BEFORE THE COMMISSIONERS APPOINTED BY
THE CANTERBURY REGIONAL COUNCIL

IN THE MATTER	of Proposed Plan Change 7 to the Canterbury Land and Water Regional Plan
SUBMITTER	**MULLIGAN, M E & KERSE, I J & KINGSTON N S** Submitter 384

STATEMENT OF EVIDENCE OF IAN MCINDOE

GALLAWAY COOK ALLAN
LAWYERS
DUNEDIN

Solicitor on record: Bridget Irving
Solicitor to contact: Simon Peirce
P O Box 143, Dunedin 9054
Ph: (03) 477 7312
Fax: (03) 477 5564
Email: bridget.irving@gallawaycookallan.co.nz
Email: simon.peirce@gallawaycookallan.co.nz

STATEMENT OF EVIDENCE OF IAN MCINDOE

May it please the Commissioners:

Introduction

1. My name is Ian McIndoe, I am the Principal Water Resources Engineer and Managing Director at Aqualinc Research Limited.

2. Relevant to this statement of evidence, I have over 40 years' experience in hydrology, hydrogeology, groundwater hydraulics, and irrigation water supply and demand, particularly to do with water supply reliability and the impacts of reliability on agricultural production.

3. I have been given a copy of the Environment Courts code of conduct for expert witnesses. I have reviewed that document and confirm that this evidence has been prepared in accordance with it and that all opinions that I offer in this evidence are within my expertise. I have not omitted to refer to any relevant document or evidence except as expressly stated. I agree to comply with the code and in particular to assist the Commissions in resolving matters that are within my expertise.

4. I have been asked by the Submitters to provide this brief of evidence in relation to their submission (**OS384** or **Submission**) on the Proposed Plan Change 7 to the Canterbury Land and Water Regional Plan (**PC7**).

Scope of Evidence

5. The key hydrological issues raised by the Submitters relate to:

   (a) Whether the proposed 50 l/s minimum flow at the Coopers Creek SH72 flow monitoring site achieves its purpose.

   (b) The impact that the proposed minimum flow restriction will have on productive farming, given the expected impact on water supply reliability.

   (c) Consideration of alternative ways of achieving the outcomes of the Plan.

6. My evidence addresses the following matters:

   (a) A general description of the Upper Coopers Creek hydrology.

   (b) Determining the 7 day mean annual low flow (**7D MALF**) of Upper Coopers Creek at monitoring sites known as State Highway 72 Bridge (**SH72**) and Mulligans Weir.

   (c) Comment on the steady state modelling carried out by ECan to determine the effect of pumping on Coopers Creek

   (d) An assessment of effects of the Submitters pumping on flows in Upper Coopers Creek.

   (e) An assessment of the reliability of water supply available to the Submitters for irrigation, based on minimum flow scenarios at each monitoring site.

   (f) An assessment of the impact of the supply reliability on the Submitters pasture production based on each submitter's irrigation method and their consented flows and volumes.

Upper Coopers Creek Hydrology

7. Upper Coopers Creek as identified in the LWRP is located within the upper part of the Orari lowland catchment. **Error! Reference source not found.** Figure 1 provides a topographic map of the study area location.

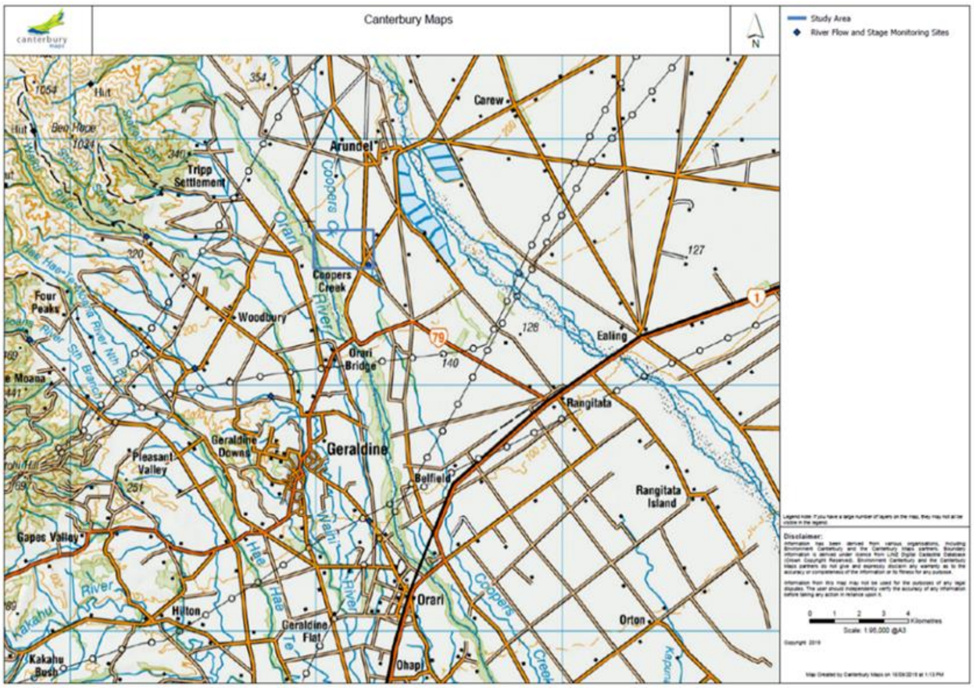

Figure 1: Topographic map of Coopers Creek study area

8. Within the Upper Coopers Creek catchment, we have defined a sub-catchment that incorporates the three Submitters farms, as shown in Figure 2. (reproduced from Keri Johnston's evidence).

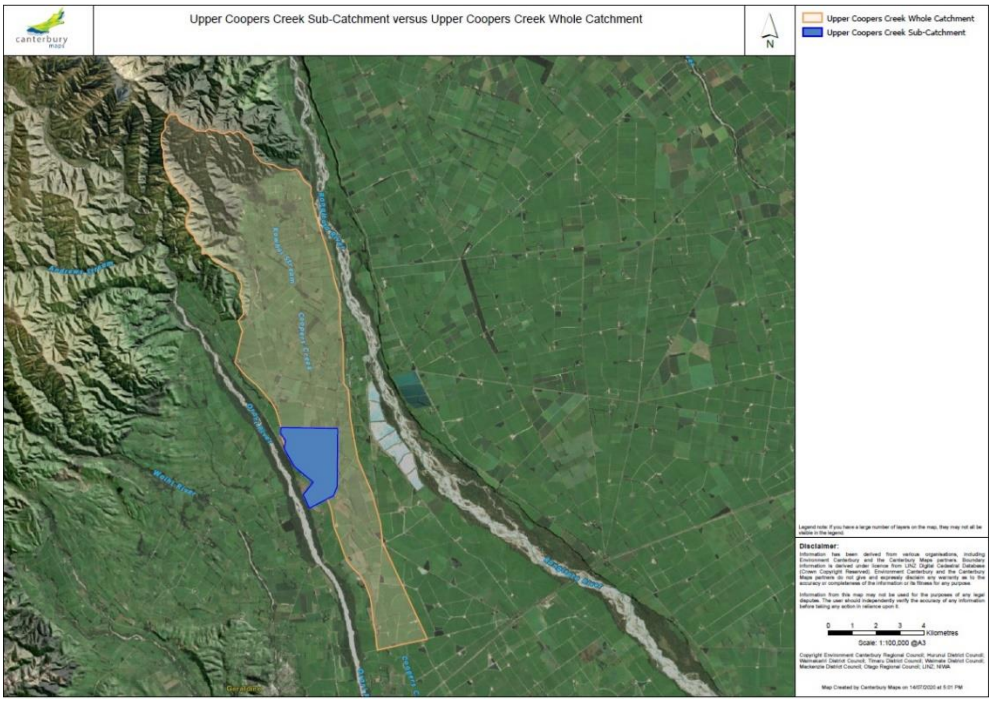

Figure 2: Upper Coopers Creek catchment and sub-catchment (from Keri Johnston)

9. The groundwater proposed to be taken for irrigation by the three Submitters represents the total consented groundwater in the sub-catchment.

