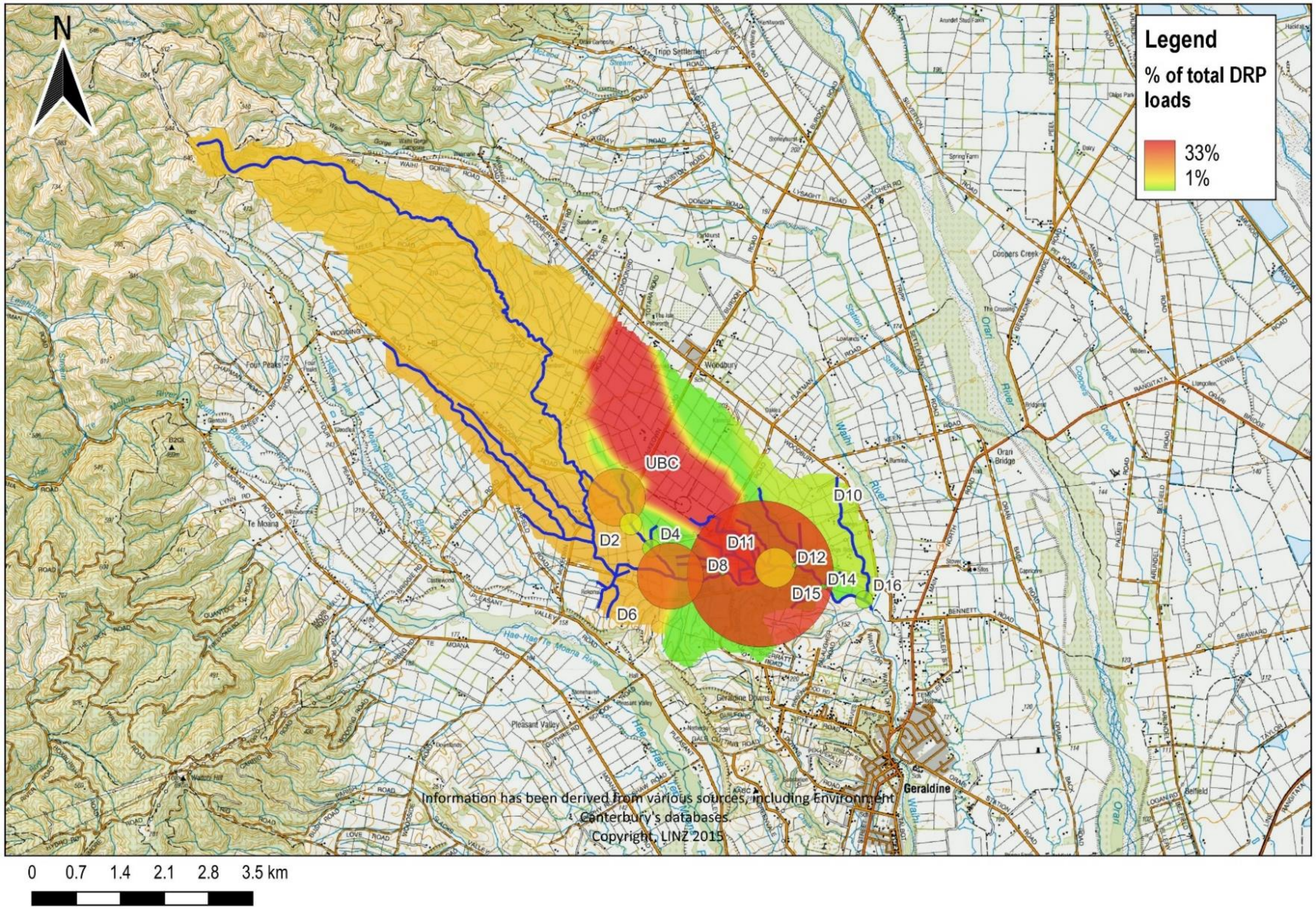

Figure 3: Contribution of DRP loads in Barkers Creek by different joint surface-groundwater sub-catchments in 2016/17 (based on data in Graham (2019)). The percentage contribution of each catchment is depicted using a a traffic light scale across the sub-catchment (overlay) and at the bottom of the catchment (variably sized dots) (see Table 1 and Figure 1 for the locations of each sub-catchment).

