BEFORE THE OTAGO REGIONAL COUNCIL

IN THE MATTER	of the Resource Management Act 1991 ("the Act")
AND	
IN THE MATTER	Criffel Water Limited, Luggate Irrigation Company and Lake MacKay Station. Water Permit Application RM16.093.01 RM18.345.01 and RM18.345.02

STATEMENT OF MATTHEW AARON HICKEY
EVIDENCE ON BEHALF OF CRIFFEL WATER LTD, LUGGATE IRRIGATION COMPANY AND LAKE MACKAY STATION.

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Executive Summary:

A. Luggate Creek water quality has been classed as excellent by the ORC, with water quality currently meeting all but one attribute under Schedule 15 of the Regional Plan: Water, where DRP is slightly elevated. Under the NPSFM Luggate Creek is classified in the A Band for nitrate and ammonia toxicity and swimmability[1].

B. Biological monitoring of Luggate Creek using the Macroinvertebrate Community Index (MCI) shows that based on 8 years of data (2008-17) Luggate creek has recorded an MCI score of between 100 and 110 each year, this score corresponds to a "good" water quality grading and is ranked the 8th best stream in ORC's SoE monitoring network based on median MCI scores[2].

C. Since regular SoE fish monitoring began only brown trout have been recorded at the SH 6 site. In the most recent survey results for the 2017/18 season 75 brown trout were recorded, with no native fish being present, this ranked as the second highest number of brown trout caught across Otago[3]. Both the number of trout caught, and the consistently high number of trout indicates that Luggate Creek is a healthy brown trout spawning stream.

D. Historically Koaro have been recorded in low densities at different locations in the catchment, however their lack of abundance has been attributed to the high densities of trout in Luggate Creek, with the expectation that increased flows will result in higher levels of predation by trout on koaro[4].

E. Longfin eels would be expected to naturally occur in Luggate Creek; however, they are currently at very low levels[5] due to the presence of the Roxburgh and Clyde dams effectively preventing both upstream and downstream migration.

F. Dr Ian Jowett provides analysis that shows that the existing minimum flow of 180 l/s at the SH 6 Bridge provides in excess of 80% habitat for Longfin eel (both larger and smaller than 300mm), ~70% habitat at MALF for koaro and 80% habitat at MALF for juvenile brown trout (<100mm) using habitat curves published in Jowett and Richardson 2008[6].

G. Hydrological analysis shows that it would be reasonable to expect that under stable natural low flow conditions that the Alice Burn would contribute ~33% of the flow recorded at the SH 6 flow site and the North Branch of Luggate Creek would contribute ~66% of the recorded flow.

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[1] Tables 46, 47 and 48 of State of the Environment Surface Water Quality in Otago 2006 to 2017. ORC report available at www.orc.govt.nz/media/6957/final_orc_soe_report_2006_to_2017.pdf

[2] Page 213 of State of the Environment Surface Water Quality in Otago 2006 to 2017. ORC report available at www.orc.govt.nz/media/6957/final_orc_soe_report_2006_to_2017.pdf

[3] 2017-18 Bio monitoring report card available at https://www.orc.govt.nz/media/6296/2017-2018-soe-report-card.pdf.

[4] Allibone, R. 2016. Luggate Creek Fish Survey Summary.

[5] Anecdotal observations from landowners suggest a few still occupy Luggate Creek.

[6] All habitat curves used can be found in; Jowett, I.G.; Richardson, J. (2008). Habitat use by New Zealand fish and habitat suitability models. NIWA Science and Technology Series No. 55.

H. Based on flow contributions required from upstream to deliver the minimum flow SH 6 and the levels of taking from each of the two main branches of Luggate Creek I would expect to meet the minimum flow of 180 l/s the majority of flow recorded would need to come from the North Branch.

I. As it stands the Luggate Creek water users' proposal reduces the maximum primary allocation rate that can be taken from the Luggate Creek catchment from 785 l/s to 538 l/s. While also reducing the maximum annual volume taken by Luggate Creek water users as primary allocation from 11 Mm^3/yr to 7 Mm^3/yr.

J. The Luggate Creek water users proposal will reduce actual water taken as primary allocation from the catchment by ~30% and consented abstraction by ~50%. It is anticipated that this reduction will

K. It is anticipated that the residual flows proposed in concert with the minimum flow at SH 6 will protect and enhance the existing ecological values of Luggate Creek.

Introduction

Qualifications and experience

1. My full name is Matthew Aaron Hickey.

2. I hold a Bachelor of Science Double Major, Geography and Ecology (2000), a Post Graduate Diploma of Science in Ecology (2002) and a Master of Science (MSc) in Ecology (2005) all from the University of Otago. My MSc was focused on comparing two methods for obtaining fish population estimates - electric fishing compared to night spotlight counts.

3. Between 2003 and 2006, I was a Water Resource Scientist - Water Quantity within the Resource Science team at Otago Regional Council (ORC). While at ORC, I authored reports on management flows for the Waianakarua River[7], Trotters Creek[8], Taieri River at Tiroiti[9], Waiwera River[10], Luggate Creek[11], Pomahaka River[12] and Manuherikia River[13]. These reports include hydrological analysis, a summary of aquatic ecosystem values, as well as consideration of the flow requirements of fish communities. In support of these documents I also carried out assessments of water surety for the respective plan change assessments.

4. In April 2006 I moved roles at ORC taking up the position of Manager of Resource Science. In this role I was responsible for managing the science program including the delivery of technical information for minimum flow setting across Otago. As Manager of Resource Science I also oversaw numerous hydrological investigations, as well as reporting on water quantity issues at a regional level[14].

5. In 2015 I left ORC and started my own company (Water Resource Management Ltd) providing technical advice on ecological flow setting, hydrology, reliability of supply and water sharing. I currently work for more than 15 water management groups or irrigation companies in both Otago and Canterbury helping them prepare for the transition from deemed permits to Resource Management Act (1991) (RMA) consents post 2021. I also currently work on behalf of three catchments groups either in or about to enter the minimum flow process, providing technical advice and liaising with the ORC and stakeholders.

6. Over the last 15 years I have made or reviewed over 100 technical recommendations for residual flow conditions to protect the ecological values at individual takes points across Otago; worked on setting environmental flows and allocation limits for a number of Otago's rivers; as well as water quantity policy development for the Regional Plan: Water for Otago (RPW), specifically around managing the transition from deemed permits to RMA consents.

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[7] ORC (2006). Management flows for aquatic ecosystems in the Waianakarua River. Otago Regional Council, Dunedin. 31 p.
[8] ORC (2006). Management flows for aquatic ecosystems in Trotters Creek. Otago Regional Council, Dunedin. 29 p.
[9] ORC, (2006). Management flows for the Taieri River at Tiroiti. Otago Regional Council, Dunedin. 30 p.
[10] ORC, (2006). Management flows for aquatic ecosystems in the Waiwera River. Otago Regional Council, Dunedin. 33 p.
[11] ORC, (2006). Management flows for aquatic ecosystems in Luggate Creek. Otago Regional Council, Dunedin. 31 p.
[12] ORC, (2006). Management flows for aquatic ecosystems in the Pomahaka River. Otago Regional Council, Dunedin. 38 p.
[13] ORC, (2006). Management flows for aquatic ecosystems in the Manuherikia River. Otago Regional Council, Dunedin. 37 p.
[14] ORC, (2008). Surface Water Resources of Otago. Otago Regional Council, Dunedin. 68 p.

7. As well as working at a regional level I've also worked on national level initiatives. In 2006 I started work on the Sustainable Water Program of Action, specifically the proposed National Environmental Standard on Ecological Flows and Water Levels[15]. As a member of the working group I applied my allocation knowledge to both policy and technical issues in a limit setting context. Further to this I was also a reviewer of the final science report[16] regarding ecological methods prepared by many of the lead scientists in the field in New Zealand.

8. In 2014 I contributed to the freshwater accounting guidance being prepared by the Ministry for the Environment as part of the implementation of the National Policy Statement for Freshwater Management, specifically providing a case study on managing water allocation and reviewing the wider document.[17]

9. For the purpose of my evidence When I refer to LIC it incorporates both Luggate Irrigation Company (LIC) and Lake MacKay Station (LM) unless stipulated otherwise.

10. I confirm that I have read and agree to comply with the Environment Court Code of Conduct for Expert Witnesses (Consolidated Practice Note 2014). This evidence is within my area of expertise, except where I state that I am relying on what I have been told by another person. I have not omitted to consider material facts known to me that might alter or detract from the opinions that I express.

SCOPE OF EVIDENCE

11. I have been asked by Criffel Water Limited (CWL), Luggate Irrigation Company (LIC) and Lake McKay Station (LM) to present evidence to this hearing. My evidence addresses the following:

a. Luggate Creek ecological values

b. Hydrology of Luggate Creek and its two main branches (North Branch and Alice Burn)

c. Assessment of actual and efficient use

d. reliability of supply

e. Water sharing between water users.

12. To assess the cumulative effects of the proposed take regime by CWL and LIC/LM I use the following three flow regimes.

a. Natural Flow Regime – flows that would occur in the absence of taking for irrigation.

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[15] Ministry for the Environment, 2008. Proposed National Environmental Standard on Ecological Flows and Water Levels. https://www.mfe.govt.nz/publications/fresh-water/draft-guidelines-selection-methods-determine-ecological-flows-and-water-24

[16] Beca. 2008. Draft Guidelines for the Selection of Methods to Determine Ecological Flows and Water Levels. Report prepared by Beca Infrastructure Ltd for MfE. Wellington: Ministry for the Environment.

[17] Ministry for the Environment. 2015. A Guide to Freshwater Accounting under the National Policy Statement for Freshwater Management 2014. Wellington: Ministry for the Environment.

b. The Exiting Flow Regime - Based on the current level of taking water (785 l/s) from the Luggate Creek catchment under existing intake and irrigation infrastructure, whereby none of the existing water takes within primary allocation are subject to a minimum flow restriction.

c. The Future Flow Regime (based on proposed consent allocations) - Based on a total primary allocation water take of 538 l/s with a minimum flow of 180 l/s. A supplementary take of 250 l/s from the 1st Supplementary Block with a supplementary minimum flow of 788 l/s and a supplementary take of 166 l/s from the 2nd Supplementary Block with a supplementary minimum flow of 1038 l/s.