10. Figure 3 presents an aerial image of the study area.

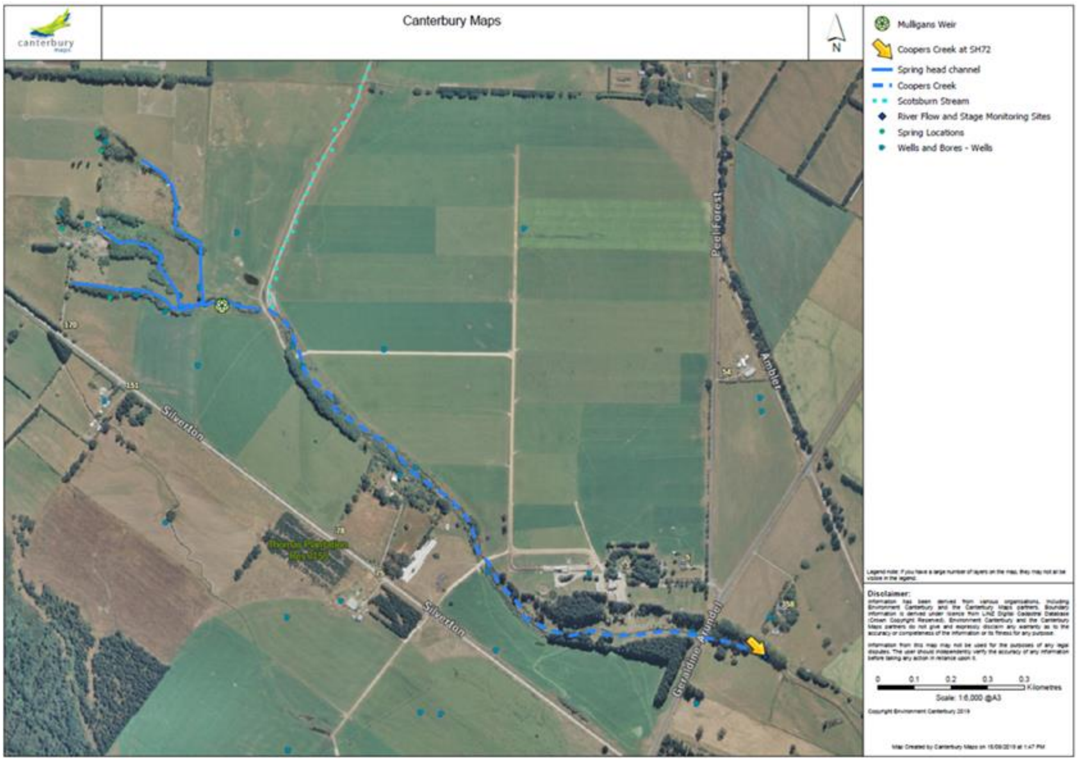

Figure 3: Aerial image of Coopers Creek spring head channels (solid blue), and the Scots Burn (green dash) confluence with Coopers Creek main channel (blue dash)

11. Within the sub-catchment, there are four main spring heads located at the NW end of the spring head channels (see Figure 3). There are two flow recorder sites - Coopers Creek at SH72 (arrow at bottom right of Figure 3), and Mulligans Weir (circle at top left of Figure 3, just below the three spring head branches).

12. The Coopers Creek at SH72 flow site is located at the SH72 road crossing approximately 2 km downstream of the spring heads. It is an open channel flow recorder maintained by Canterbury Regional Council and used as a minimum flow site. Mulligans Weir is an old flow recorder site, located on the main spring head channel, but is no longer operational.

13. The flow from the spring's confluences into a single spring head channel approximately 400 m downstream of the spring heads. The spring head channel then flows into the Coopers Creek main channel approximately 500 m downstream of the spring heads.

14. The Scotsburn joins with the main spring flow about 100 m downstream of Mulligans Weir.

15. The Coopers Creek main channel is ephemeral. It drains rainfall run-off from the foothills (Burbery, 2011)[1], with storm flow contributions from the Scotsburn and Kowhai Streams. For the majority of the time the springs provide the flow observed in the Coopers Creek main channel downstream of the Scotsburn confluence. The creek periodically goes dry at the SH72 monitoring site (Burbery, 2011).

16. It has been established by several experts (for example Burbery, 2011, Burbery & Ritson, 2010[2]) that a shallow groundwater aquifer is present in the vicinity of Upper Coopers Creek. This groundwater provides the source of water for the springs at the head of the Coopers Creek sub-catchment.

17. Groundwater in the aquifer comes from a combination of water leaking from the Orari River, land surface recharge, recharge from losses from the Coopers Creek main channel and losses from the Scotsburn. The Orari River is located approximately 600 m west of the springs. The springs flow year-round and are sustained by the flow losses from the River (Burbery, 2011).

18. Hydro chemical analysis shows that while the Coopers Creek spring water is predominantly sourced from the Orari River, it also has a contribution from land-surface recharge (Burbery, 2011). Burbery states that the shallow groundwater and springs exhibit the same chemical signature as Orari River water; hence they are strongly

---

[1] Burbery, L. (2011). Review of the Spring-Fed Coopers Creek, South Canterbury. Lincoln Ventures Ltd Report No. 1050-8-R1. Prepared for Environment Canterbury. Environment Canterbury Reference C14C/30501.

[2] Burbery, L; Ritson, J: 2010: Integrated study of surface water and shallow groundwater resources of the Orari catchment. ECan Report R10/36. ISBN 978-1-87757-06-1 March 2010.

dependent on the Orari River for recharge, more so than land surface recharge.

19. As there are no known impermeable barriers separating groundwater from surface water bodies (the Orari River, Uppers Coopers Creek and the Scotsburn), changes to groundwater levels in the Coopers Creek headwaters affects flows in the Coopers Creek springs.

20. The Coopers Creek flow data shows that the Coopers Creek spring flow is responsive to Orari River flows and local land surface recharge, but the relationship is temporally variable (Burbery, 2011). Part of the variability may be explained by the antecedent groundwater conditions around the spring heads.

21. Upper Coopers Creek only gains from groundwater in the vicinity of the spring heads (ECan, 2017)[3]. A significant proportion, and sometimes all, of the spring flow leaks through the Coopers Creek streambed into groundwater, particularly between Mulligans Weir and the SH72 Road Bridge. This helps to sustain the shallow aquifer downstream of the springs and will be contributing in a general sense to the groundwater aquifers further down the plains.

22. The flow loss has been quantified by a series of concurrent flow gauging at the Mulligan's Weir and the SH72 Road Bridge (average loss of 75 l/s, ranging from 65 l/s to 85 l/s) (ECan, 2017).

23. There is no evidence of stream losses being proportional to stream flow (ECan, 2017) and the observed flow losses do not vary significantly throughout the year. My own analysis confirms this.

24. Further evidence of the source of groundwater and spring flow can be obtained by examining piezometric contours, which are groundwater levels referenced to a common datum, usually mean sea level. Groundwater flows in a direction perpendicular to the contours.

---

[3] Groundwater-surface water interaction in the Coopers Creek catchment (R17/30), prepared by Louisa Peaver, Nicola Kaelin, Patrick Durney and Mark Trewartha, July 2017 (Referred to as ECan, 2017 or work undertaken by Canterbury Regional Council throughout this evidence)

25. Work carried out by Canterbury Regional Council (ECan, 2017) shows that groundwater is moving in an easterly direction from the Orari River towards the spring heads. Groundwater levels and spring head elevations are similar, with piezometric contours showing flow converging towards the spring heads.

26. On that basis, Upper Coopers Creek spring flows, which drive the Creek flows, are dependent on groundwater levels in the vicinity of the springs. The variation in groundwater levels is driven by a balance of inflows - leakage from the Orari River, land surface recharge and groundwater flow from further up the plains, and outflows - spring flows, groundwater flows down plains, abstraction and perhaps capillary water rising up from the groundwater table to plant roots zones to support transpiration.

27. As the inflows and outflows are constantly changing, groundwater levels are constantly changing, which causes the variation in spring flows. In dry periods, groundwater levels can be low due to a combination of little or no land surface recharge, lower Orari river flows (less leakage) and lower groundwater through-flow. As stream flow is constantly lost between Mulligans Weir and SH72, the flows at Mulligans Weir best describe flows from the springs.

Effects of proposed takes on stream flows

28. The Submitters’ consented irrigation takes are from shallow groundwater bores in the vicinity of Upper Coopers Creek. Under PC7, Canterbury Regional Council proposes to implement a minimum flow condition on groundwater takes based on flows at SH72. The hypothesis for this is that because there is a hydraulic connection between groundwater and stream flows, restricting groundwater takes will protect flows in Upper Coopers Creek.

29. What needs to be kept in mind when using the term “protect” is that Upper Coopers Creek regularly goes dry naturally at or around SH72, and imposing restrictions via a minimum flow limit will not in any way

prevent the Creek in the vicinity of SH72 from going below the minimum flow or going dry in the future.