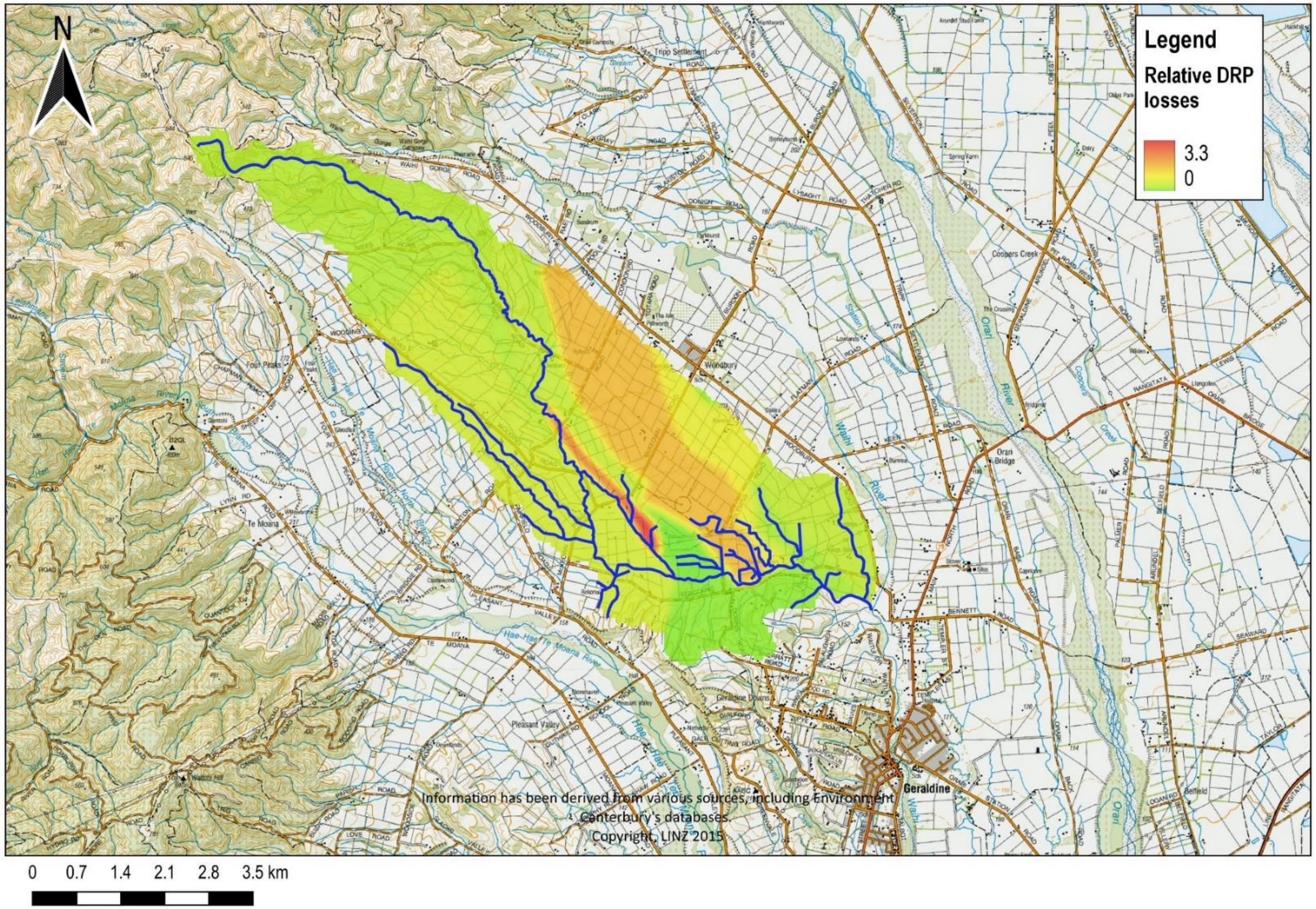

Figure 4 Relative DRP loss rates in different joint surface-groundwater sub-catchments of Barkers Creek in 2016/17 (based on data in Graham (2019)). The DRP load contributed by each sub-catchment divided by proportion of the catchment it covers is depicted on a traffic light scale. Green sub-catchments contributed less DRP than would be expected based on catchment area and red sub-catchments contributed more (yellow = neutral)

3.1.2 Nitrate

- As with DRP, D10 was a significant source of the NO_3-N load in Barkers Creek (36%) between 2016 and 2017, with the Upper Barkers Creek catchment being another important contributor (11%) (Figure 6). However, unlike for DRP, the Rokonui Drain contributed very little of the NO_3-N load, despite its significant catchment size (Figure 7).
- Also similar to DRP, relative NO_3-N loss rates were highest in the catchments of D4 and D10.
- The NO_3-N loads and losses described above resulted in a steady increase in median NO_3-N concentrations in Barkers Creek between Rices and Middlemiss Roads. Concentrations then doubled downstream of where D10 enters (Figure 5).

  Note: This is consistent with the findings of Kelly (2015).