Luggate Creek Water Quality and Ecological Health

Water Quality

13. In recent years actual standards for comparison with stream water quality have been introduced through the Regional Plan: Water and the NPSFM, these are discussed below.

Water Quality – Otago Schedule 15 Limits.

14. Luggate Creek water quality has been classed as excellent by the ORC. Table 1 provides the nutrient and bacteria levels recorded compared to the Schedule 15 the Regional Plan: Water in the latest State of the Environment Report produced by ORC[18].

Table 1. 80th percentile values for water quality variables identified in Schedule 15. Values are calculated from samples taken when flows are below median flow. The orange cells show where the 80th percentile exceeds the Schedule 15 limit.

	NNN	NH_4	DRP	*E.coli*	Turbidity
Schedule 15 limit when flows < median flow	0.075 mg/L	0.100 mg/L	0.010 mg/L	260 CFU Per 100ml	5.0 NTU
Luggate Creek at SH6	0.003	0.009	0.015	228	1.32

[18] Table 45 on page 90 of State of the Environment Surface Water Quality in Otago 2006 to 2017. ORC report available at www.orc.govt.nz/media/6957/final_orc_soe_report_2006_to_2017.pdf

Water Quality – 2014 NPSFM (amended 2017) using the NOF.

15. Under the National Policy Statement for Freshwater Management (NPSFM) levels for nitrate and ammonia toxicity have been set along with *E.coli* levels for swimmability. Under the NPSFM Luggate Creek is classified in the A Band for nitrate and ammonia toxicity and swimmability[19].

Biological Monitoring

16. Biological monitoring is often used to assess whether the outcome expected by managing water quality parameters is being achieved. In Otago macroinvertebrate and fish monitoring is completed at regular intervals through ORC's State of the Environment (SoE) monitoring program, below is a brief summary of what this data shows[20].

Macroinvertebrates

17. Macroinvertebrate Community Index (MCI) scores provide an integrated indicator of the general state of water quality and aquatic ecosystem health at a site. Based on 8 years of data (2008-17) Luggate creek has recorded an MCI score of between 100 and 110 each year, this score corresponds to a "good" water quality grading and is ranked the 8th best stream in ORC's SoE monitoring network based on median MCI scores[21].

Fish Monitoring

18. ORC has monitored fish at the SH6 Bridge on Luggate Creek regularly since the 2007/08 irrigation season. Since regular SoE fish monitoring began only brown trout have been recorded at the SH 6 site and Luggate Creek has always ranked in the top three sites for numbers of brown trout caught. In the most recent survey results for the 2017/18 season 75 brown trout were recorded, with no native fish being present, this ranked as the second highest number of brown trout caught across Otago[22]. Both the number of trout caught, and the consistently high number of trout indicates that Luggate Creek is a healthy brown trout spawning stream, which appears to be supported by Fish and Game observations[23]. Interestingly, no rainbow trout have been caught during ORC's fish monitoring between 2007/08 and 2017/18 at SH 6.

[19] Tables 46, 47 and 48 of State of the Environment Surface Water Quality in Otago 2006 to 2017. ORC report available at www.orc.govt.nz/media/6957/final_orc_soe_report_2006_to_2017.pdf

[20] Algal monitoring is also done but was considered not to be sufficient for conclusion of stream health to be made. Page 174 of State of the Environment Surface Water Quality in Otago 2006 to 2017. ORC report available at www.orc.govt.nz/media/6957/final_orc_soe_report_2006_to_2017.pdf

[21] Page 213 of State of the Environment Surface Water Quality in Otago 2006 to 2017. ORC report available at www.orc.govt.nz/media/6957/final_orc_soe_report_2006_to_2017.pdf

[22] 2017-18 Bio monitoring report card available at https://www.orc.govt.nz/media/6296/2017-2018-soe-report-card.pdf.

[23] Van Klink, P. 2017. Luggate Creek Spawning Survey. Fish and Game Otago Council Paper.

19. Historically Koaro have been recorded in low densities at different locations in the catchment, however their lack of abundance has been attributed to the high densities of trout in Luggate Creek, with the expectation that increased flows will result in higher levels of predation by trout on koaro[24].

20. Longfin eels would be expected to naturally occur in Luggate Creek; however, they are currently at very low levels[25] due to the presence of the Roxburgh and Clyde dams effectively preventing both upstream and downstream migration.

21. A population of rainbow trout appears to exist immediately above and below the Criffel Weir, Dr Allibone addresses this in his evidence.

Fish Habitat Modelling

22. Prior the Luggate Creek Management Flow report being prepared in 2006 for the Luggate Creek minimum flow process, NIWA was contracted to provide fish habitat modelling. Earlier habitat modelling (prior to 2006) results were often presented as the "point of inflection" or "sharp decline" or "optimum habitat". This was the case when the Luggate Creek Management Flow report was written.

23. This approach of using break points, particularly the point of sharp decline has had some criticism, including that it can be hard for different practitioners to replicate and that for some species the break point can be higher than the natural flows the stream provides. As a result, more recent fish habitat analysis is presented as a percentage of habitat at natural MALF[26] which allows results to account for the streams hydrology and allows for a yardstick comparison across other rivers.

24. Flows that provide 70% to 90% of habitat at MALF have been highlighted recently by Cawthron Institute as more precautionary than some minimum flows set in New Zealand[27].

25. Recently Dr Ian Jowett was asked to update the earlier NIWA habitat modelling results for Luggate Creek[28] using the percent habitat at MALF approach. His analysis shows that the existing minimum flow of 180 l/s at the SH 6 Bridge provides in excess of 80% habitat for Longfin eel (both larger and smaller than 300mm), ~70% habitat at MALF for koaro and 80% habitat at MALF for juvenile brown trout (<100mm) using habitat curves published in Jowett and Richardson 2008[29]. Dr Jowett's recent report is produced by way of affidavit for this hearing.

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[24] Allibone, R. 2016. Luggate Creek Fish Survey Summary.

[25] Anecdotal observations from landowners suggest a few still occupy Luggate Creek.

[26] Jowett, I.G. and Hayes, J.W. 2004. Review of Methods for Setting Water Quantity Condition in the Environment Southland Draft Regional Water Plan. NIWA Client Report HAM 2004-018. June 2004.

[27] Second paragraph of page 13 in Hayes J, Hay J, Gabrielsson R, Goodwin E, Jellyman P, Booker D, Wilding T, Thompson M 2018. Review of the rationale for assessing fish flow requirements and setting ecological flow and allocation limits for them in New Zealand—with particular reference to trout. Prepared for NIWA, Envirolink, Greater Wellington Regional Council and Hawke's Bay Regional Council. Cawthron Report No. 3040. 150 p.

[28] Jowett, I. 2019. Fish Habitat in Luggate Creek. Client Report IJ1902.

[29] All habitat curves used can be found in; Jowett, I.G.; Richardson, J. (2008). Habitat use by New Zealand fish and habitat suitability models. NIWA Science and Technology Series No. 55.

26. A flow of 500 l/s was identified as providing optimum spawning habitat for brown trout and this is the existing winter minimum flow for Luggate Creek[30].

Hydrological Regime of Luggate Creek

Natural 7-day MALF

27. For the three seasons of record where flows and takes have been measured the natural 7-day MALF is 637 l/s[31] (with 7-day ALF's ranging from 400 to 852 l/s). As part of the plan change process to set the Luggate Creek minimum flow the natural 7-day MALF was calculated by ORC as 550 l/s[32]. For comparison NIWA's shiny model predicts the natural 7-day MALF for Luggate Creek at the SH 6 flow site as 367 l/s. Given the 550 l/s estimate falls within the recorded range of natural 7-day ALF's and the period of record is very short it appears to provide a reasonable estimate of the natural 7-day MALF.

Historic Flows

28. Low flows in Luggate Creek prior to the minimum flow of 180 l/s at the SH 6 Bridge being set could be extremely low. Historic flow gauging's carried out by the ORC at the SH 6 Bridge have recorded flows as low as 16 l/s[33] with numerous gaugings less than 100 l/s prior to the existing minimum flow being set. In part it was these historical low flows that lead to a plan change to determine a more appropriate minimum flow for Luggate Creek in advance of the deemed permit renewal process so that existing users could prepare for a new management regime following consent renewals.

Existing Flow

29. In March 2010 a minimum flow of 180 l/s was set for Luggate Creek at SH 6, however as all the water takes from Luggate Creek are deemed permits it was not anticipated to become fully operative until 2021. In December 2015 a telemetered flow site was installed at SH6 to aid coordinated water management.

30. With both continuous flows and water takes being measured it has made it possible to model natural[34] flows for comparison to observed[35] flows at the SH 6 flow site since February 2016. Figure 1 to Figure 3 below provides comparison of the low flow period over three seasons between natural and observed flows, with the difference between the two lines being the amount of water taken.

[30] Schedule 2A of the Regional Plan: Water.
[31] This hydrological record is very short, the 2015/16 irrigation season 7-day ALF is based on flows measured from February 2016 onwards, so it is assumed lower flows prior to February didn't occur.
[32] Appendix 2 presented in ORC's Management Flows Report for Luggate Creek.
[33] ORC gauging data presented in Table 2.2 of ORC's Management Flows Report for Luggate Creek.
[34] Natural flows assume no taking for irrigation.
[35] Observed flows are those that were recorded after the influence of takes.