30. Imposing restrictions could potentially have environmental benefits if restricting groundwater abstraction results in meaningful changes. The environmental effects of groundwater abstractions on Coopers Creek relate to flows (hydrology) and ecology. These have been discussed in the evidence of Mr Matt Hickey.

31. Imposing restrictions could also have economic effects. The economic effects of imposing restrictions relate to the impact on farm production, through having to cease irrigation, which I have addressed below.

32. Because Upper Coopers Creek goes dry naturally, the hydrological question that arises is whether restricting the Submitters groundwater takes on the basis of flows at SH72 is going to provide significant flow benefits to Coopers Creek.

33. The only way that implementing surface water minimum flows on groundwater takes could benefit Upper Coopers Creek from a flow perspective is if ceasing groundwater pumping resulted in the rate of flow reduction to slow significantly. If it did, in theory it might prevent the stream from going completely dry on occasions at SH72, or, if it was going to go dry in any case, reduce the number of days it was dry. To be of benefit, the differences would have to be ecologically significant.

34. What this means is that understanding the degree of connection between the groundwater bores and the Creek between restricting/ ceasing groundwater takes and flow changes in Coopers Creek is important if “protection” is to be considered.

35. Canterbury Regional Council has used the methodology described in Schedule 9 in the LWRP to categorise the degree of stream depletion effect applying to groundwater takes for water allocation purposes. The effects are listed in Appendix 1 of Keri Johnston’s evidence as “direct” or “high” in the case of groundwater takes in the vicinity of Upper

Coopers Creek. I am not sure where Canterbury Regional Council obtained the parameters from for these assessments.

36. While this method is a useful and convenient way of categorising takes for allocation purposes, it does not tell you what the effect of pumping groundwater on stream flow is. In the Coopers Creek case, we know that a significant proportion of the groundwater source is from the Orari River, and groundwater is flowing NW to SE, so it would be difficult to argue that a "direct" categorisation resulted in a reduction in stream flow anywhere near equal to the pumping rate , which is what this category implies.

37. A common way of establishing the degree of connection is to carry out aquifer tests – pump a bore and measure responses in nearby groundwater levels and stream flows and then from the analysis of the test, use empirical equations to predict the impact on stream flows. If aquifer tests show a reduction in stream flows, a connection between pumping bores and stream flows is highly likely. If a change in stream flows is not detected, it is likely that the degree of connection is small, or possibly non-existent.

38. Aquifer test data from the area is summarised in Burbery (2011). Tests resulted in "no measurable effect on spring flows from pumping groundwater". However, Burbery (2011) flags this is a 'false negative' result because groundwater abstraction contributes to the depletion of creek flows either by a direct hydraulic connection or an indirect hydraulic connection (Burbery, 2011). In my view, this comment is not helpful, as it does not provide any guidance on the likely degree of connection.

39. Burbery (2011) suggests that there is no reliable method for determining what the drawdowns in the shallow aquifer near the spring heads translates to in terms of reduction in Coopers Creek flows.

40. In my view, appropriate groundwater modelling calibrated to measured data can provide a sufficiently robust relationship between groundwater levels and spring flows for water management.

41. Interestingly, Canterbury Regional Council, reported in ECan (2017)[4], did exactly this by carrying out extensive data collection to calibrate a complex numerical model for predicting groundwater and surface water exchange, and to predict effects of groundwater abstraction on the Coopers Creek system under different abstraction scenarios.

42. While we were not able to obtain a copy of the model to assess it in detail, our view is that the model is reasonably structured and calibrated.

43. The model is a steady-state model, which reduces its usefulness. Nevertheless, it provides a guide on the order of magnitude of effects that could be expected. In a steady state model (**SSM**), inputs (and therefore outputs) are constant (they do not change over time). With an SSM, land surface recharge (long-term average) and river flows are constant. Given this, all abstracted water will ultimately be derived from river flows and recharge (which are the model inputs) and not from groundwater storage.

44. The magnitude of stream depletion effect determined from an SSM will potentially be larger than what would be calculated via a transient model (with the same inputs), as the SSM assumes that pumping continues forever. In reality, pumping is time-variable.

45. A key issue of the Canterbury Regional Council modelling is that most of the abstraction scenarios do not reflect the abstraction flows and volumes of the actual consented takes. I comment further on this issue below.

46. Keri Johnston has summarised the relevant groundwater consents and flow allocation for Upper Coopers Creek, and after accounting for stream depletion using Schedule 9, determined it to be 218.42 l/s, which is 66% of Canterbury Regional Council's figure of 331 l/s as specified in Table 14(h) of Plan Change 7.

---

[4] Groundwater-surface water interaction in the Coopers Creek catchment, Peaver, L., Kaelin, N., Durney, P. and Trewartha, M., Report No. R17/3 July 2017

47. The Submitters' peak consented take from groundwater is 234 l/s. After accounting for the short-term volume limits specified in the consents, the average daily flow that can be taken from groundwater by the Submitters within the sub-catchment is 214.8 l/s. After implementing Schedule 9 of the LWRP, the surface water allocation applying to Upper Coopers Creek becomes 199.48 l/s.

48. The 199.48 l/s surface water allocation for the three farms is 100% of the proposed take for the sub-catchment. There are no other surface water or hydraulically connected groundwater takes that add to the total allocated to the three Submitters.

49. The Submitters proposed surface water allocation is 91% of the total of 218.42 l/s for the catchment, so represents the majority of the Upper Coopers Creek LWRP allocation. I understand that the 9% balance of 18.94 l/s is located in the Upper Catchment, and well outside the sub-catchment area.

50. I stress that the 199.48 l/s is not an actual stream depletion effect on Upper Coopers Creek as a result of the three Submitters exercising their consents. It is a number that has resulted from the application of Schedule 9 to the consents to determine a surface water allocation for accounting purposes.

51. The annual volume allocation of the three Submitters' consents is proposed to be 1.78 million m^3. A portion of the annual volume will be accounted for in Table zb of the LWRP – for the Orari-Opihi groundwater zone.

52. Canterbury Regional Council in their 2017 report[5] describe running eight scenarios through their SSM, ranging from no abstraction through to taking the maximum legally abstractable volumes.

53. In their 2017 report, Table 4-1[6] compares measured use with allocated volume for individual consents and shows that use was at most 24% of the maximum legally abstractable allocation.

---

[5] Groundwater-surface water interaction in the Coopers Creek catchment, Peaver, L., Kaelin, N., Durney, P. and Trewartha, M., Report No. R17/3 July 2017

54. One of the Canterbury Regional Council scenarios was based on actual metered takes from the 2015/16 irrigation season, which they refer to as the Recent Actual Scenario. The volume abstracted was 1.75 million m^3. The Submitters annual volume proposed (1.78 million m^3) is almost identical to this figure, which means that for this scenario the Canterbury Regional Council modelling represents 100% of the Submitters proposed takes in the sub-catchment in a 1 in 10 year (a dry year).

55. The average irrigation take over a range of wet and dry years is 76% (see Table 3 below) of the 1 in 10 year allocation. This implies that in most years, the effect of the takes on Upper Coopers Creek flow will be lower than the value modelled under the Recent Actual Scenario. That is a key point when assessing the effect of the proposed takes on flows.

56. Canterbury Regional Council found that in general, the effects of groundwater pumping on stream flows using measured abstraction data from the 2015/16 irrigation season (the Recent Actual Scenario) would be small.[7] The modelled effect on stream flows was 7 l/s, which was 5% of the flow at Mulligans Weir. Canterbury Regional Council concluded that "These calculations suggest that Coopers Creek is resilient to the current shallow groundwater abstraction practices and that halting all abstraction could have only minimal effects on spring flow."[8]

57. Because it was legally possible under the consent conditions occurring at the time that the modelling was completed, Canterbury Regional Council also modelled, amongst other scenarios, a "maximum take" scenario that assumed that all groundwater consents were abstracting continuously (365 days per year) at their maximum physical or consented rate and estimated that stream flows would drop by 36%. In my view, this scenario is meaningless, as (a) it will never happen, and

---

[6] Groundwater-surface water interaction in the Coopers Creek catchment, Peaver, L., Kaelin, N., Durney, P. and Trewartha, M., Report No. R17/3 July 2017 at page 20.

[7] At page 34.

[8] At page 31.

(b) if it did, a lot of the applied water would soak straight back into the shallow groundwater system thereby mitigating the effect of the take.