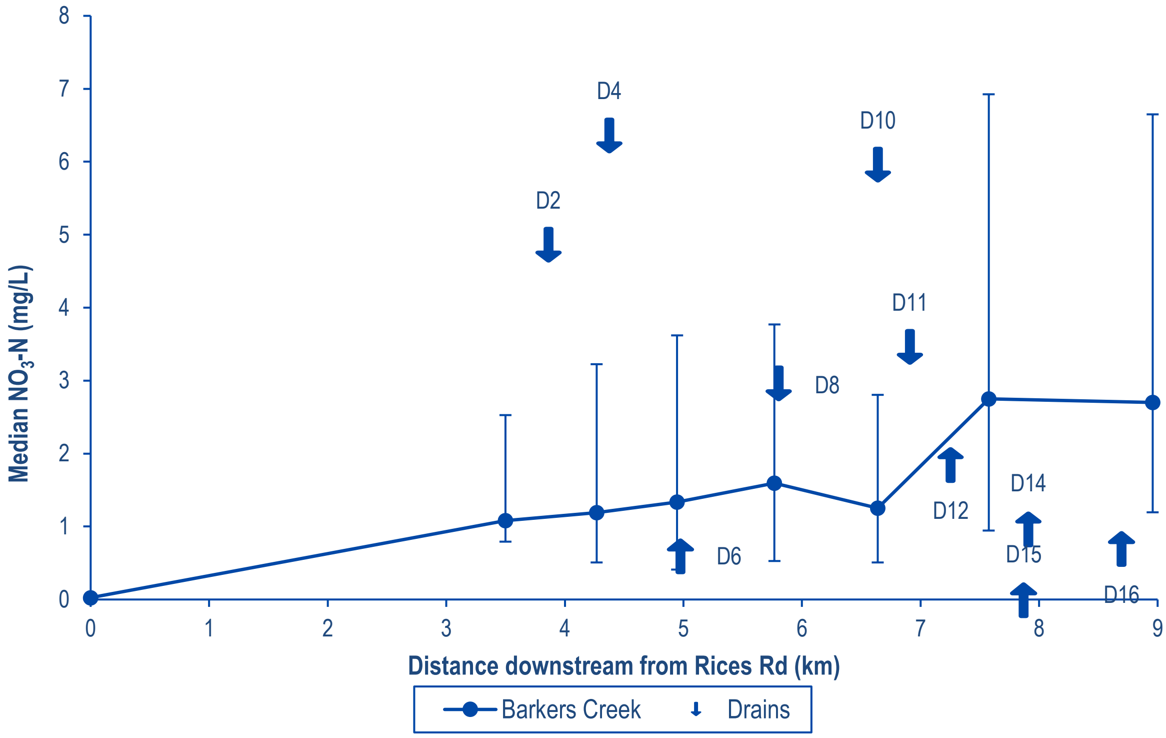

Figure 5: Median NO_3-N concentrations (±S.E.) along Barkers Creek (blue dots and lines) and in the drains entering it (blue arrows) in 2016/17 (as reported by Graham (2019)). See Table 1 and Figure 1 for the locations of each drain sub-catchment.