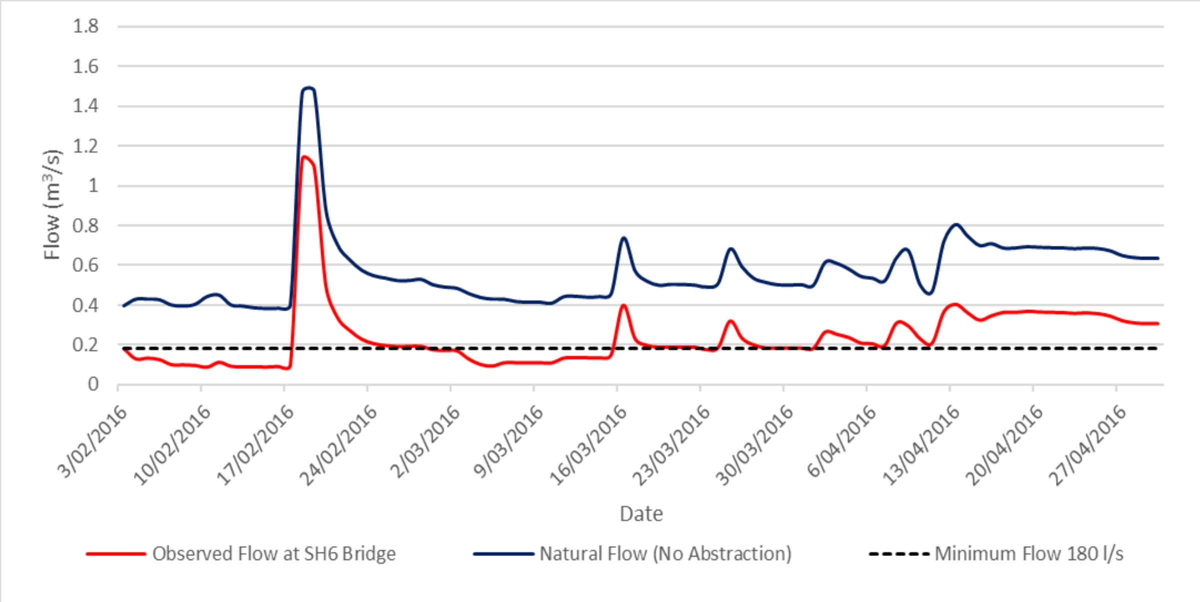

Figure 1. Observed and natural flows at ORC's SH 6 flow site from 03/2/2016 to 30/4/2016.

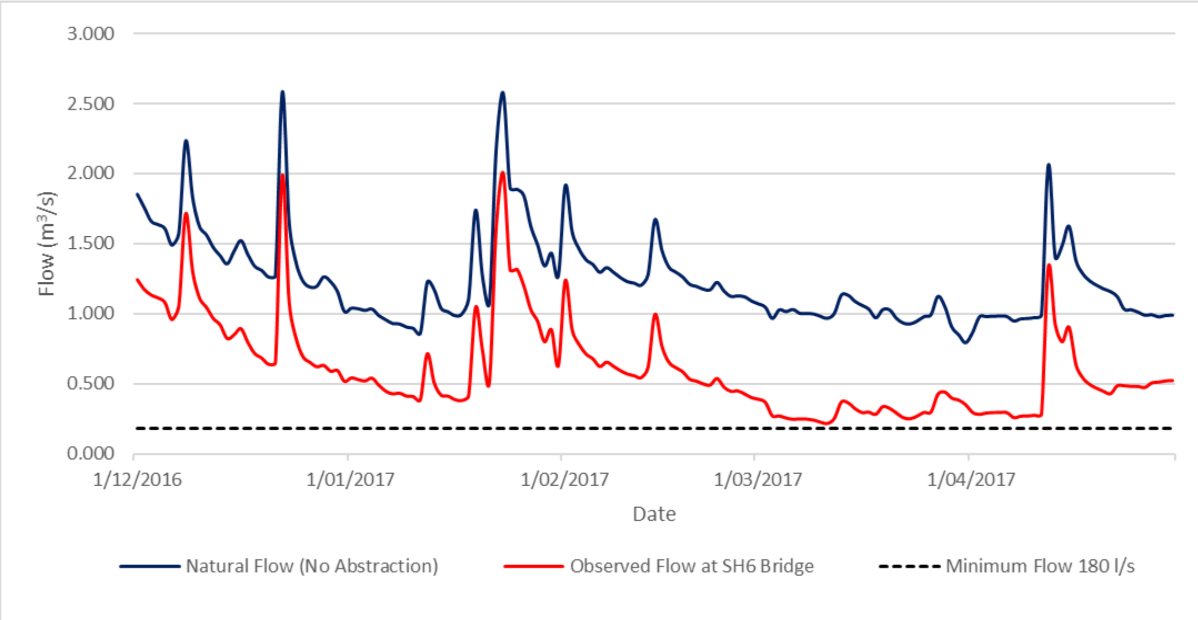

Figure 2. Observed and natural flows at ORC's SH 6 flow site from 01/12/2016 to 30/4/2017.

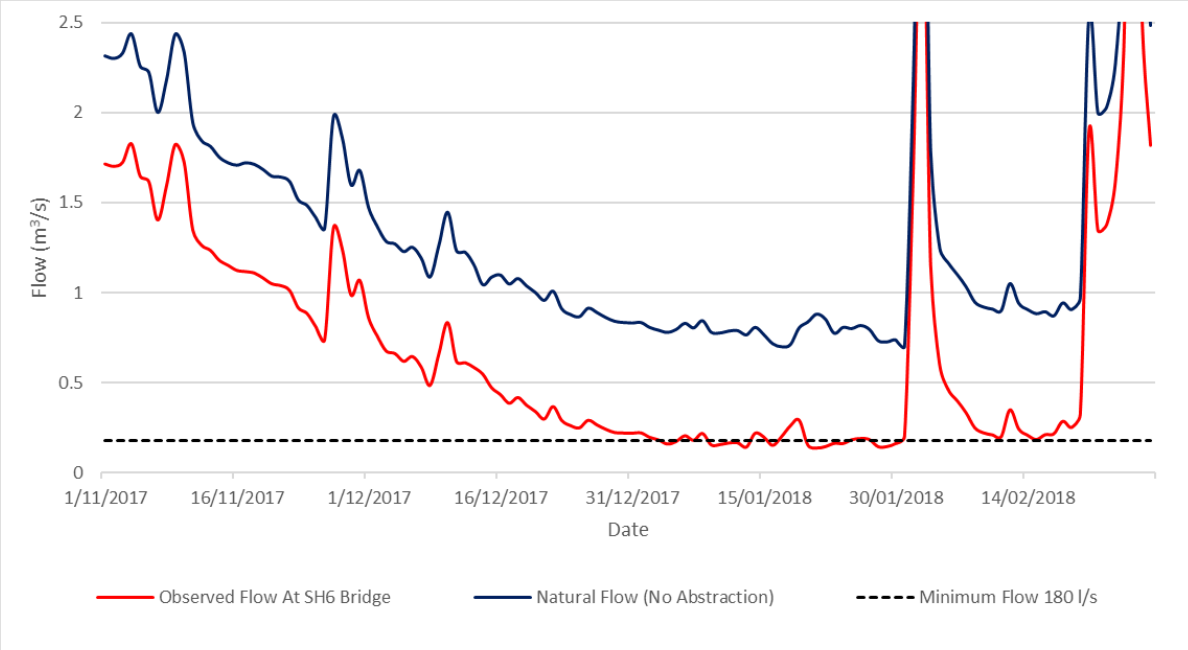

Figure 3. Observed and natural flows at ORC's SH 6 flow site from 01/11/2017 to 28/02/2018.

Future Flows

31. With both Criffel and LIC reducing their consented takes and shifting some water use to supplementary allocation it allows for modelling the flows that would have occurred at the SH 6 flow site since February 2016 had the proposal been in place and adhered to.

32. The following hydrographs model the allocation and minimum flow proposal advanced in para. 11 (c) above.

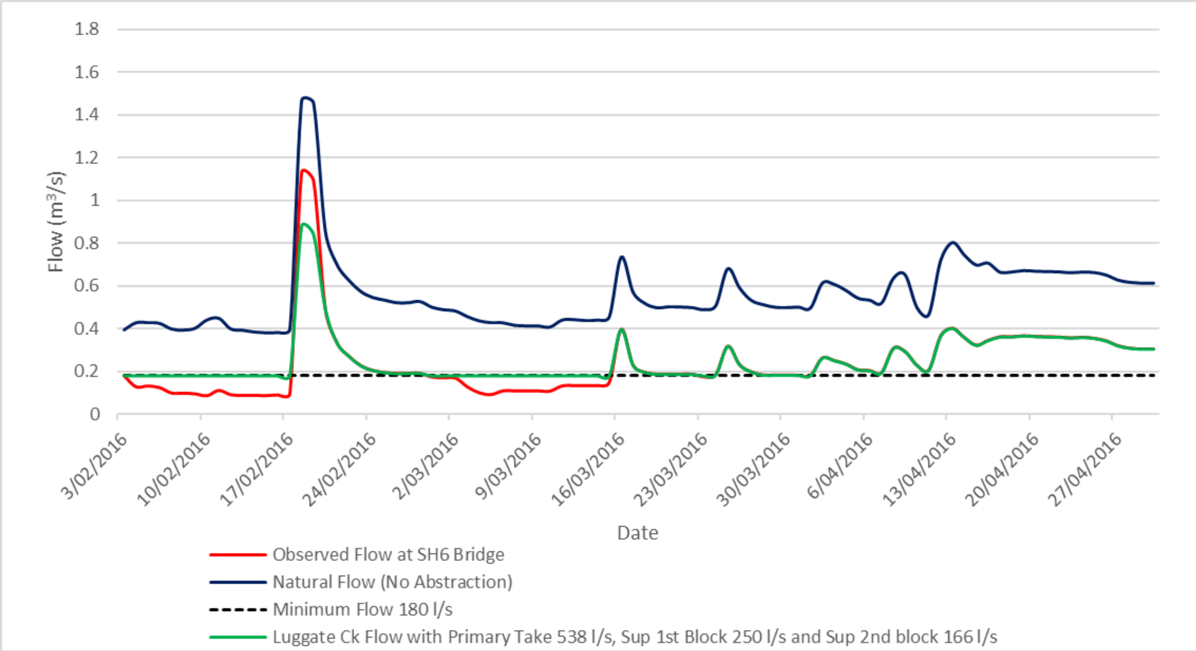

Figure 4. Observed, natural and expected flows based on the Criffel and LIC allocation proposal at ORC's SH 6 flow site from 03/2/2016 to 30/4/2016.