58. In addition, annual volume limits will be applied to all consents. It will not be legally possible to take the "maximum" take volume as modelled by Canterbury Regional Council in the future.

59. I also make the point that all of the other scenarios modelled by Canterbury Regional Council using the SSM are of no value today (and in my view were of no value when they were completed, other than perhaps looking at what-if situations).

60. In summary, we know that test pumping of the groundwater aquifer was unable to detect a drop in stream flows. We know that the empirical equations used to assess the actual stream depletion effect have little value on defining actual stream depletion. We also know that steady state modelling using proposed volumes predicts that the effect of groundwater pumping on stream flows is small.

61. Based on flow rates, the Submitters' irrigation represents 92% of the Upper Coopers Creek surface water allocation. My conclusion, therefore, is that the combined effect of groundwater pumping in the Upper Coopers Creek catchment on Coopers Creek flows will be small. I agree with Canterbury Regional Council that "that halting all abstraction could have only minimal effects on spring flow."[9]

62. It follows from that conclusion that if small changes in stream flow do not adversely affect the stream environmental values, (this is addressed by Matt Hickey in his evidence), annual volume limits on takes will be sufficient to manage the effects of the groundwater takes on Coopers Creek spring flows.

Mean Annual Low Flow

63. If it were determined that a minimum flow restriction is required to manage groundwater takes, the key questions are; (1) where the flow should be measured, and (2) what the minimum flow should be set at.

---

[9] At page 31.

64. Minimum flows set by regional councils are most commonly defined as a percentage of habitat at MALF (if hydraulic habitat modelling is available) or simply as a percentage of MALF in other cases.

65. Keri Johnston, in her evidence, (paragraphs 14 and 15) states that the proposed minimum flow of 50 l/s measured at the SH72 site was an interim flow, and the hydrology knowledge of the creek was very limited. This view is reinforced by Mr Hickey in his evidence and by the Submitters in each of their briefs of evidence.

66. If a minimum flow approach is to be taken, it is critical therefore to know what the 7DMALF is at the two measurement sites - SH72 and Mulligans Weir.

67. Aqualinc hydrologists have analysed all available data from both measurement sites. Using correlation between measured flow at the two sites and with a nearby groundwater bore (K37/2986), we have both filled gaps in data and extended data to generate a daily time-series of flow at each site.

68. Graphs of stream flows are presented in Figure 4 and Figure 5.

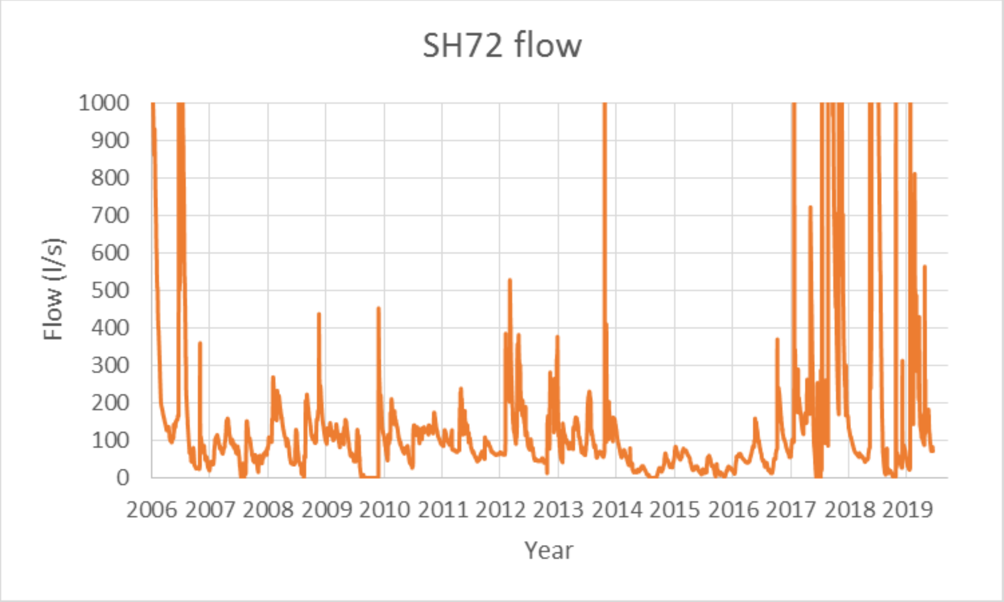

Figure 4: Coopers Creek flow at SH72 measuring site

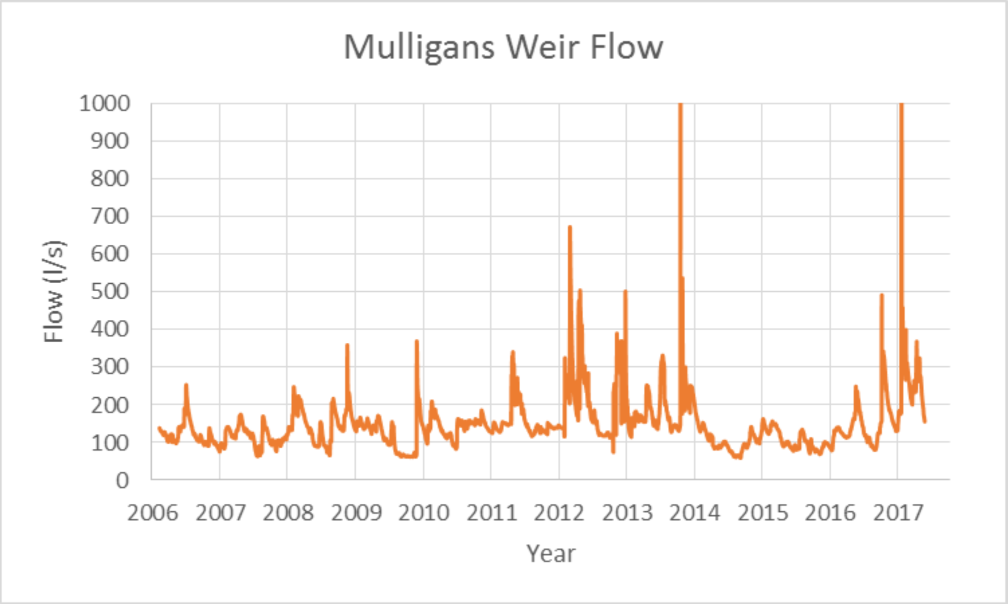

Figure 5: Coopers Creek flow at Mulligans Weir measuring site

69. Because only high SH72 flows are affected by the Scotsburn (the Scotsburn is dry at lower flows) and because our key interest is in what happens at Coopers Creek low flows, we removed the high flows above 186 l/s from the SH72 data. That is the same approach that Canterbury Regional Council took in 2017.

70. Our determination of 7DMALF is that it is about 28 l/s at SH72 and 93 l/s at Mulligans Weir. It means that there is approximately 65 l/s loss of flow between the two sites at low (MALF) flows. This is consistent with the previous estimates made by Canterbury Regional Council.

Minimum flow scenarios

71. If a minimum flow is adopted, where it is measured and what flow is used depends on the effects of setting it at a particular location and level. Mr Hickey has addressed the ecological impacts of implementing a specific minimum flow. He concludes that a minimum flow is not necessary to maintain ecological health in this sub-catchment.

72. I now provide information on the likely effects on various minimum flow scenarios on irrigation water supply reliability and pasture production.

73. To determine reliability, we need to:

    (a) define the minimum flow scenarios;

(b) calculate irrigation demand; and

(c) compare supply with demand.

74. We have modelled eight flow scenarios, one to represent takes with no minimum flow implemented, four for the SH72 site and three 7DMALF scenarios for the Mulligans Weir site, as follows.

Table 1: Minimum flow scenarios

Scenario	**SH72**	**Mulligans**
No minimum flow	Not applied	Not applied
Proposed in PC7	50 l/s	Not applicable
7D MALF	28 l/s	93 l/s
90% of 7D MALF	25.2 l/s	83.7 l/s
50% of 7D MALF	14 l/s	46.5 l/s

75. I have applied each scenario to the relevant daily time-series of Coopers Creek flows for the irrigation seasons from 2006/07 through to 2017/18 and calculated an “available” time-series of water supply that the farms would have experienced if they had been irrigating from 2006.

76. Under the PC7 proposal, restrictions would commence at a SH72 flow of 381 l/s (being the minimum flow of 50 l/s plus the ECan allocation limit of 331 l/s) and pro-rated down so that no takes would be possible once the flow reached 50 l/s.