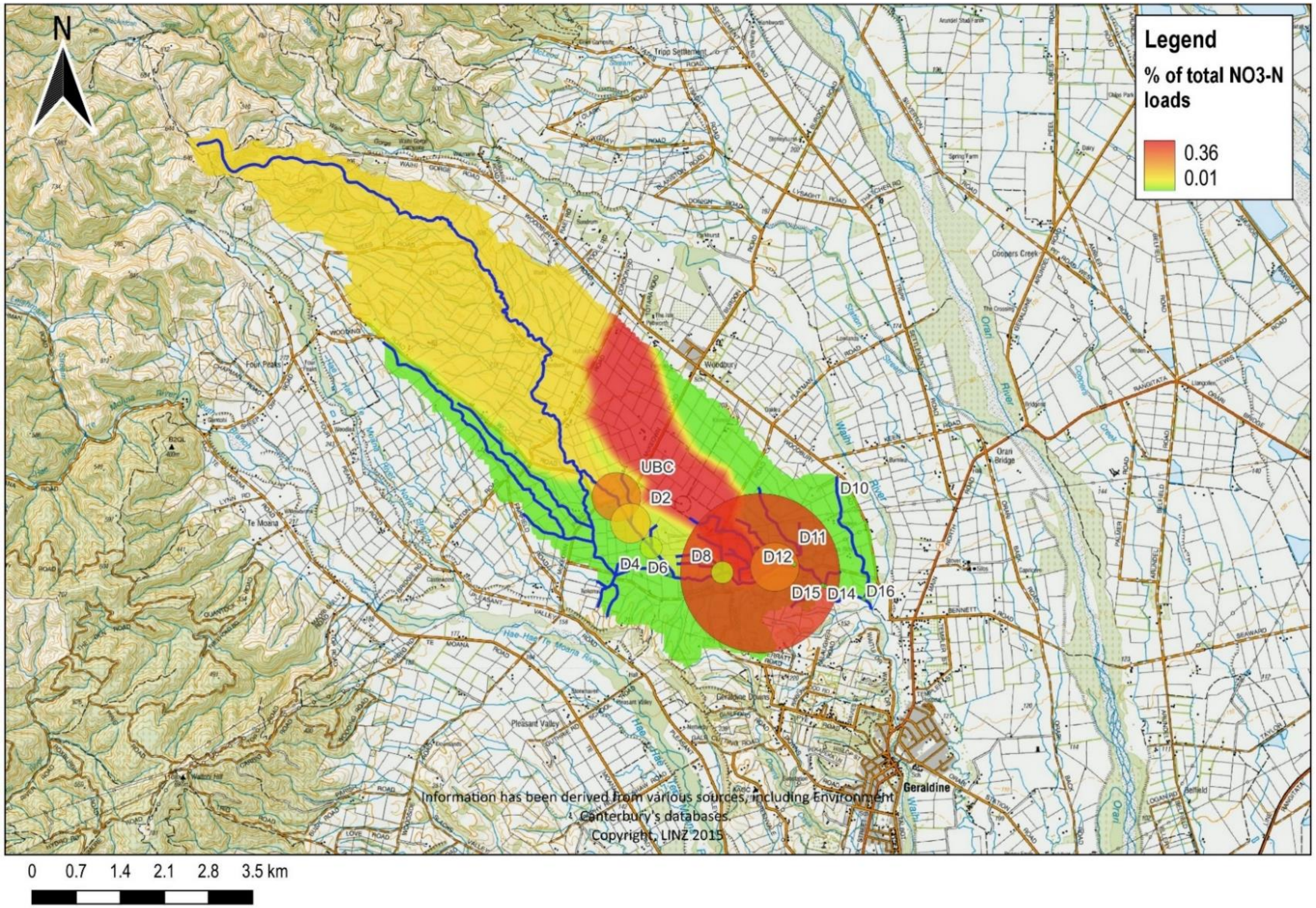

Figure 6: Contribution of NO_3-N loads in Barkers Creek by different joint surface-groundwater sub-catchments in 2016/17 (based on data in Graham (2019)). The percentage contribution of each catchment is depicted using a a traffic light scale across the sub-catchment (overlay) and at the bottom of the catchment (variably sized dots) (see Table 1 and Figure 1 for the locations of each sub-catchment).

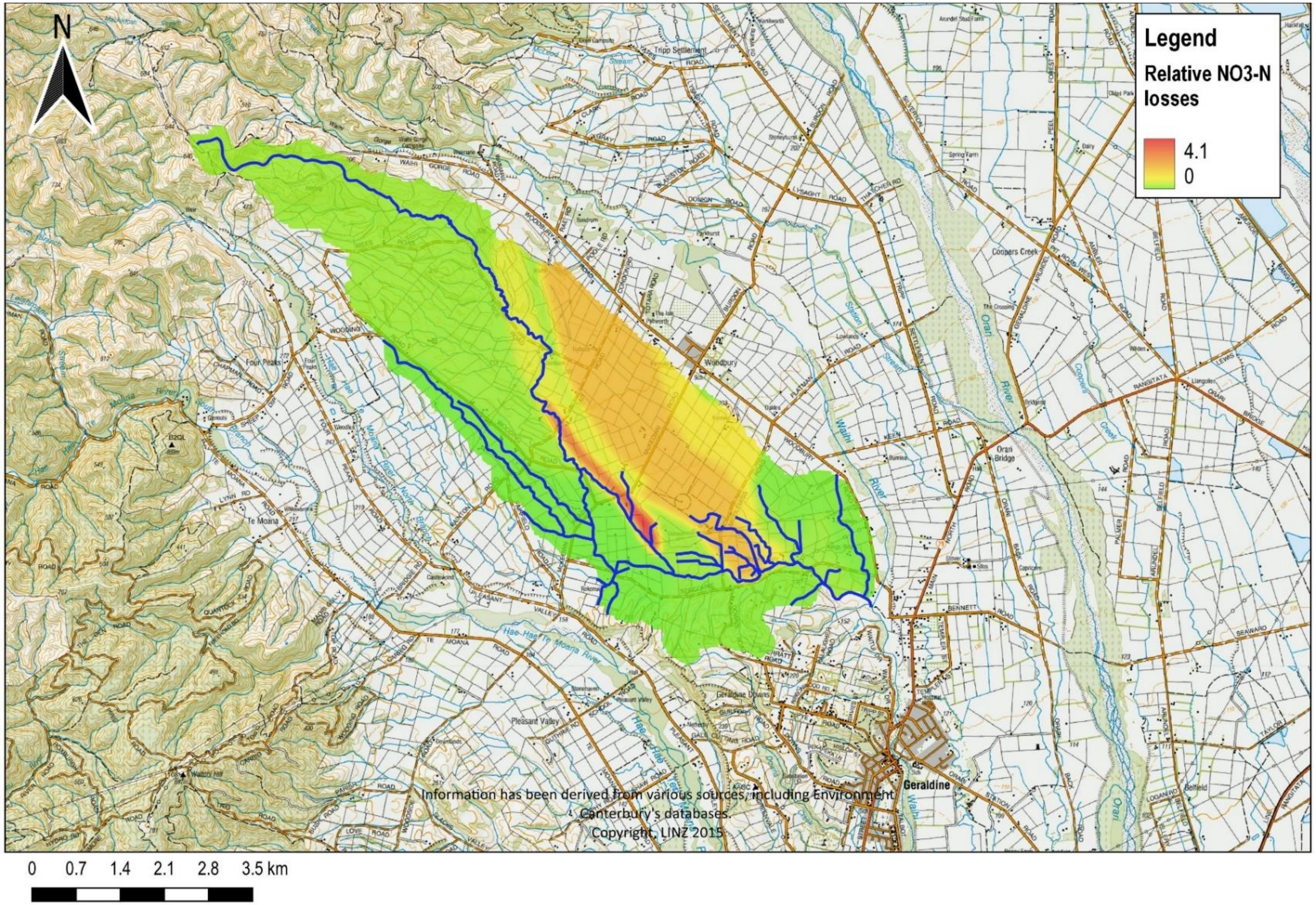

Figure 7: Relative NO_3-N loss rates in different joint surface-groundwater sub-catchments of Barkers Creek in 2016/17 (based on data in Graham (2019)). The NO_3-N load contributed by each sub-catchment divided by proportion of the catchment it covers is depicted on a traffic light scale. Green sub-catchments contributed less NO_3-N than would be expected based on catchment area and red sub-catchments contributed more (yellow = neutral)

3.2 Are nutrient concentrations naturally high or has human activity increased them?

3.2.1 Dissolved reactive phosphorus

Based on modelling work by McDowell (2013) DRP concentrations in Barkers Creek between 2016 and 2017 were well within natural conditions for most of the length upstream of its confluence with the Rokonui Drain, with median concentrations reflecting reference state (i.e., the expected median concentration in rivers with no pastoral land cover) between McKeowns Road and the confluence with the Rokonui Drain. However, the significant increase in concentrations downstream of this point were unlikely to be natural, with median concentrations well above the level cited in McDowell (2013) as being reflective of a 'measurable perturbation' from natural conditions.