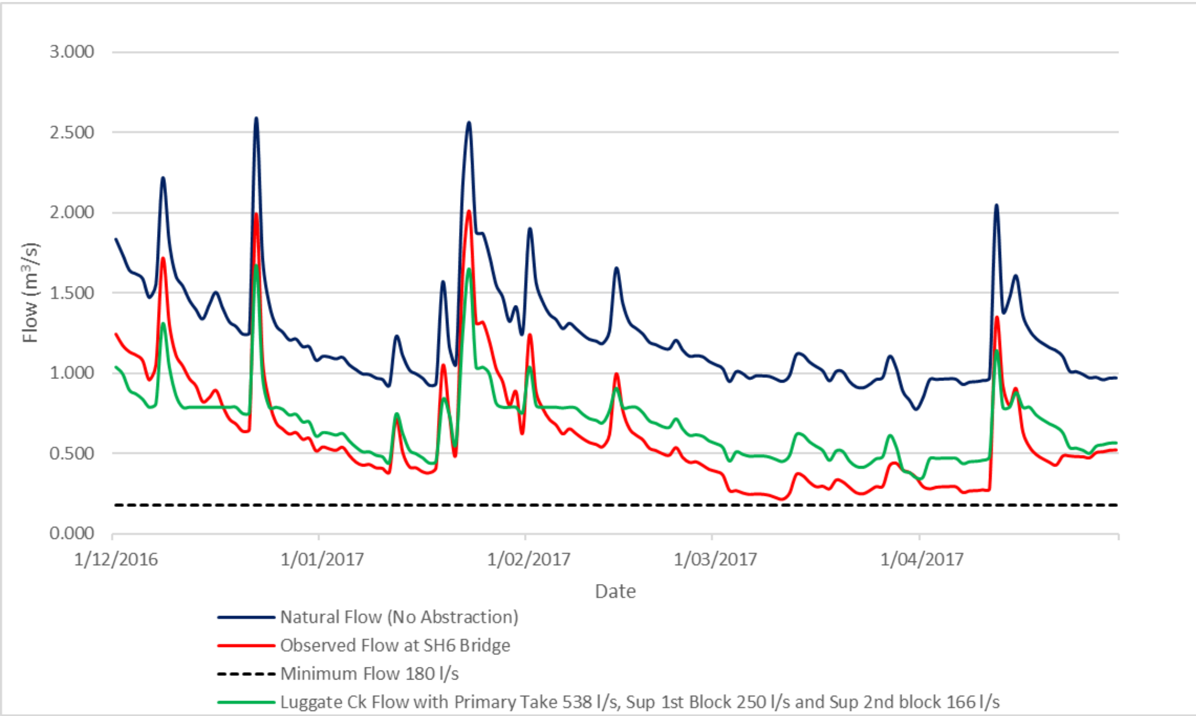

Figure 5. Observed, natural and expected flows based on the Criffel and LIC allocation proposal at ORC's SH 6 flow site from 01/12/2016 to 30/4/2017.

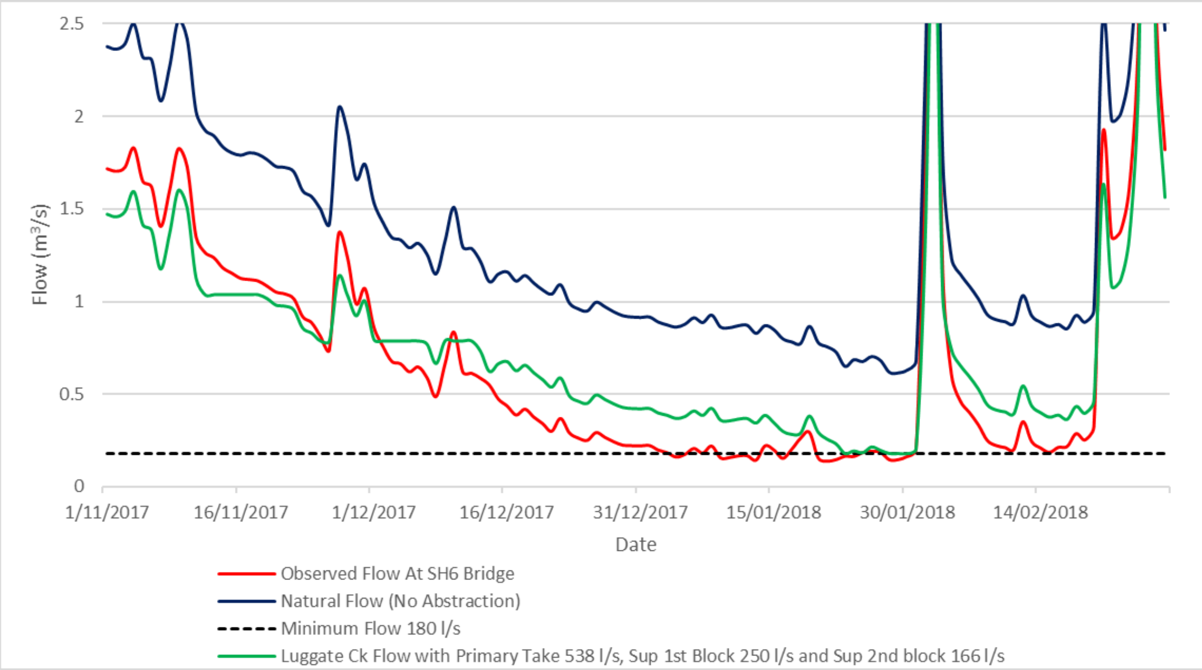

Figure 6. Observed, natural and expected flows based on the Criffel and LIC allocation proposal at ORC's SH 6 flow site from 01/11/2017 to 28/2/2018[36].

33. The hydrographs in Figure 4 to Figure 6 clearly show that the allocation regime put forward by Criffel and LIC significantly reduces time at low flow for two of the three seasons. For the summer of 2016 abstraction caused flows to settle at the minimum flow for up to 15 days consecutively, however abstraction would have also been severely restricted by more than 50% during this period. Recently the 2015/16 irrigation season was ranked as having the second lowest natural 7-day MALF at the nearby Lindis Peak flow site out of 41 seasons, with a return period of a 1 in 10yr low flow[37].

34. For both the 16/17 and 17/18 season the catchment allocation regime either reduces the severity of the low flows (Figure 4) or reduces the duration of time at minimum flow (Figure 6). Table 2 below provides a comparison of flow statistics between natural, observed and those expected under the proposed allocation and minimum flow regime. The 2016/17 irrigation season was ranked with the 13th lowest natural 7-day MALF at the nearby Lindis Peak flow site out of 41 seasons, the 17/18 season was not included in the analayis[37].

[36] Flows to the end of April were not included because flows remained high from the end of February through April due to consistent rainfall.

[37] Lindis Environment Court Hearing Attachment 2 of the hydrology Joint witness statement ranking the different seasons based on severity of low flows.

Table 2. Daily average flow statistics for Luggate Creek at SH6 for February 2016 to April 2018 during the irrigation season (Oct – April).

	Natural Flow (l/s)	Observed Flow (l/s)	Proposed Regime - post consents (l/s)
Minimum	383	86[38]	180
7-day MALF	637[39]	164	261
Median	1,231	613	744
Maximum	5,649	5,014	4,843

35. A flow exceedance curve at SH 6 flow site during the irrigation season for the term of record has been provided below comparing observed flows to what would have occurred based on the proposed catchment allocation regime (Figure 7).

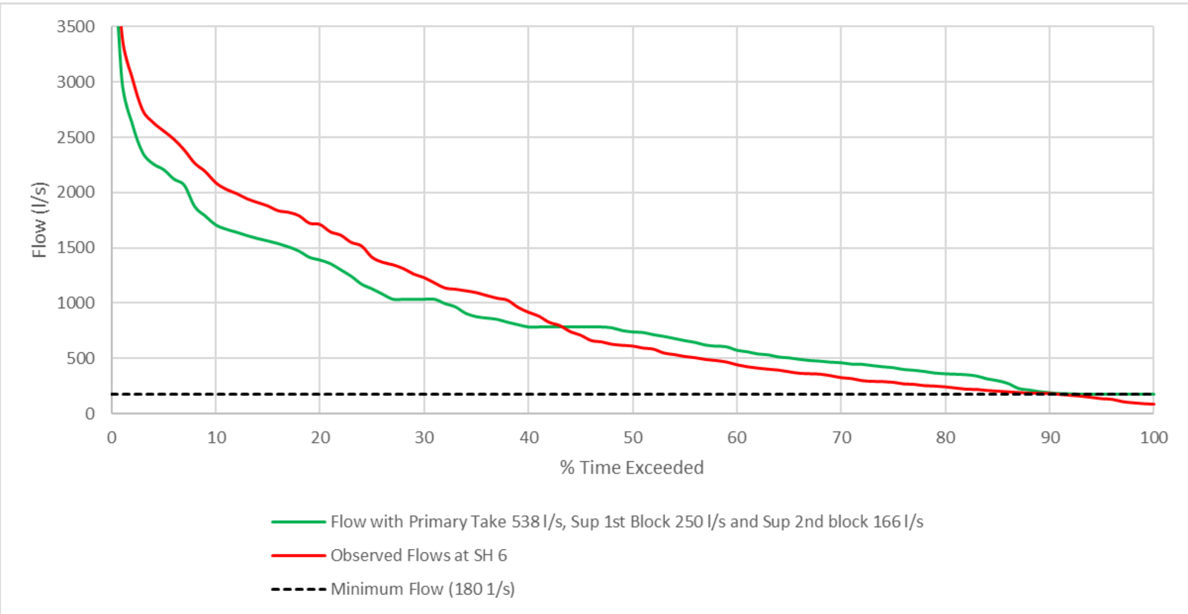

Figure 7. Flow exceedance for Luggate Creek at the SH 6 flow site during the irrigation season (Oct – April) for the period February 2016 – April 2018, based on observed flows and what would have occurred based on the allocation proposal advanced by Criffel and LIC/LM. The black hashed line is the minimum flow of 180 l/s.

[38] Historical gaugings at SH6 by ORC show flows as low as 16 l/s.
[39] 637 l/s is calculated of 2.5 irrigation seasons of data. ORC previously calculated the natural 7-day MALF at 550 l/s.