77. Under the proposal I have put forward, I have implemented the minimum flow limits when the flow limits were reached, meaning that consents could be fully exercised above the minimum flow and would be off below the minimum flow. The proposed PC7 method results in a significantly greater deterioration of water availability and reliability than for the on-off method.

78. The logic behind applying an on-off approach is that Upper Coopers Creek flows are responding over time to the balance of inflows and outflows in the vicinity of the springs and abstraction is only a minor

part of that. In my view, implementing pro-rata restrictions would make virtually no difference to the water balance at the springs in the timeframes that the restrictions would be implemented.

79. In addition, pro-rata restrictions on a real-time (daily basis) are difficult to implement at an individual farm level. It can only be done by adjusting irrigation times to change abstraction volumes, as irrigator flow rates tend to be fixed.

Irrigation demand

80. I have used an Aqualinc in-house daily soil water balance model to determine the expected irrigation demand for the three farms, taking into account the following:

    (a) Local climate – rainfall (Coopers Creek climate station, 1 km SE of SH72) and potential evapotranspiration (Orari Estate, near SH1 Orari Bridge).

    (b) The specific consented flow conditions applying to each farm.

    (c) The actual irrigation methods and management used on each farm.

    (d) The soil water holding capacity (PAW) on each farm.

    (e) Water supply reliability.

81. The soil water balance model I have used is an Aqualinc model that incorporates the same principles as the widely-used Aqualinc Irricalc model but allows water supply restrictions to be applied interactively with demand.

82. The analysis has been based on six on-farm irrigation situations. It includes three on the Kerse farm, two on the Kingston farm and one on the Mulligan farm, all with different parameters, as described in Table 2. Total irrigated area is 407.5 hectares.

Table 2: Farm irrigation scenarios

Farm	**Area (hectares)**	**Soil PAW (mm)**	**Method**	**Application depth (mm)**	**Return interval (days)**
Kerse	24	45	Rotary[1] Boom	22.5	4
	24	80	Rotary[10] Boom	35	6
	80	80	Pivot[11]	15	3
Kingston	115	45	Pivot	14	3
	29	80	Pivot	14	3
Mulligan	135	45	Pivot	15.3	3

83. The rainfall, PET and irrigation application percentage takes area-averaged over the three farms are presented in Table 3. The irrigation is on an irrigation season basis, from 1 July to 30 June each year, with volume and flow limits applied, but with no minimum flows. The irrigation takes have been area-averaged over the three farms.

Table 3: Rainfall, PET and irrigation demand for the three Submitters farms

Irrigation season	**Irrigation Season Rainfall (mm)**	**Irrigation Season PET (mm)**	**Irrigation demand (%) of allocation**
2006/07	564.6	527.1	41%
2007/08	399.0	603.6	98%
2008/09	452.8	619.2	90%
2009/10	712.0	588.4	38%
2010/11	411.7	597.1	100%
2011/12	567.0	547.7	60%
2012/13	475.3	596.7	86%

---

[10] This is one irrigator running over two soil types. The return interval for the rotary boom irrigation is 4 + 6 = 10 days.

[11] This is actually a rotary boom irrigator applying small depths of water on fast runs.

2013/14	467.7	566.0	82%
2014/15	635.8	599.8	61%
2015/16	365.2	609.4	88%
2016/17	366.9	550.8	76%
2017/18	376.9	620.0	94%

84. The analysis shows that irrigation demand, taking into account the conditions occurring on each farm, is quite variable on a year by year basis. Average demand is about 76% of allocation. The 2015/16 irrigation season, which ECan used for the Recent Actual Scenario, ranks as about a 1 in 8 year event, so was a relatively high demand year.

Reliability of supply

85. Four factors have to be considered to fully quantify reliability of supply. They are:

    (a) Severity – size or amount of restriction;

    (b) Frequency – how often the restrictions occur;

    (c) Duration – how long the restrictions last;

    (d) Timing – when restrictions occur.

86. A restriction in water supply results in the inability of an irrigation system to fully replenish soil moisture deficits. When that occurs, production and farm profitability is reduced. The four factors noted above determine the magnitude of decreases in production and profit.

87. There are several methods available to quantify reliability of supply of water for irrigation from a hydrological perspective. Each method encompasses some of the four factors of severity, frequency, duration and timing, but no one method fully addresses all factors.

88. One of the most useful methods of assessing reliability on an annual or irrigation season basis is to compare the available water with irrigation

demand on a daily basis and amalgamate the values into annual figures. These are known as supply-demand ratios.

89. On any day during the irrigation season, the supply of water available under an allocation rule or water supply scenario can be compared with the demand for irrigation on that day. If available supply equals or exceeds demand, reliability is 100%. If demand exceeds supply, reliability is calculated by dividing supply by demand to give a supply/demand ratio.

90. My evidence quantifies the level of restriction imposed by the different minimum flow scenarios at the water supply-demand level to provide a relative level of effect of different scenarios on supply reliability.

91. While supply-demand ratios inherently include the accumulated effects of reliability on a daily basis, and therefore include the effects of severity, frequency, duration and timing of restrictions, the full effects are best addressed by considering the effects on production and profitability. That is provided in evidence by Mr Hayden Craw.

92. The categories of supply-demand ratio reliability[12] are presented in Table 4.

Table 4: Supply-demand ratio reliabilities

Description	**Reliability**
Very good reliability	100%
Good reliability	94-99%
Marginal reliability	87-94%
Poor or very poor reliability	<87%

---

[12] Robb, C and McIndoe, I (2001): Reliability of supply for irrigation in Canterbury. Report No 4465/1, prepared for Environment Canterbury by Lincoln Environmental, a division of Lincoln Ventures Ltd.

93. For efficient irrigation, reliability needs to be in the good or very good reliability range. It allows farmers to plan the growing of crops and pasture with certainty. It also allows farmers to manage irrigation on an efficient “just-in-time” basis rather than a “just-in-case” basis, which helps to reduce drainage of water and nutrients below the root zone of crops. Efficient irrigation with very poor reliability is absolutely not recommended.

94. Table 5 provides the reliability for the Kerse farm for each minimum flow scenario for the SH72 site. The 50 l/s PR refers to the **pro-rated rules** as proposed in PC7 based on the full allocation being available at flows of 381 l/s linearly ramping down to no flow being available at 50 l/s.

95. The reliability for the Kingston and Mulligan farms follow very similar trends. I have included the results for them in Appendix 1 at the end of this evidence.

96. In the Appendix, I have also included reliability for a minimum flow of 10 l/s at SH72, as that has been referred to by Mr Hickey as a suitable minimum flow for Uppers Coopers Creek, if that is deemed necessary.

Table 5: Reliability for Kerse farm for SH72

Season	50 l/s PR	50 l/s	MALF	90%MALF	50%MALF
2006/07	95.9%	100.0%	100.0%	100.0%	100.0%
2007/08	65.4%	82.3%	88.1%	88.1%	90.9%
2008/09	63.6%	77.3%	94.2%	94.6%	97.1%
2009/10	88.0%	90.9%	91.7%	91.7%	91.7%
2010/11	62.4%	93.4%	99.6%	100.0%	100.0%
2011/12	79.4%	96.3%	100.0%	100.0%	100.0%
2012/13	77.7%	88.4%	100.0%	100.0%	100.0%
2013/14	74.4%	100.0%	100.0%	100.0%	100.0%
2014/15	76.4%	76.4%	76.9%	76.9%	82.2%
2015/16	58.8%	63.0%	72.8%	75.3%	94.2%
2016/17	70.7%	79.8%	89.3%	89.7%	97.9%
2017/18	77.3%	88.8%	90.5%	90.5%	92.6%
Average	74.2%	86.4%	91.9%	92.2%	95.6%

97. While seasons such as 2006/07 and 2013/14 had very good reliability under all scenarios, reliability in 2014/15 and 2015/16 was very poor. On average, reliability was very poor for the 50 l/s minimum flow (both pro-rated and on-off), marginal for the 90% of MALF and the MALF minimum flow options, and good for the 50% MALF option.

98. The reduction in reliability when the Canterbury Regional Council PC7 pro-rated rule is applied is large, even when compared to the 50 l/s option without the prorated rule. Good reliability occurs in only one year out of the 12 (2006/07). In all other years, reliability is poor or very poor, which is not suitable for irrigation. I would not recommend irrigation at all for a 50 l/s minimum flow regardless of whether it is pro-rated or not.