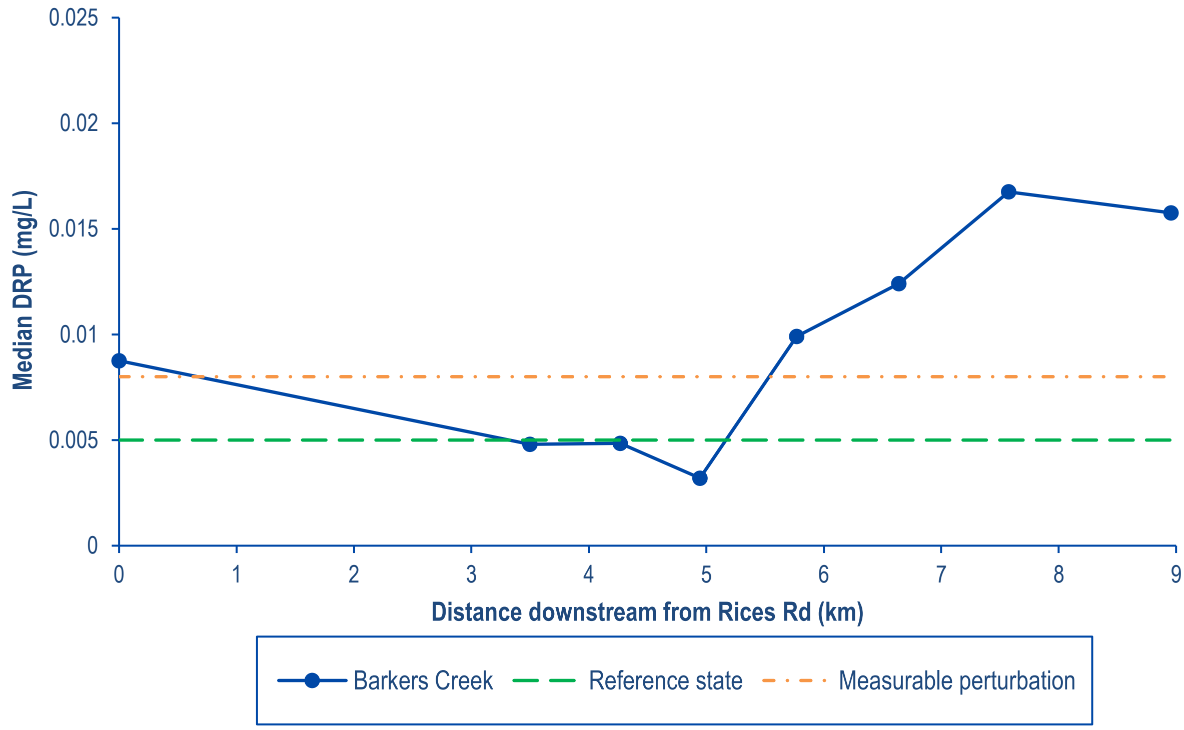

Figure 8: Median DRP concentrations along Barkers Creek (blue dots and lines) in 2016/17 (as reported by Graham (2019)) compared to the modelled reference state in McDowell (2013) (green dashed line) and the, level cited in McDowell (2013) as being reflective of a 'measurable perturbation' from natural conditions (orange dashed line).

3.2.2 Nitrate

Median NO_3-N concentrations in Barkers Creek at Rices Road between 2016 and 2017 approximated the modelled reference condition in McDowell (2013). However, by McKeowns Road concentrations exceeded the level cited in McDowell (2013) as being reflective of a 'measurable perturbation', and this is unlikely to be the result of naturally occurring processes.