36. Figure 7 shows that on average flows have been at or less than 180 l/s 10% of the time during the irrigation season, or 21 days per season, while under the consent proposal from Criffel and LIC flows would be at 180 l/s for 6% of the time during the irrigation season, or 13 days per season on average, with no time spent below 180 l/s.

37. Time at minimum flow is considered important when assessing effects with risks of adverse effects increasing with duration of low flows (depending on how low they are of course). Table 3 provides a summary of days at or below the minimum flow at SH6.

Table 3. Number of days at or below 180 l/s at SH6 flow site based on daily average flows statistics for February 2016 to April 2018 during the irrigation season (Oct – April).

Season	Natural Flow days at or below 180 l/s	Observed Flow **days at or below** 180 l/s. Bracketed number is the maximum consecutive days **below** the minimum flow.	Proposed Regime - post consents **days at** 180 l/s. Bracketed number is the maximum consecutive days at the minimum flow.
2015/16	0	32 (16)	33 (15)
2016/17	0	0	0
2017/18	0	16 (6)	3 (3)

38. Understanding the relative take size compared to monthly flows is often useful to get an understanding of the effect of taking over a longer timeframe than instantaneous or daily flows. Figure 8 below provides natural monthly average flows compared to the observed monthly average take and the expected monthly average take proposed by CWL and LIC in their consents for the primary allocation block.

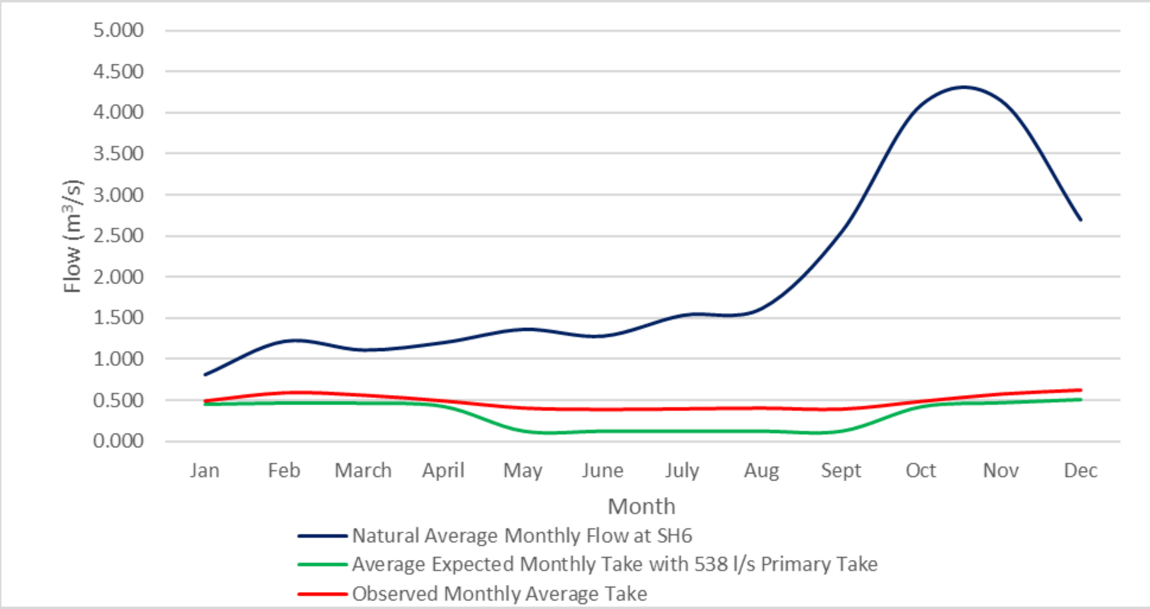

Figure 8. Natural Monthly Average flows compared to Observed average monthly take and Expected monthly average take for the Primary block under the CWL and LIC/LM consents proposal for the period January 2016 to December 2018.

39. Figure 8 clearly shows a reduction in primary allocation monthly average take across all months under the CWL and LIC/LM consent proposal, resulting in a lower proportion of the natural flow being taken as primary allocation compared to what has occurred historically.

Tributary Hydrology

40. Both the Alice Burn and Luggate Creek North Branch drain similar topography, aspect and have similar landcover. The Alice Burn makes up 33% of the catchment area upstream of the SH6 Flow Site while the Luggate Creek North Branch makes up 62% of the that area, leaving 5% of the catchment between the Alice Burn and Luggate Creek North Branch and the SH 6 flow site.

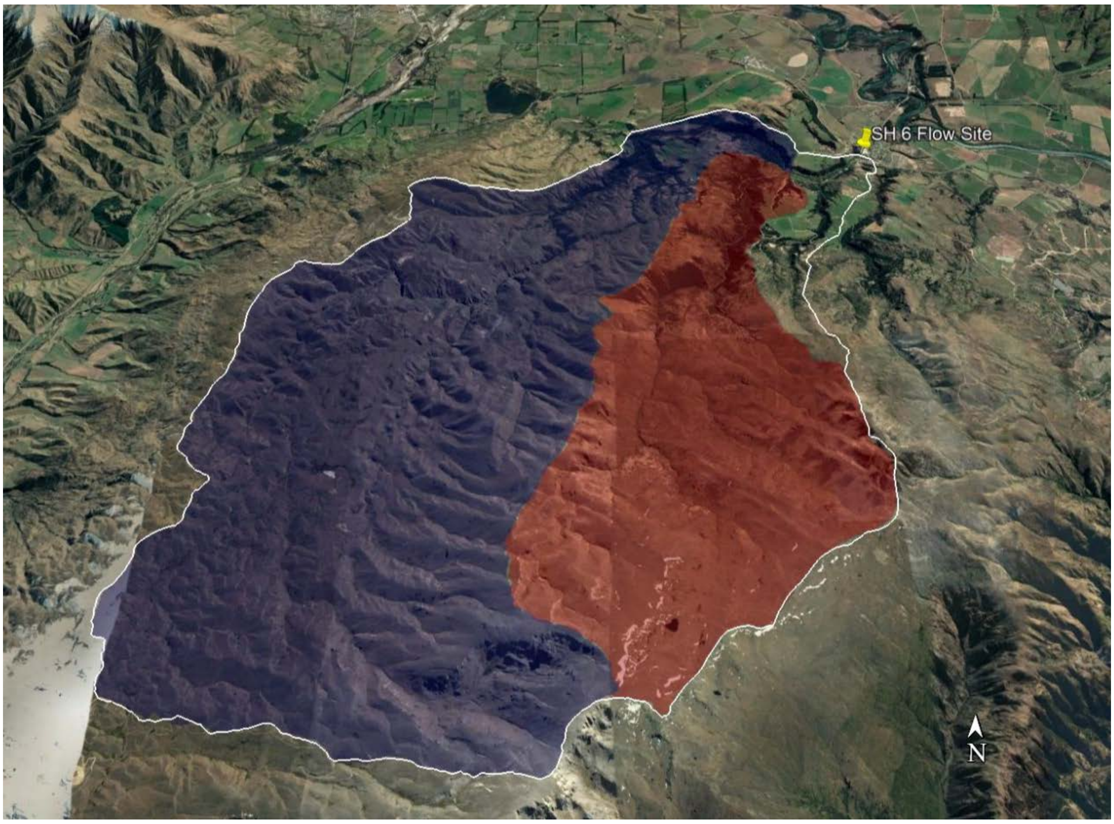

Figure 9. Luggate Creek catchment upstream of the SH6 flow site (white outline), the Luggate Creek North Branch catchment (shaded blue) and the Alice Burn catchment (shaded red).

41. Low flow estimates are provided for both the Alice Burn and Luggate Creek North Branch at their confluence for both observed flows and expected flows under CWL's and LIC/LM's allocation proposal (Table 4 and Table 5). These estimates are based on the following assumptions:

- The specific yield per Km^2 from the Alice Burn and Luggate Creek North branch catchments are the same.
- Flows recorded at SH6 are able to be equally apportioned to catchment area upstream.
- That the balance of water takes are operating proportionately based on the catchment yields.

42. Because of these assumptions the flows provided in Table 4 and Table 5 should be viewed with the following key points in mind.

- Firstly, because the flows assume yields are the same from each square kilometre of catchment. The lower catchment (below the confluence) is assumed to yield the same as the headwaters, this is unlikely, thus in reality flows will be proportionally higher upstream with smaller gains lower down the catchment.

- Secondly, because the takes do not necessarily operate proportionately to the yield from their respective catchments minimum observed flows could potentially be less than outlined in Table 4 and Table 5 at times.

Table 4. Modelled low flows expected to have occurred (observed) compared to those that would have been expected below the Criffel Weir based on the Criffel and LIC allocation proposal (expected).

Irrigation Season	Observed Min (l/s)	Expected Min (l/s)	Observed 7-day MALF (l/s)	Expected 7-day MALF (l/s)
2015/16	53	112	57	112
2016/17	132	216	147	255
2017/18	86	112	101	118
Average	90	146	101	162

Table 5. Modelled low flows expected to have occurred (observed) compared to those that would have been expected at the Alice Burn confluence based on the Criffel and LIC allocation proposal.

Irrigation Season	Observed Min (l/s)	Expected Min (l/s)	Observed 7-day MALF (l/s)	Expected 7-day MALF (l/s)
2015/16	28	59	30	59
2016/17	70	115	78	136
2017/18	46	59	54	63
Average	48	78	54	86

43. As outlined in Para. 41 it would be reasonable to expect that under stable natural low flow conditions that the Alice Burn would contribute ~33% of the flow recorded at the SH 6 flow site and the North Branch of Luggate Creek would contribute ~66% of the recorded flow.

44. Based on flow contributions required from upstream to deliver the minimum flow SH 6 and the levels of taking from each of the two main branches of Luggate Creek I would expect to meet the minimum flow of 180 l/s the majority of flow recorded would need to come from the North Branch.

Luggate Creek Primary Allocation and Efficient Use

45. The amount of water taken from a river does four key things: increases the likelihood of reaching a minimum flow; increases the duration of a river being held at or about the minimum flow; reduces flow variability; and increases the time water users ration water.