99. While the Submitters have already invested in irrigation and have been using it for a number of years, poor or very poor reliability makes it very difficult to plan for and manage production as would occur for an irrigated farm, because the reliability that will occur in specific years is

unknown. In seasons such as 2007/08 or 2014/15, irrigation would be extremely limited and provide little benefit to production in some months.

100. An example of good (Figure 6) and very poor (Figure 7) reliability is shown in the following figures (Kerse farm).

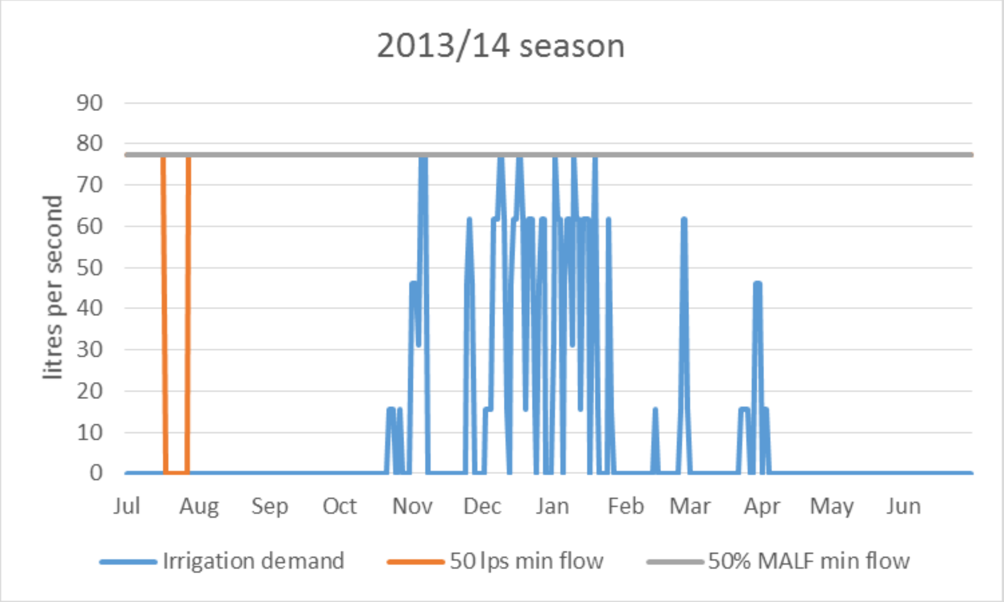

Figure 6: Comparison of irrigation demand with supply in a reliable season (2013/14)

101. In Figure 6, demand was able to be met for both the 50 l/s minimum flow and for the 50% MALF minimum flow, which resulted in 100% (very good) reliability in the 2013/14 season. This is despite the season having a higher than average irrigation demand.

102. This is contrasted by the following (Figure 7).

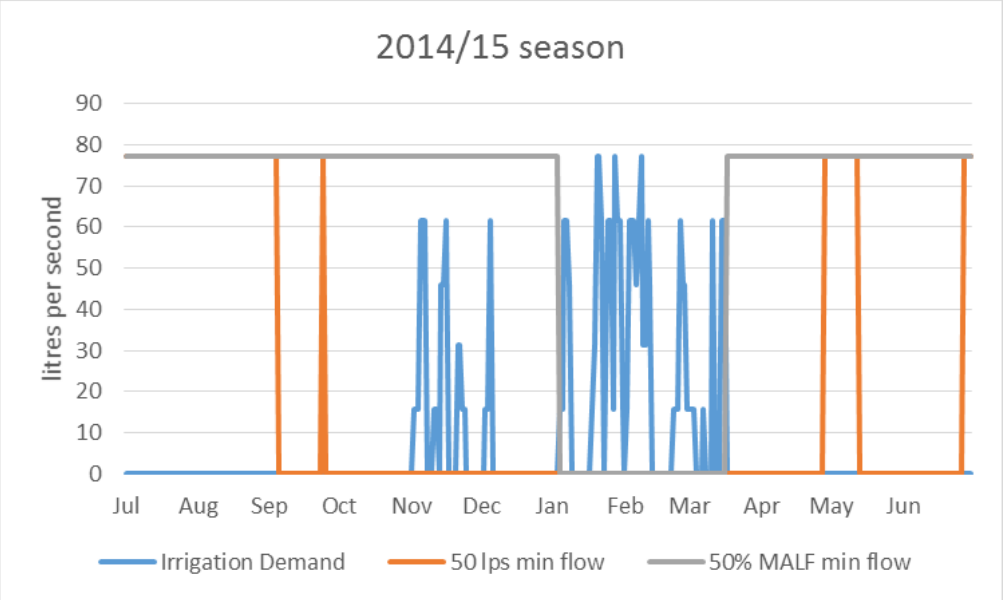

Figure 7: Comparison of irrigation demand with supply in an unreliable season (2014/15)

103. Figure 7 shows that in the 2014/15 season, none of the irrigation demand was met under the 50 l/s minimum flow option in the 2014/15 season. Irrigation would not have been possible in that season, except perhaps in the early or late part of the season. Even under the 50% of MALF minimum flow, from January through to mid-March none of the demand was able to be satisfied. This season had a moderate irrigation demand.

104. The impact of flows on reliability is illustrated in the following figures.

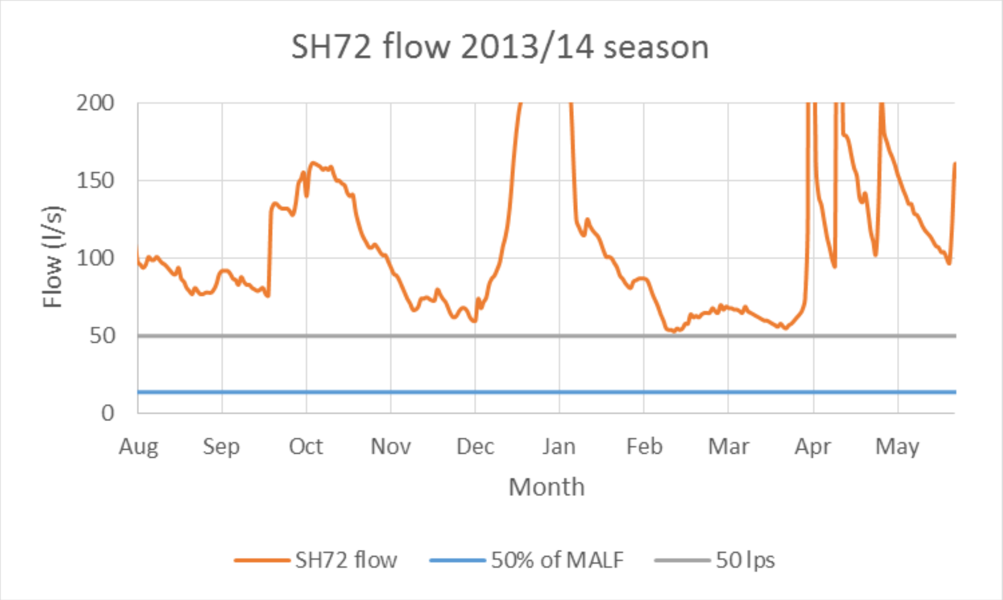

Figure 8: Comparison of 2013/14 SH72 flows with 50 l/s and MALF minimum flows

105. Figure 8 shows that SH72 flows in the 2013/14 irrigation season exceeded 50 l/s (and 50% of MALF) throughout the season, resulting in 100% reliability.