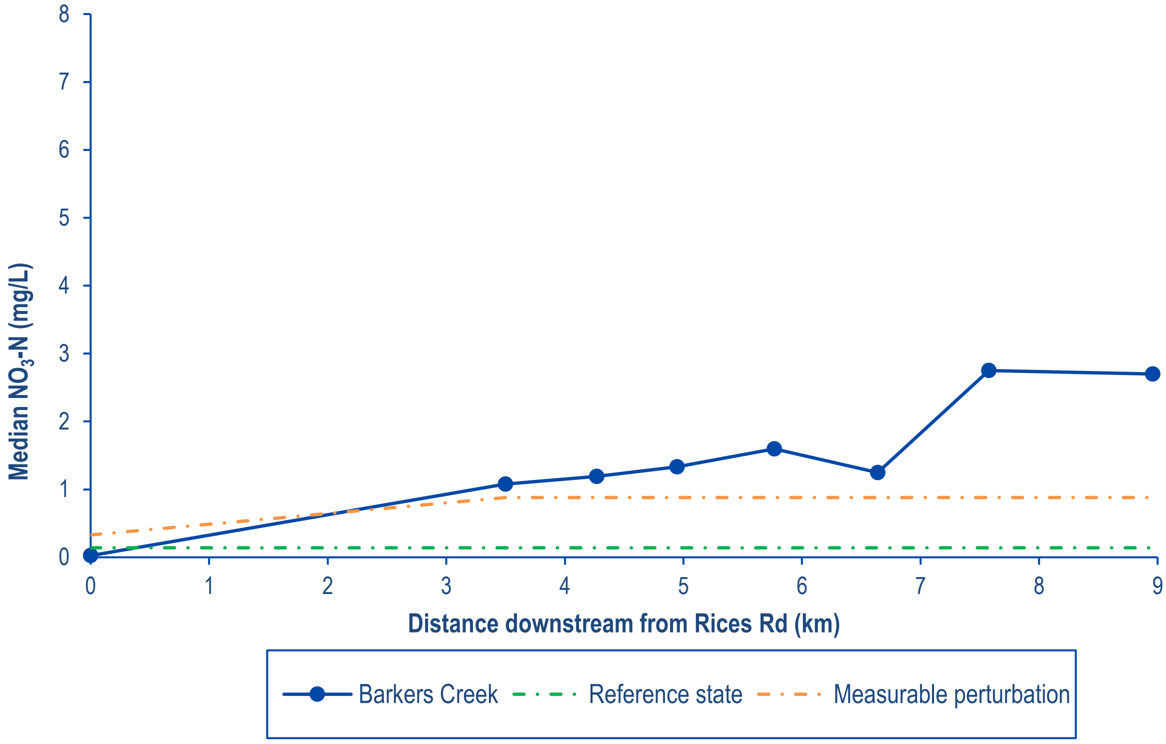

Figure 9: Median NO_3-N concentrations along Barkers Creek (blue dots and lines) in 2016/17 (as reported by Graham (2019)) compared to the modelled reference state in McDowell (2013) (green dashed line) and the, level cited in McDowell (2013) as being reflective of a 'measurable perturbation' from natural conditions (orange dashed line).

3.3 What improvements can be achieved through mitigations?

The WebApp[4] developed by the OLW National Science Challenge provides an estimate of feasible improvements that can be made to DRP and NO_3-N concentrations through the mitigations set out in Table 2. Those mitigations are estimated to reduce median NO_3-N concentrations in Barkers Creek by between 22% and 28% and decrease DRP concentrations by between 29% and 35%.

It is important to note, however, that these improvements represent the maximum possible through a comprehensive suite of mitigations, many of which actually constitute land use change. Of particular import, is the assumed shift of 11% of the farmland in the catchment to plantation forestry, the retirement of a further 6% through wetland construction, riparian setbacks and targeted revegetation (Table 3). The adoption of this mitigation package would also require no winter grazing of dairy cattle on pasture or crops. I understand that winter grazing is a core component of many farming businesses in the catchment, and that ceasing this activity would have significant financial implications for many landowners (Danette McKeown *pers. comm.*).

Note: Due to the way the OLW WebApp[4] is built it is not feasible to identify the contribution of different mitigations to the provided nutrient reduction estimates. Consequently, it is not possible to quantify the reductions that are possible in the Barkers Creek catchment in the absence of land use change or reduced winter grazing with the tools/budget currently available.

Table 2: Mitigations assumed as feasible in by the OLW National Science Challenge.

Land-cover	Mitigation
Sheep + Beef	Increasing forested area
	Retirement
Sheep + Beef & Dairy	Constructed wetlands
	Stock exclusion
	Controlled release fertiliser
	Variable rate fertiliser
	Controlled drainage
	Edge of field nutrient attenuation
Dairy	Strategic grazing of pasture within CSAs
	Strategic grazing of crops within CSAs
	Alum applied to pasture or crops in CSAs
	Variable rate irrigation and fertigation
	On-off grazing in autumn and winter
	Nitrification inhibitors
	Decreasing N inputs

Table 3: The area of land use change in the Barkers Creek catchment that could be required by the mitigations assumed as feasible by the OLW National Science Challenge.

Land-cover	Mitigation	Land use change	
		Area (ha)	%of farmland
Sheep + Beef	Increasing forested area	342	11%
	Retirement	95	3%
Sheep + Beef & Dairy	Constructed wetlands	63	2%
	Stock exclusion	35	1%
Total		**535**	**17%**

3.4 Are the LWRP targets achievable and through what actions?

It is my understanding that the relevant nutrient related Freshwater Outcomes and Water Quality Limits in PC7 are as follows

- Median NO_3-N in the Opihi River at Grass Banks = 0.45 mg/L (requires a 16.7% reduction)[6];
- Median DRP in Temuka River at Manse Bridge = 0.008 mg/L (requires a 20.4% reduction)[6]; and
- Periphyton biomass = 200 mg Chl-*a*/m^2.