46. Policy 6.4.2 specifically defines the primary allocation limit as the greater of three possible amounts. In simplistic terms, the three possible numbers are:

1. An amount specified in Schedule 2A for that catchment as the primary allocation limit;

2. where there is no number specified in Schedule 2A, 50% of the 7-day mean annual low flow (often referred to as the 'default limit')

3. The sum of consented maximum instantaneous rates of take of all permits that were originally granted before set cut off dates - this includes all deemed permits. (I refer to this as the consented sum).

47. Where the consented sum exceeds the Schedule 2A or default amount then Policy 6.4.2 identifies the catchment as "fully allocated". It does not define these catchments as over-allocated as ORC has done in its S42a report.

48. The consented sum that can be taken as primary allocation from the Luggate Creek catchment is currently 1,024 l/s[40], this is the primary allocation limits for Luggate Creek as it is greater than the 500 l/s Schedule 2A limit.

Because the primary allocation limit or consented sum of 1024 l/s exceeds the Schedule 2A limits of 500 l/s a second tranche of policies known as the sinking lid policies are triggered aimed at eliminating allocation that:

a) has not been used (history of use – Policy 6.4.2A and Policy 6.4.18)

b) is not required (purpose of use – Policy 6.4.0A)

c) is not used efficiently (Policy 6.4.0A)

d) is only taken at high flows (Policy 6.4.2AA) or

e) is not renewed in time or at all (refer to Policy 6.4.2(b)(ii)(4)&(6))

49. ORC appear to have applied policies 6.4.2A and 6.4.0A (via a percentile approach) to arrive at a primary allocation limit of 754 l/s[41]. In my view the percentile approach to Policy 6.4.0A is not an efficiency test.

50. My approach to the sinking lid policies was to apply Policy 6.4.2A and assess the sum of the maximum recorded rates of take as primary allocation from the catchment. This meant the consented rate of 1,024 l/s, can be reduced to 785 l/s[42]. This means there is 265 l/s of 'paper water' in the Luggate Creek Catchment. Paper water is consented water that is not actually taken and is common in catchments dominated by deemed permits.

[40] S42a Report from ORC
[41] 559 l/s CWL + 195 LIC/LM
[42] 590 l/s CWL + 195 LIC/LM

51. I then applied Policy 6.4.0A to determine an efficient amount of water required for the purpose. This was done by engaging Mr Roger Simpson from Irritech Ltd to assess actual water requirements to spray irrigate existing irrigation areas and I worked on the reliability of supply needed to effectively operate the existing spray infrastructure. From this work we were able to further reduce instantaneous take from 785 l/s to 538[43] l/s for the catchment.

52. The greatest reduction was from CWL who have reduced their actual take from 590 l/s to 358 l/s. My understanding is that historically CWL have taken 590 l/s and used it within the scheme and that 358 l/s is used to irrigate 619 Ha of spray irrigation with the difference between 358 and 590 l/s used to contour flood with some attributed to loses. This approach has meant that CWL in particular would be forgoing water that has been used to irrigate.

53. The next step is to determine if the existing spray infrastructure can run on the proposed take rate, in this case it can. In many cases the rate of take is geared specifically to a pump capacity which can't be altered without significant changes to the pump and the infrastructure it drives.

54. In the case of the Luggate catchment we found that the existing spray infrastructure in place with CWL and LIC/LM has essentially fully utilised the water over and above the minimum flow that I would consider of adequate reliability to spray irrigate.

55. In discussion with CWL and LIC/LM we explained that the rate at which water is taken has the greatest effect on instream ecology, thus any long-term reductions in take rate would benefit ecological values in Luggate Creek.

56. Further to this a reduction in total rate of take along with upgrades in conveyance efficiency increases reliability of supply for the spray infrastructure.

57. The downside to this approach is that total command area reduces, reducing production and more significantly there is a cost component of upgrading conveyance infrastructure to irrigate the same area – there are no production gains with expanded irrigation area.

58. From here although CWL's and LIC/LM's actual use records allowed them to apply for at 785 l/s, in terms of outcomes for Luggate Creek it was agreed to reduce the take further to 538 l/s with the understanding that there would need to be significant conveyance upgrades over time at significant cost.

59. On top of the conveyance cost it was anticipated there would be the need to build some storage, hence the application to take 250 l/s of Supplementary from block 1 and 166 l/s from block 2 by CWL and LIC/LM. Essentially the supplementary take with storage would replace the existing contour flood and border dyke areas for CWL and LIC and allow some expansion by all three parties using efficient infrastructure.

60. As it stands the Luggate Creek water users' proposal reduces the maximum primary allocation rate that can be taken from the Luggate Creek catchment from 785 l/s to 538 l/s. While also reducing the maximum annual volume taken by Luggate Creek water users as primary allocation from 11 Mm^3/yr to 7 Mm^3/yr.

[43] 358 l/s CWL + 180 l/s LIC/LM

61. In the case of Luggate Creek by implementing the sinking lid policy suite – it means that an applicant cannot be allocated more water than they have historically used efficiently and that any reductions in take by one party can't be realised by another thus preventing further over allocation in the catchment. It is not until allocation falls below the Schedule 2A value that ORC can allocate any new primary water take consents in the catchment.

62. The existing catchment primary take of 785 l/s from the Luggate Creek with a minimum flow of 180 l/s means overall the primary block has reliability of supply of 68% during the irrigation season. With the reduction in primary take proposed by Criffel and LIC/LM to 538 l/s this lifts the reliability of supply for that reduced rate to 83%, a reliability of supply I consider sufficient to run spry irrigation system such as k-line.

63. The Luggate Creek water users proposal will reduce actual water taken as primary allocation from the catchment by ~30% and consented abstraction by ~50%. It is anticipated that this reduction will

a. Reduce the duration of time spent at minimum flow.

b. Provides reliability of supply levels that maintain the investment in efficient irrigation infrastructure (spray).

c. Reduces the need for long periods of rostering, Figure 6 illustrates this point.

d. Incentivise the investment over time in infrastructure upgrades and storage

Supplementary Allocation

64. Supplementary allocation is provided on a 50:50 flow sharing principle between the river and the users. Supplementary allocation is allocated in blocks based on the size of the river[44]. For Luggate Creek the recommended Supplementary Block is 250 l/s[44].

65. By applying the supplementary minimum flow formula[45] of Supplementary minimum flow = Primary allocation + Supplementary allocation(s) the supplementary minimum flow for the first block would be 788 l/s[46] and the second block minimum flow 1038 l/s (788 l/s + 250 l/s).

66. The Supplementary minimum flow is measured below all takes at the SH6 Flow site, it means that if the observed flow is 788 l/s and the primary take if being taken (538 l/s) and the first supplementary block (250 l/s) is also being taken the natural flow at SH 6 would be 1576 l/s (788 l/s is 50% of 1576 l/s). The Supplementary allocation approach ensure at least 50% of the natural flow remains instream.

44 15.8.1A Methodology for determining supplementary allocation – Regional Plan Water.
45 15.8.1A.2 Methodology for determining supplementary minimum flow – Regional Plan Water.
46 354 l/s actual efficient use for Criffel + 180 l/s actual use for LIC/Lake McKay + 250 l/s supplementary allocation = 788 l/s

67. In some cases, supplementary takes can be used without the need for storage depending on the crop the water is irrigating. In Central Otago it is common for less reliable water to be used early in the season to irrigate Lucerne until December. The first supplementary block from Luggate Creek with a minimum flow of 788 l/s would provide access to water up until December in most seasons and till Christmas in some. Therefore, using the first supplementary block without the need for storage is feasible. To access the second block of supplementary with a minimum flow of 1038 l/s however in my view would require storage.

Aqualinc Assessment

68. As part of the application Aqualinc was used to determine the appropriate monthly and seasonal volumes for water based on the areas proposed to be irrigated. In order to get the appropriate PAW values for the irrigated area I relied on ORC's water information website[47]. The water information website provides GIS layers of both mean annual rainfall (MAR) and Plant Available Water (PAW) values that are then used to determine appropriate PAW and monthly and seasonal allocation volumes using Aqualinc[48]. The water information PAW layer provides ranges that do not match exactly with the PAW values in the Aqualinc report. For example, the water information website breaks soils into the following water holding capacity categories with the associated PAW range:

- Very high (PAW 250 - 350)
- High (PAW 150 – 250)
- Moderately high (PAW 90 - 150)
- Moderate (PAW 60 – 90)
- Low (PAW 30 - 60)
- Very Low (PAW <30)

69. While the Aqualinc Report[49] uses Single PAW categories as follows:

- 40
- 60
- 90
- 120
- 150

70. Below when determining the irrigation area water requirements I list the water information website PAW range for the soils irrigated and then also provide the Aqualinc PAW value and MAR value used to determine the water requirements so that it can be easily followed for how I arrived at the recommended numbers.

71. Seasonal maximum volumes from Aqualinc have been used after considering the following factors:

[47] https://www.arcgis.com/apps/webappviewer/index.html?id=1254b99969b24b848ea236f6aa35b144

[48] McIndoe I, Brown P, Rajanayaka C, KC. B, 2017. Guidelines for Reasonable Irrigation Water Requirements in the Otago Region. Otago Regional Council, 2. Aqualinc Research Limited.

[49] For example, Table 5 of McIndoe I, Brown P, Rajanayaka C, KC. B, 2017. Guidelines for Reasonable Irrigation Water Requirements in the Otago Region. Otago Regional Council, 2. Aqualinc Research Limited.

- The application methods are efficient spray irrigation.
- All the applicants (CWL, LIC/LM) have actively reduced their instantaneous rates of take, this increases reliability of supply in drier seasons.
- All the applicants (CWL, LIC/LM) are considering incorporating storage into their systems in the future. Storage allows water users to plan for providing water in dry seasons.
- It is the rate of take that has the greatest potential effect on instream values, not volume. Rate of take has been significantly reduced.
- Minimum and residual flows are in place to protect ecological effects on Luggate Creek and its tributaries, meaning that in principle if the water is needed in a dry season, will be applied efficiently and is available while meeting these flow conditions then why would the volume be restricted?

Criffel Water Aqualinc Requirements

72. Table 6 below details how the Aqualinc monthly and seasonal volumes were arrived at for both the existing and future irrigation areas applied for by CWL.