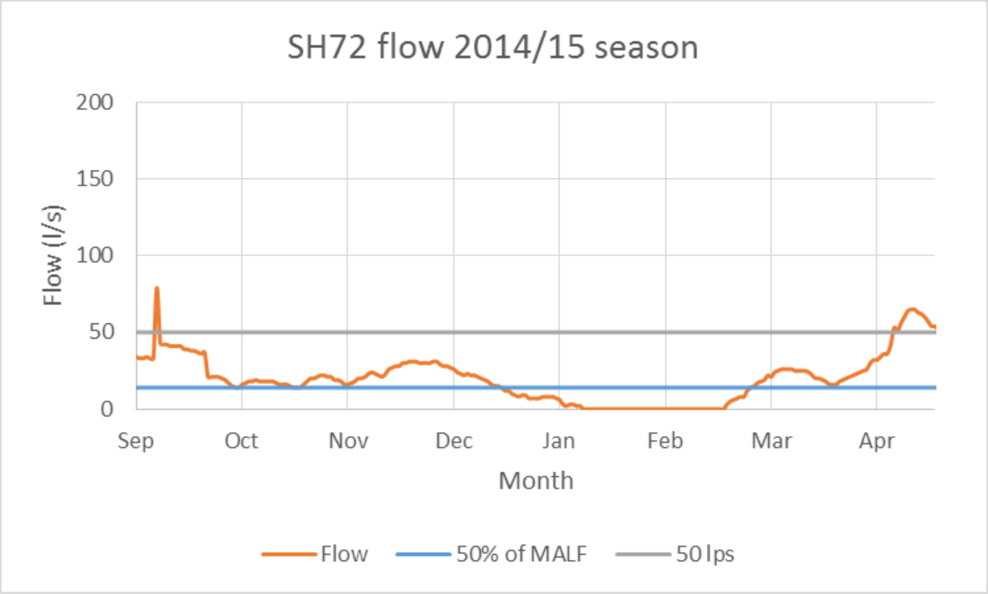

Figure 9: Comparison of 2014/15 SH72 flows with 50 l/s and MALF minimum flows

106. Figure 9 shows that SH72 flows in the 2014/15 irrigation season did not exceed 50 l/s at any point during the season, resulting in very poor reliability. Likewise, flows rarely exceeded 50% of MALF during the season.

107. The reliability of supply for the Kerse farm based on flows at Mulligans Weir are presented in Table 6.

Table 6: Reliability for Kerse farm for flows at Mulligans Weir

Season	**MALF**	**90%MALF**	**50%MALF**
2006/07	100.0%	100.0%	100.0%
2007/08	83.5%	88.1%	100.0%
2008/09	81.0%	94.2%	100.0%
2009/10	91.7%	91.7%	100.0%
2010/11	94.2%	99.6%	100.0%
2011/12	100.0%	100.0%	100.0%

2012/13	100.0%	100.0%	100.0%
2013/14	100.0%	100.0%	100.0%
2014/15	77.7%	82.2%	100.0%
2015/16	78.6%	93.8%	100.0%
2016/17	91.7%	97.5%	100.0%
Average	90.8%	95.2%	100.0%

108. There are differences in reliability between Mulligans Weir and SH72 despite the same criteria (% of MALF) being used at both sites. This is due to the differences in flow profiles at the two sites.

109. Mulligans Weir tends to have more stable flows because they are driven by groundwater levels at the springs. SH72 flow tends to be more variable as in addition to receiving spring flow, it is also influenced by flow losses to groundwater and flow gains from the Scotsburn.

110. The reliability at MALF is slightly lower for Mulligans Weir than for SH72 (90.8% vs 91.9%). Reliability improves substantially at 90% MALF and is 100% reliable at 50% MALF.

111. Based on the reliability criteria shown in Table 4, MALF reliability is marginal, 90% of MALF is good and 50% of MALF is very good for the Mulligans Weir site.

Pasture production

112. While I have established that irrigation reliability is very dependent on the minimum flow scenarios, there is a high degree of variability in reliability from month to month and year to year depending on irrigation demand and water supply availability. The same variability occurs with pasture production, on which each of the farm enterprises depends.

113. To examine the variability in pasture production, we have entered the daily irrigation demand time-series for the eight scenarios into a biophysical pasture production model for dairy and dairy support

systems called DairyMod[13] that Aqualinc routinely uses to determine pasture production.

114. After setting up DairyMod for each farm, the only adjustment to the DairyMod inputs that we made for each scenario was to the irrigation applications. That approach meant that we could determine the changes in pasture production due to changes in minimum flow alone and maintain relativity between scenarios.

115. For the no minimum flow scenario, and using specific climate, soil and irrigation strategies for each farm, DairyMod was used to calculate initial production values.

116. To calibrate DairyMod pasture production to the actual production occurring on each farm, Hayden Craw supplied us with average monthly pasture growth rates for each farm. We have adjusted the average DairyMod production values to match the supplied values for the no minimum flow scenario. We have then applied the percentage changes of the difference between supplied values and DairyMod values to all other scenarios.

117. Monthly pasture production figures for each year of historical record for each irrigation scenario and minimum flow scenario have been provided to Hayden Craw for further analysis.

118. To illustrate the variability in annual pasture production under the various minimum flow scenarios, I have presented a summary of annual production for the Kerse farm in Figure 10.

119. Please note that DairyMod takes into account a wide range of variables and sequences of events to determine daily pasture production. On occasions, and particularly during wetter events, it will produce small yield differences that appear to be counter-intuitive to what you would expect to see. This is due to the way the yield algorithms work. The trends in the drier years or years of restrictions however, are very consistent.

---

[13] Johnson IR (2016). DairyMod and the SGS Pasture Model: A mathematical description of the biophysical model structure. IMJ Consultants, Dorrigo, NSW, Australia.

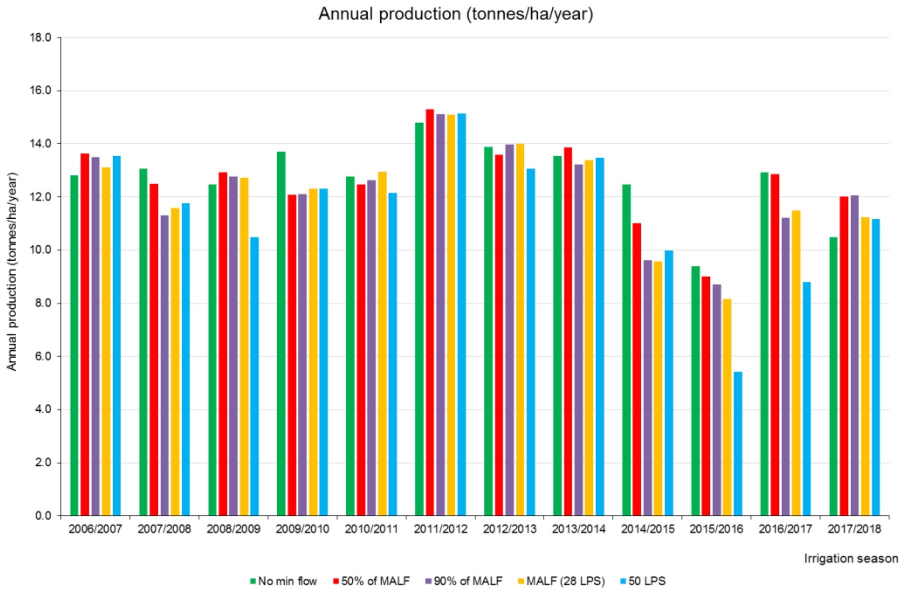

Figure 10: Annual production for Kerse farm under various minimum flow scenarios at SH72

120. Figure 10 illustrates the significant impact that the minimum flow rules have in the more restrictive years, such as 2015/16. I must stress that the annual values tend to hide the shorter term effects of restrictions as there may be several consecutive weeks or months where pasture production is very low due to being unable to irrigate. These effects have been addressed by Hayden Craw in his evidence.

121. Production based on flows at Mulligans Weir follows similar patterns, as shown in Figure 11.

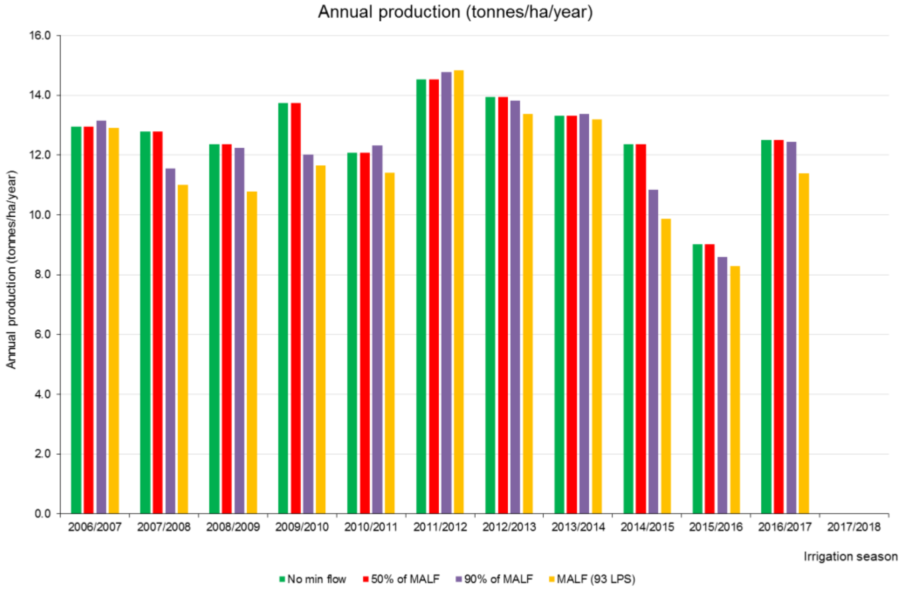

Figure 11: Annual production for Kerse farm under various minimum flow scenarios at Mulligans Weir

122. Because stream flows are more stable at Mulligans Weir than at SH72, production is slightly higher overall. As noted in Table 6, reliability for a minimum flow of 50% of MALF is 100%, which means that the no minimum flow production and the 50% MALF production are the same.