Analysis of the available data indicates that the implementing all of the mitigations set out in Table 2 could reduce DRP and NO_3-N concentrations/loads at the bottom of Barkers Creek by 35% and 28% respectively. Thus, the nutrient reductions[6] required by the LWRP Water Quality Limits equate to ~55% of what can feasibly achieved through mitigation (Figure 10 and Figure 11). It is not possible to determine the exact mitigations required to achieve this improvement. However, for DRP at least it is reasonable to assume that it may require land use change (pastoral to retired, riparian retired, wetland, or plantation forestry) over as much as 10% of the catchment and potentially a reduction in winter grazing.

Clearly, there will be financial costs associated with the mitigations needed to achieve the LWRP Water Quality Limits, and it is my understanding that for some landowners (especially those with farms used for winter grazing) these costs may be high. However, I am unable to comment on whether such costs are justified or whether the Water Quality Limits should be changed in the next plan change to the LWRP. Basically, the level at which freshwater quality should be managed and the extent to which the finances of individuals should be factored into resource management decisions is subjective. Thus, the opinion of one scientist on the appropriateness of water quality limits that have already been the subject of a council hearing is redundant.

The nutrient exceedance criteria in Snelder & Kilroy (2023) indicate that current NO_3-N and DRP concentrations in Barkers Creek are sufficiently low to achieve the Freshwater Outcomes for periphyton biomass. Specifically, there is less than a 30% probability of 92^{nd} percentile periphyton biomass concentrations exceeding 200 mg Chl-*a*/m^2.

Note: The Group has obtained the necessary permissions to release dung beetles in the Barkers Creek catchment. This release may decrease particulate phosphorus losses in that catchment through reduced sediment runoff (Forgie et al., 2018). This could, potentially reduce the extent of the additional mitigations required to achieve the LWRP Water Quality Limits for NO_3-N and DRP. However, it is my understanding that the impact of dung beetles on nutrient losses is uncertain (Alsable & Pronger, 2020). Thus, their effect on nutrient quality in Barkers Creek is also uncertain.

[6] Based on the difference between current state (as defined on LAWA) and the PC7 limit. Assumes that all farms in the catchment upstream of the listed monitoring site will be required to contribute equally to the reduction through the FFP process. It is not certain whether this is the approach ECan will take.

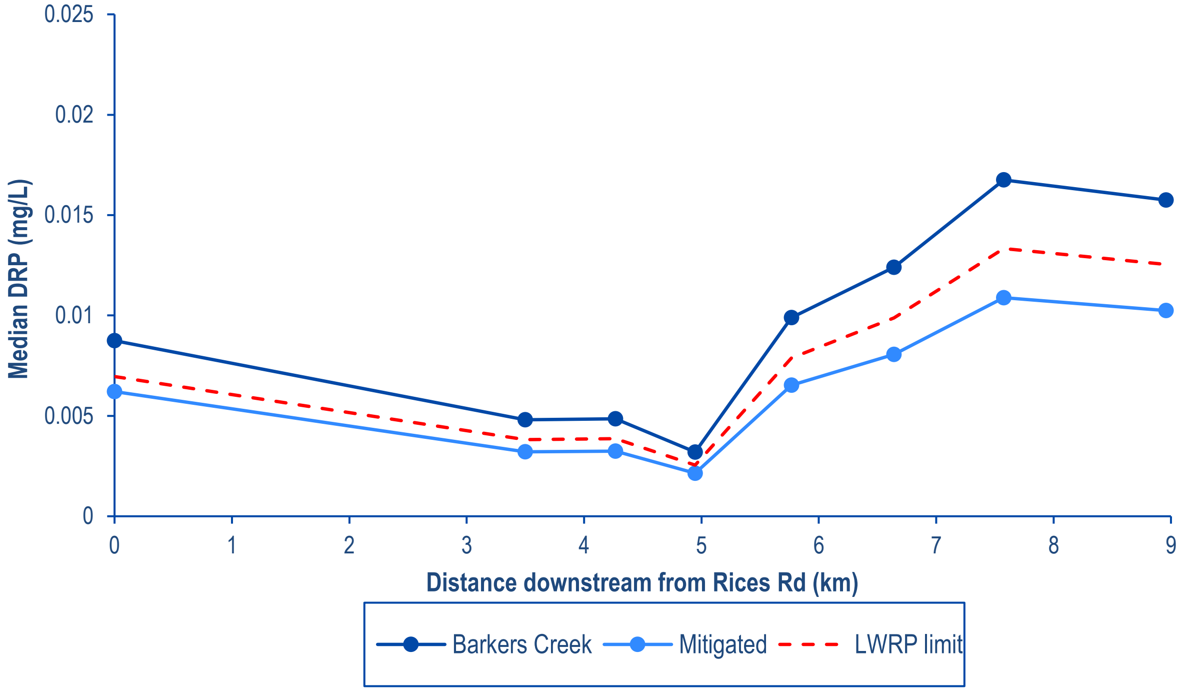

Figure 10: Median DRP concentrations along Barkers Creek (blue dots and lines) in 2016/17 (as reported by Graham (2019)) compared to predicted concentrations with the mitigations in Table 2 applied (calculated through the OLW WebApp[4]). The red dashed line reflects the concentration needed to meet Water Quality Limits in PC7.