Table 6. existing spray and future irrigation area's with required monthly and seasonal volumes based on maximum Aqualinc requirements[50].

CWL Existing Spray Irrigation Water Requirements									
Land use	**MAR Rainfall Central Lakes District**	**Landcare Soil Layer PAW**	**Aqualinc PAW**	**PAW Area as a % of Irrigation Area**	**Area (Ha)**	**Aqualinc Monthly Volume (m^3/Ha)**	**Aqualinc Max Monthly Need for area (m^3)**	**Aqualinc MAX Annual Volume (m^3/Ha)**	**Aqualinc MAX Annual Need for area (m^3)**
Pasture	650	30-60	60	10	61.9	1460	90374	7850	485,915
Pasture	650	60-90	90	50	309.5	1460	451870	7710	2,386,245
Pasture	650	90-150	120	40	247.6	1300	321880	7140	1,767,864
Existing Total					**619**		**864,124**		**4,640,024**
CWL Future Irrigation Water Requirements									
Land use	**MAR Rainfall Central Lakes District**	**Landcare Soil Layer PAW**	**Aqualinc PAW**	**PAW Area as a % of Irrigation Area**	**Area (Ha)**	**Aqualinc Monthly Volume (m^3/Ha)**	**Aqualinc Max Monthly Need for area (m^3)**	**Aqualinc MAX Annual Volume (m^3/Ha)**	**Aqualinc MAX Annual Need for area (m^3)**
Pasture	650	30-60	60	10	40			7850	314,000
Pasture	650	60-90	90	40	160	1460	233600	7710	1,233,600
Pasture	650	90-150	120	50	200	1300	260000	7140	1,428,000
Future Total					**400**		**493,600**		**2,661,600**
Combined Total					**1019**		**1,357,724**		**7,301,624**

Lake McKay Aqualinc Requirements

73. Table 7 below details how the Aqualinc monthly and seasonal volumes were arrived at for both the existing and future irrigation areas applied for by LM.

[50] Taken from Table 5 of McIndoe I, Brown P, Rajanayaka C, KC. B, 2017. Guidelines for Reasonable Irrigation Water Requirements in the Otago Region. Otago Regional Council, 2. Aqualinc Research Limited.

Table 7. LM existing spray and future irrigation area's with required monthly and seasonal volumes based on maximum Aqualinc requirements[51].

Land use	MAR Rainfall Central Lakes District	Landcare Soil Layer PAW	Aqualinc PAW	Area (Ha)	Aqualinc Monthly Volume (m^3/Ha)	Max Monthly Need for area (m^3)	Aqualinc MAX Annual Volume (m^3/Ha)	MAX Annual Need for area (m^3)
Lake McKay Stage 1 Existing Spray Irrigation Water Requirements								
Pasture	650	<30	40	85	1670	141950	8210	697850
Lake McKay Stage 2 Existing Spray Irrigation Water Requirements								
Pasture	650	<30	40	41	1670	68470	8210	336,610
Pasture	550	60-90	90	21	1460	30660	8180	171,780
Pasture	550	<30	40	21	1710	35910	8750	183,750
Existing Total				168		276,990		1,389,990
Lake McKay Stage 3 Future Irrigation Water Requirements								
Land use	**MAR Rainfall Central Lakes District**	**Landcare Soil Layer PAW**	**Aqualinc PAW**	**Area (Ha)**	**Aqualinc Monthly Volume (m^3/Ha)**	**Max Monthly Need for area (m^3)**	**Aqualinc MAX Annual Volume (m^3/Ha)**	**MAX Annual Need for area (m^3)**
Pasture	550	<30	40	80	1710	136800	8750	700,000
Lake McKay Stage 3 extension Future Irrigation Water Requirements								
Land use	**MAR Rainfall Central Lakes District**	**Landcare Soil Layer PAW**	**Aqualinc PAW**	**Area (Ha)**	**Aqualinc Monthly Volume (m^3/Ha)**	**Max Monthly Need for area (m^3)**	**Aqualinc MAX Annual Volume (m^3/Ha)**	**MAX Annual Need for area (m^3)**
Pasture	550	<30	40	30	1710	51300	8750	262,500
Future Total				110		188,100		962,500
Combined Total				**278**		**465,090**		**2,352,490**

[51] Taken from Table 5 of McIndoe I, Brown P, Rajanayaka C, KC. B, 2017. Guidelines for Reasonable Irrigation Water Requirements in the Otago Region. Otago Regional Council, 2. Aqualinc Research Limited.

Luggate Irrigation Company Aqualinc Requirements

74. Table 8 below details how the Aqualinc monthly and seasonal volumes were arrived at for both the existing and future irrigation areas applied for by LIC.

Table 8. LIC existing spray and future irrigation area's with required monthly and seasonal volumes based on maximum Aqualinc requirements[52].

LIC Existing Spray Irrigation Water Requirements (Big River and Umbers)									
Land use	**MAR Rainfall Central Lakes District**	**Landcare Soil Layer PAW**	**Aqualinc PAW**	**MAR Area as a % of Irrigation Area**	**Area (Ha)**	**Aqualinc Monthly Volume (m^3/Ha)**	**Max Monthly Need for area (m^3)**	**Aqualinc MAX Annual Volume (m^3/Ha)**	**Aqualinc MAX Annual Need for area (m^3)**
Pasture	650	60-90	90	85	97.5	1460	142350	7710	751,725
Pasture	550	60-90	90	15	32.5	1460	47450	8180	265,850
Existing Total					130		189,800		1,017,575
LIC Future Irrigation Water Requirements (Home Block)									
Land use	**MAR Rainfall Central Lakes District**	**Landcare Soil Layer PAW**	**Aqualinc PAW**	**MAR Area as a % of Irrigation Area**	**Area (Ha)**	**Aqualinc Monthly Volume (m^3/Ha)**	**Max Monthly Need for area (m^3)**	**Aqualinc MAX Annual Volume (m^3/Ha)**	**Aqualinc MAX Annual Need for area (m^3)**
Pasture	550	60-90	90	100	85	1460	124100	8180	695,300
LIC Future Irrigation Water Requirements (Umbers Block)									
Land use	**MAR Rainfall Central Lakes District**	**Landcare Soil Layer PAW**	**Aqualinc PAW**	**MAR Area as a % of Irrigation Area**	**Area (Ha)**	**Aqualinc Monthly Volume (m^3/Ha)**	**Max Monthly Need for area (m^3)**	**Aqualinc MAX Annual Volume (m^3/Ha)**	**Aqualinc MAX Annual Need for area (m^3)**
Pasture	650	<30	40	100	78	1670	130260	8210	640,380
Future Total					**163**		**254,360**		**1,335,680**
Combined Total					**293**		**444,160**		**2,353,255**

[52] Taken from Table 5 of McIndoe I, Brown P, Rajanayaka C, KC. B, 2017. Guidelines for Reasonable Irrigation Water Requirements in the Otago Region. Otago Regional Council, 2. Aqualinc Research Limited.

Water Sharing Between Users at times of low flow

75. Under the Regional Plan: Water for Otago an individual can take water under a permit as long as their take specific residual flow requirement is being met in conjunction with the relevant catchment minimum flow. Essentially, there is no obligation for a user to let more water go for sharing purposes. In over-allocated catchments ORC has promoted that individual consent holders work together in groups to develop sharing regimes which allow water users to share water at low flows, while providing for instream values, maintaining good access to water across users and reducing conflicts amongst users.

76. Working as a group allows a more innovative approach to managing the effects of takes and conflicts between users than just relying on a minimum flow. I was heavily involved in the development of Plan Change 1C (Water Allocation and Use) to the Regional Plan: Water for Otago in my role Manager of Resource Science at the ORC, and in my opinion, the recognition of these benefits underpinned that plan change (which became operative in 2012) in preparation for the transition from deemed permits.

77. It is expected that working as a group provides the opportunity for a catchment-based approach that:

- Ensures the minimum flow is maintained.
- Makes best use of the water resource.
- Can take advantage of specific hydrology to mitigate the effects of taking.
- Can use sharing and subsequent conveyance to downstream users to mitigate the effects of taking.
- Provides flexibility between users for better water management during times of water shortage.
- Can reduce the length of river affected by low flows.

78. My preference is that that conditions of a flow sharing agreement (triggers, cuts etc) are not stipulated rigidly as consent conditions. I believe that as much flexibility as possible should be maintained to allow adaptive decisions to be made depending on the circumstances of a particular season (flow, demand, forecast etc).

79. Sharing regimes are self-policing as if one party is getting more than they should at the expense of another it will be dealt with quickly by the water users, usually without the need for council to intervene or even know about it. Ultimately the key controls for council are whether any relevant residual and minimum flows are being met.

Criffel Take Residual Flow

80. Criffel Water is a proposing a residual flow of 90 l/s at their point of take on the North Branch of Luggate Creek. Hydrological analysis suggests that in order to meet the minimum flow of 180 l/s at SH6 a flow of at least 112 l/s would pass the intake at all times (Table 4). Given the catchment upstream of the intake is

likely to yield significantly more flow than the downstream it is expected that flows more like 120 l/s to 140 l/s would be pass the intake to deliver a minimum flow of 180 l/s at SH 6.

81. Electric fishing surveys recently conducted both above and below the Criffel intake found only rainbow trout[53]. Historically some large individual koaro have been found immediately below the weir[54]. Dr Allibone discusses fish values in the Luggate Creek North Branch in depth in his evidence.

82. Recent fish habitat analysis in the reach below the Criffel Weir by Dr Ian Jowett[55] found that flows of 120 l/s in this reach would provide optimum rainbow trout habitat and a flow of 90 l/s provides more than 90% habitat at MALF.

83. Hydrological analysis in Para. 36 shows that on average Luggate Creek will be at minimum flow 6% of the time, this would correspond with a flow of ~120 l/s below the Criffel Weir in my opinion.