Summary

123. Uppers Coopers Creek is located in the upper part of the Orari lowland catchment. A sub-catchment of Uppers Coopers Creek contains a spring-fed reach of the Creek. The springs are fed from groundwater at the spring-heads. The groundwater is sustained by leakage from the Orari River, land surface recharge and groundwater flow from foothills catchments above the springs.

124. Each of the Submitters pump groundwater for irrigation from shallow bores in the sub-catchment of Uppers Coopers Creek. The surface water allocation component for the Submitters takes is approximately 91% of the total current surface water allocation of Upper Coopers Creek.

125. Canterbury Regional Council maintains a flow measuring site on Uppers Coopers Creek about 200m downstream of the SH72 Road Bridge. Canterbury Regional Council, through PC7, proposes to

implement a pro-rated minimum flow of 50 l/s for Uppers Coopers Creek, which will be applied to the three Submitters takes.

126. Historically, a flow monitoring site was maintained at Mulligans Weir, which is about 1.5 km upstream of the SH72 monitoring site. The Mulligans Weir site is not currently functioning.

127. Mean annual low flow (MALF) for SH72 is about 28 l/s and about 93 l/s for Mulligans Weir. Water leaks through the bed of the creek into groundwater below Mulligans Weir at a steady rate of about 70 l/s, which accounts for the primary difference in flow between the sites.

128. Upper Coopers Creek periodically goes dry below SH72 and at the Canterbury Regional Council monitoring site. The lowest flow at Mulligans Weir is likely to be about 50 l/s.

129. The degree of hydraulic connection between the Submitters bores and Upper Coopers Creek has been characterised by Canterbury Regional Council using Schedule 9 as ‘High” or “Direct”. Schedule 9 is an assessment method that models the degree of connection to determine the percentage of the groundwater take to be allocated to surface water and to groundwater.

130. Aquifer testing carried out historically failed to identify any measurable impact of groundwater pumping on flows. More recent groundwater modelling by Canterbury Regional Council using a pumping scenario consistent with the proposed pumping of the 1 in 10 year allocation by the Submitters predicted a 6 l/s effect on Upper Coopers Creek flows.

131. Despite the degree of hydraulic connection characterisation, there is no evidence that groundwater pumping by the Submitters will have a significant effect on flows in Upper Coopers Creek.

132. With respect to the modelling, Canterbury Regional Council concluded that “These calculations suggest that Coopers Creek is resilient to the current shallow groundwater abstraction practices and that halting all abstraction could have only minimal effects on spring flow.” I agree with that conclusion.

133. With the Submitters proposing to have or already having annual volume limits on their consented takes, I am comfortable with the proposition put forward by them that the impacts of their groundwater pumping on spring flows can be managed with annual volume limits.

134. If a minimum flow condition is required, linking the condition to the Mulligans Weir site is likely to provide better supply reliability than for the SH72 site, especially under a minimum flow condition based on 50% of MALF. However, the Mulligans Weir site would need to be re-established.

135. Implementation of the proposed PC7 prorated minimum flow of 50 l/s at SH72 will have a major impact on water supply reliability for the Submitters. Under that limit, average reliability is 74%, which places it in the very poor reliability category. I would not recommend investing in irrigation under those circumstances. The same conclusion applies to the on-off 50 l/s minimum flow scenario.

136. For both SH72 and Mulligans Weir, the only minimum flow scenario we have considered that will provide good or very good reliability on average for both sites is that based on 50% of MALF.

137. Reliability varies from year to year and from month to month. In some years (the wetter years), reliability is good or very good, partly because irrigation demand is low and partly because stream flows are high. In other years, reliability is very poor. An example of this occurs in the 2014/15 season.

138. The DairyMod pasture production modelling that we have completed shows that the various minimum flow scenarios have a direct impact on pasture production, particularly in the years of high irrigation demand and low Uppers Coopers Creek flows such as in the 2014/15 season.

Dated this 17th day of July 2020

I.McIndoe.

Ian McIndoe

Appendix 1: Supply/demand reliability

Table A1: Supply/demand reliability for Kerse at SH72

Season	50 l/s PR	50 l/s	MALF	90%MALF	50%MALF	10 l/s
2006/07	95.9%	100.0%	100.0%	100.0%	100.0%	100.0%
2007/08	65.4%	82.3%	88.1%	88.1%	90.9%	91.8%
2008/09	63.6%	77.3%	94.2%	94.6%	97.1%	97.5%
2009/10	88.0%	90.9%	91.7%	91.7%	91.7%	91.7%
2010/11	62.4%	93.4%	99.6%	100.0%	100.0%	100.0%
2011/12	79.4%	96.3%	100.0%	100.0%	100.0%	100.0%
2012/13	77.7%	88.4%	100.0%	100.0%	100.0%	100.0%
2013/14	74.4%	100.0%	100.0%	100.0%	100.0%	100.0%
2014/15	76.4%	76.4%	76.9%	76.9%	82.2%	82.6%
2015/16	58.8%	63.0%	72.8%	75.3%	94.2%	96.7%
2016/17	70.7%	79.8%	89.3%	89.7%	97.9%	100.0%
2017/18	77.3%	88.8%	90.5%	90.5%	92.6%	93.0%
Average	74.2%	86.4%	91.9%	92.2%	95.6%	96.1%

Table A2: Supply/demand reliability for Kingston at SH72

Season	50 l/s PR	50 l/s	MALF	90%MALF	50%MALF	10 l/s
2006/07	95.0%	100.0%	100.0%	100.0%	100.0%	100.0%
2007/08	67.1%	85.2%	89.7%	89.7%	91.8%	92.6%
2008/09	68.2%	83.5%	95.5%	95.9%	97.5%	97.9%
2009/10	81.8%	88.4%	90.5%	90.5%	90.5%	90.9%
2010/11	70.7%	92.6%	99.6%	100.0%	100.0%	100.0%
2011/12	86.4%	98.8%	100.0%	100.0%	100.0%	100.0%
2012/13	78.1%	90.5%	100.0%	100.0%	100.0%	100.0%
2013/14	75.2%	100.0%	100.0%	100.0%	100.0%	100.0%
2014/15	74.4%	74.4%	76.0%	76.4%	83.9%	84.3%
2015/16	65.4%	69.1%	79.0%	81.5%	93.8%	97.1%
2016/17	72.7%	82.2%	91.7%	92.6%	98.8%	100.0%
2017/18	81.0%	88.8%	89.7%	89.7%	91.7%	92.1%
Average	76.3%	87.8%	92.6%	93.0%	95.7%	96.3%

Table A3: Supply/demand reliability for Mulligan at SH72

Season	50 l/s PR	50 l/s	MALF	90%MALF	50%MALF	10 l/s
2006/07	95.9%	100.0%	100.0%	100.0%	100.0%	100.0%
2007/08	77.0%	88.1%	92.2%	92.2%	94.2%	94.7%
2008/09	77.3%	88.4%	97.1%	97.5%	98.8%	99.2%
2009/10	87.6%	91.3%	92.6%	92.6%	92.6%	93.0%
2010/11	83.9%	93.8%	99.6%	100.0%	100.0%	100.0%
2011/12	91.4%	99.6%	100.0%	100.0%	100.0%	100.0%
2012/13	87.6%	93.4%	100.0%	100.0%	100.0%	100.0%
2013/14	81.8%	100.0%	100.0%	100.0%	100.0%	100.0%
2014/15	81.0%	81.0%	82.2%	82.6%	88.4%	88.8%
2015/16	75.7%	78.2%	85.2%	86.8%	95.9%	97.1%
2016/17	81.4%	86.4%	93.8%	94.2%	99.2%	100.0%
2017/18	88.0%	92.1%	93.0%	93.0%	93.8%	94.2%
Average	84.0%	91.0%	94.6%	94.9%	96.9%	97.2%