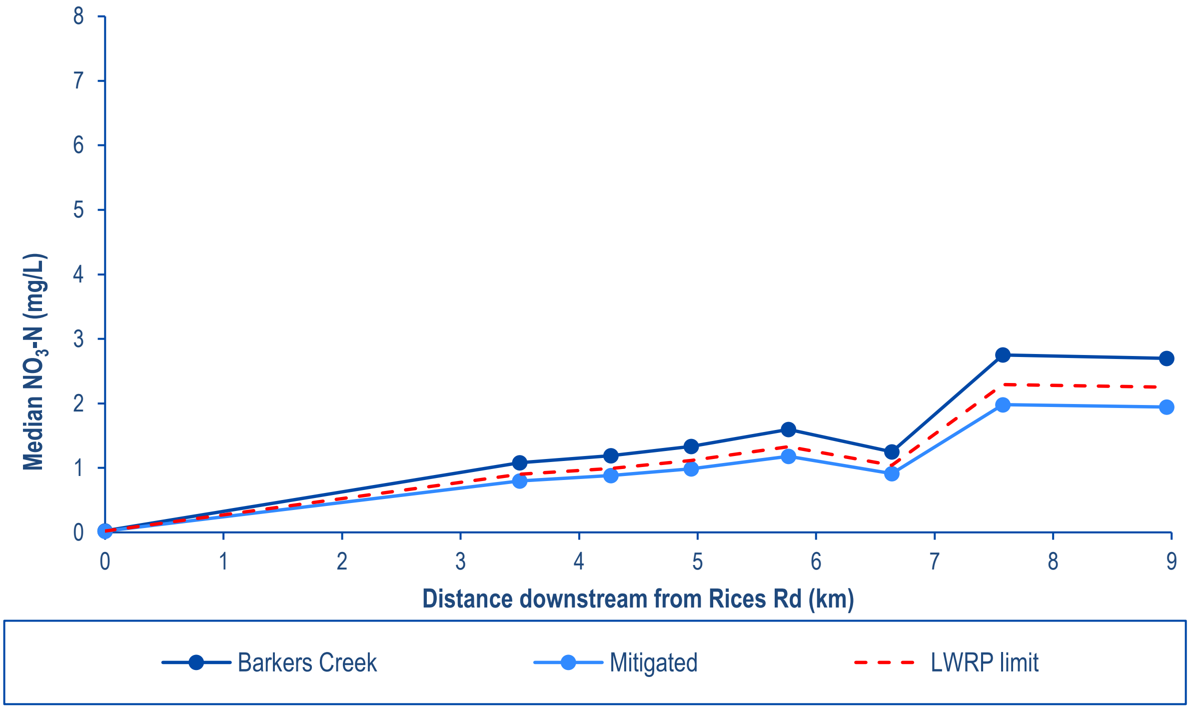

Figure 11: Median NO_3-N concentrations along Barkers Creek (blue dots and lines) in 2016/17 (as reported by Graham (2019)) compared to predicted concentrations with the mitigations in Table 2 applied (calculated through the OLW WebApp[4]). The red dashed line reflects the concentration needed to meet Water Quality Limits in PC7.

Table 4: Nutrient criteria to achieve the PC7 Freshwater Outcome for periphyton biomass in shaded hill-fed lower rivers in the Temuka Freshwater Management Unit (like the lower reaches of Barkers Creek). The left data column represents the concentrations where there is a 5% risk of the Freshwater Outcome being exceeded, while the far right data column represents concentrations where there is a 50% risk of the Freshwater Outcome being exceeded. Whether current (2016/17) concentrations fall meet or exceed the criteria with or without mitigation is denoted by ticks and crosses

Parmeter		Risk of Freshwater Outcome for periphyton biomass being exceeded		
		5%	30%	50%
NO_3-N	Nutrient criteria (mg/L)	0.074	2.783	3.522
	Currently met	×	✓	✓
	Met with full mitigation	×	✓	✓
DRP	Nutrient criteria (mg/L)	0.0025	0.11	0.216
	Currently met	×	✓	✓
	Met with full mitigation	×	✓	✓

4 Possible next steps

Given the potential challenges in meeting the LWRP Water Quality Limits for NO_3-N and DRP possible next steps are to use this report to engage with ECan to:

- Determine how they intend to interpret and enforce the water quality limits through the FFP process; and
- Highlight the need for further studies aimed at:
  - Developing relevant catchment specific water quality targets for inclusion in future plan changes; and
  - Quantifying the actions necessary to meet such targets.

If ECan are not amenable to conducting those studies, there would be benefit in the Group starting regular water quality monitoring regularly at a limited number of locations in the catchment to ensure that such data are available to inform ECan's future modelling work and decisions around land use in the catchment.

5 References

Alsable, J., Pronger, J., 2020. Dung beetles: NZ's missing link to achieve sustainable pastoral agriculture? Soil Horizons.

Forgie, S.A., Paynter, Q., Zhao, Z., Flowers, C., Fowler, S.V., 2018. Newly released non-native dung beetle species provide enhanced ecosystem services in New Zealand pastures. Ecological Entomology 43, 431–439.

Graham, H.J., 2019. A water quality study of Barkers Creek, South Canterbury (MSc Thesis). University of Canterbury, Christchurch, New Zealand.

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