84. For the following reasons a residual flow of 90 l/s are likely to provide for the ecological values in the North Branch of Luggate Creek below the Criffel take:

   a. trout are likely limiting the Luggate Creek koaro population, not habitat[56].

   b. In the most recent fish survey below the Criffel Weir only rainbow trout were caught[57].

   c. A flow of 90 l/s provides more than 90% habitat at MALF for rainbow trout[58].

   d. The SH 6 minimum flow will likely maintain flows of ~120 l/s below the weir.

   e. Flows of ~120 l/s will only occur 6% of the time during the irrigation season on average.

   f. Historically flows have been less than 100 l/s below the weir and the rainbow trout population has been maintained.

Luggate Irrigation Company Alice Burn and North Branch Residual Flows

85. Luggate Irrigation Company are proposing residual flows that provides "*visual surface flow*" at their points of take from the lower Alice Burn and lower North Branch. Hydrological analysis suggests that in order to meet the minimum flow of 180 l/s at SH6 a flow of ~60l/s would pass the Alice Burn intake and ~120 l/s would pass the north Branch intake at all times assuming the flow at SH6 was proportional to the catchment areas upstream.

[53] Evidence of Dr Allibone.
[54] I captured several large koaro when electric fishing at the foot of the Criffel Weir in 2004.
[55] Jowett, I.G. Fish Habitat of Luggate Creek. 2019. Client Report: IJ1902.
[56] Evidence of Dr Allibone.
[57] Evidence of Dr Allibone.
[58] Jowett, I.G. Fish Habitat of Luggate Creek. 2019. Client Report: IJ1902.

86. Electric fishing surveys[59] and observations by Fish and Game Otago[60] indicate high numbers of juvenile brown trout present in the lower Luggate Creek upstream of SH6 Bridge and the lower reaches of the Alice Burn.

87. Hydrological analysis in Para. 36 shows that on average Luggate Creek will be at minimum flow 6% of the time, this would correspond with a flow of ~60 l/s at the Alice Burn confluence (less any water needed to pass the fish screen to allow it to operate effectively) with Luggate Creek in my opinion. Flows of less than 60 l/s would be short duration and infrequent with the need to deliver 180 l/s at the SH 6 recorder.

88. The proposed residual flow will only apply to ~400m of the Alice Burn between the intake and the Alice Burn's confluence with Luggate Creek.

89. It is my expectation that to maintain flows of at least 180 l/s at the SH6 flow site the majority of flow would need to be coming from the North Branch of Luggate Creek. To provide certainty on this I would suggest the following residual flow condition for the LIC intakes:

    a) "LIC must manage their combined take from the Alice Burn and North Branch of Luggate Creek to ensure that a visual flow is maintained at all times below the Alice Burn intake and that the majority of flow at the confluence is from the North Branch".

90. For the following reasons a residual flow that maintains visual surface flows between the intake and the Luggate Creek confluence is likely to provide for the ecological values in the Alice Burn below the LIC take:

    a. It is only a 400m length of stream the residual flow applies to.

    b. The SH 6 minimum flow will likely maintain flows of ~60 l/s below the LIC intake.

    c. Flows of ~60 l/s will only occur 6% of the time during the irrigation season on average.

    d. Juvenile trout are very adept at migrating out of reaches that may become constrained for habitat or food, there is likely to be good juvenile trout habitat both immediately above the LIC intake and below the Alice Burn confluence with Luggate Creek for trout that shift from the residual flow reach.

91. A residual flow below the LIC North Branch take that maintains the majority of flow observed at the confluence of the Alice Burn and Luggate Creek North Branch is likely to provide for the ecological values for the following reasons:

    a. The SH 6 minimum flow will likely maintain flows of ~120 l/s below the LIC North Branch intake.

    b. Flows of ~120 l/s will only occur 6% of the time during the irrigation season on average.

    c. Juvenile trout are very adept at migrating out of reaches that may become constrained for habitat or food, there is likely to be good juvenile trout habitat both immediately

[59] ORC fish surveys as part of their SoE monitoring program
[60] Van Klink, P. 2017. Luggate Creek Spawning Survey. Fish and Game Otago Council Paper.

above the LIC intake and below the Alice Burn confluence with Luggate Creek for trout that shift from the residual flow reach.

Lake MacKay Alice Burn Top Take Residual Flow

92. Lake Mackay Station are proposing a residual flow the equivalent of 50% of the natural 7-Day MALF of 46 l/s below their bywash on the upper Alice Burn. Based on the hydrological analysis it is expected that there is a natural gain in flow below this intake towards the LIC intake in the lower Alice Burn.

93. In order to meet the minimum flow of 180 l/s at SH6 a flow of ~60 l/s would pass the lower LIC intake from the Alice Burn (Table 5Table 1), indicating that for LIC to take water and leave 60 l/s to contribute to the minimum there would need to be a significant gain below the LM top intake or LM would need to let more than 46 l/s past their top intake.

94. Electric fishing surveys[61] and observations by Fish and Game Otago[62] indicate high numbers of juvenile brown trout are present in the lower reaches of the Alice Burn, upstream of the LIC intake. Recent electric fishing by Dr Allibone has confirmed there are no fish immediately downstream of the LM take and No fish were recorded as present in the immediate vicinity of the top LM intake.

95. The physical nature of the Alice Burn below the LM top intake means it is unlikely to hold trout, due to downstream barriers. Koaro may be present, but as Dr Allibone discusses in his evidence trout predation not habitat at low flow is likely restricting these fish[63]. Longfin eels are unlikely to be present because of the effect of the Clutha River hydro dams.

96. Potentially non-migratory galaxiids could be present in the Alice Burn between the LM and LIC intakes on the Alice Burn, though in my opinion unlikely due to the steep cascading nature of the stream. Non-migratory galaxiids are well known to cope with lower flows than species such as trout or koaro. I would expect a residual flow of 50% of natural MALF below the LM intake, with further gains downstream increasing flows would provide habitat for non-migratory galaxiids if they are present. In my experience flows of 50% of the natural 7-day MALF will provide at least 80% of habitat at MALF for non-migratory galaxiids in most cases.

97. For the following reasons a residual flow the equivalent of 50% of the natural 7-day MALF at the LM top intake is likely to provide for the ecological values downstream because:

    a. Flows downstream of the LM top intake are expected to naturally gain.

    b. The SH 6 minimum flow will likely maintain flows of ~60 l/s at the Alice Burn confluence, ensuring flows of 46 to 60 l/s at a minimum must be maintained below the LM top take.

    c. Flows of ~60 l/s at the Alice Burn confluence with Luggate Creek are only expected to occur 6% of the time during the irrigation season on average.

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[61] Electric fishing by Mr Ross Dungey as part of the deemed permit water program by ORC.
[62] Van Klink, P. 2017. Luggate Creek Spawning Survey. Fish and Game Otago Council Paper.
[63] Evidence of Dr Allibone.

Effects on Luggate Creek Mainstem Ecological Values

98. Based on the available ecological data for Luggate Creek mainstem, the creek appears to be in relatively good health, with both a good macroinvertebrate community, juvenile trout fishery and water quality (refer to Paras. 13 - 21). Longfin eel are present in low numbers, as are koaro however their low densities are not attributed to a lack of habitat but rather the Clutha dams and trout predations respectively. The present ecological values are representative of the existing flow regime.

99. Historic lows flows in Luggate Creek have been recorded as lows as 16 l/s during spot gaugings and the existing flow regime since the telemetered flow site was installed in 2016 has recorded flows as low as 86 l/s with a 7-day MALF of 164 l/s.

100. The take regime proposed by CWL and LIC/LM will significantly improve low flow conditions in Luggate Creek at the SH6 flow site. Based on existing flow record it is expected the lowest flow observed in Luggate Creek in future will be 180 l/s and the 7-day MALF will lift from 164 l/s to 261 l/s (Table 2).

101. Based on observed flows the existing minimum flow since continuous flow records began in 2016 of 86 l/s provided 60% habitat protection at MALF for juvenile trout, which will be improved to 80% habitat protection at MALF going forward. For large eels (>300mm) habitat protection will increase from ~75% to ~85% habitat at MALF. For koaro and small eels the increase in habitat protection is also significant[64].

102. The median flow statistic is often used as an indicator of macroinvertebrate production[65]. The take regime proposed by CWL and LIC/LM increases the observed median flows by ~20% (Table 2) which should result in an approximate gain of 20% in invertebrate productivity.

103. the flows that are potentially most valuable for supporting benthic invertebrate production and drift-feeding fish are those that are exceeded most of the time[66]. The take regime proposed by CWL and LIC/LM significantly decreases the duration of low flows while shifting a large portion of the take to higher flows. This is best illustrated in Figure 7 where the difference between the red and green lines for flows exceeded more than 50% of the time can be interpreted as increases in habitat for fish and invertebrates.

Conclusions

104. The consent proposal from CWL and LIC/LM significantly reduces actual water taken from Luggate Creek by 247 l/s. This results in a significant reduction of time spent at minimum flow and improved flow variability.

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[64] Jowett, I.G. Fish Habitat of Luggate Creek. 2019. Client Report: IJ1902.

[65] Page 112 of Hayes J, Hay J, Gabrielsson R, Goodwin E, Jellyman P, Booker D, Wilding T, Thompson M 2018. Review of the rationale for assessing fish flow requirements and setting ecological flow and allocation limits for them in New Zealand—with particular reference to trout. Prepared for NIWA, Envirolink, Greater Wellington Regional Council and Hawke's Bay Regional Council. Cawthron Report No. 3040. 150 p.

[66] Page 113 of Hayes J, Hay J, Gabrielsson R, Goodwin E, Jellyman P, Booker D, Wilding T, Thompson M 2018. Review of the rationale for assessing fish flow requirements and setting ecological flow and allocation limits for them in New Zealand—with particular reference to trout. Prepared for NIWA, Envirolink, Greater Wellington Regional Council and Hawke's Bay Regional Council. Cawthron Report No. 3040. 150 p.

105. The application of residual flow conditions on all takes from the catchment and the collective responsibility of maintaining the minimum flow at SH 6 should prevent adverse effects from taking water.

106. The reduction in primary take by 247 l/s will result in the most reliable water available for abstraction being used efficiently via spray irrigation infrastructure.

107. Future irrigation area development will only occur with water taken via supplementary allocation at flows greater than 788 l/s at the SH 6 flow site.

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8th October 2019