To: James Adams, Tom De Pelsemaeker; Otago Regional Council

From: Richard Allibone, Water Ways Consulting Ltd

Date: 4 November 2019

Subject: Cardrona River flow scenarios

Dear James, Tom

I have used the Cardrona habitat model for the reach upstream of Mt Barker to assess the habitat provided for fish, invertebrate and algal taxa at five flows, 300 L/s, 600 L/s, 750 L/s, 900 l/s and 1150 L/s, the latter being used to represent habitat availble at the naturalised 7dMALF 1156 L/s (Table 1). I have also determined from the 1976 to 2018 Cardrona River flow time series (provided by NIWA) the number of days with water take restrictions and no water take at all (Table 2) and provided graphs of the calender years for three constrasting years (Figures 1-3). Further analysis of the partial iwater take restrictions will be required to determine the take restriction on any day as this varies from 1 L/s to 349 L/s (if the allocation is set at 350 L/s).

Habitat availability - algae

The algal taxa assessed can be divied into two groups – firstly diatoms that are desired taxa that provide food for invertebrates and are part of the base of the aquatic food chain. Secondly, there is a set of four undesired taxa, didymo, long green filamentous algal, short filamentous algal and *Phormidium* (the sometimes toxic blue-green algae). The analysis shows that as flow declines the area of diatom habitat decreases (Table 1)and this is in part due to the area of the river bed decreasing and in part due to declining water velocity making areas of the river unsuitable for diatoms.

Habitat for tow of the undesired taxa, didymo and *Phormidium* decreases as flow decliens and this is due to declining river size. Long green filamentous algal has an increase in habitat as water velocity drops as the river flow declines and is likley to become abundant at the 300 L/s flow, exceeding the periphyton guidelines (Biggs 2000[1]). Short filamentous algae has relatively stable habitat availabiity between 600 L/s and 2000 L/s and declines either side of this range.

Habitat availability - invertebrates

The macroinvertebrate fauna show a consistent trend of declining habitat with declining flow. The 300 L/s flow provides less than 50% of the habitat the nat7dMALF does for general inverterbate food producing habitat and for the caddisfly *Aoteapysche*. The flow also has habitatr available for the key fish food species, *Deleatidium*, at 51%. Conversely, 900 L/s provides 90% of the natural 7dMALF habitat for the majority ofhte inverterbate taxa.

Habitat availability – native fish

All species and for longfin eel size ranges retain a high proportion of the habitat availble at natural 7dMALFs at the lower flows. Ony at 300 L/s does the predicted habitat avilable fall below 80% of that avialable at 1150 L/s.

Habitat availability - trout

Habitat for the two trout speices, rainbow and brown trout has high rentention at the 900 L/s flow when compared to the natural 7dMALF. However, at 600 L/s habitat availble does decline and at 300 L/s habitat is often below 505 of that availble at the natural 7dMALF for all size classes of trout with the gretest imapcts on the larger juvenile trout and adult trout, rather than trout fry and spawning habitat.

[1] Biggs, BJF. (2000) New Zealand periphyton guideline: detecting, monitoring and managing enrichment of streams. Prepared for the Ministry for the Environment.

Table 1: SEFA physical habitat model outputs for habitat for algal, invertebrates and fish at five flows. Taxa in bold are undesireable taxa. Green shading indicates, greater than 80% habitat retention comapred to natural 7dMALF orange shading 80-50% habitat retention and red less than 505 habitat retention. Nuisance algal taxa in italics have reversed colour shading.

Taxa and habitat available	300L/s	600 L/s	750 L/s	900 L/s	1150 L/s
Algal taxa					
Diatom habitat (m^2/m)	0.259	0.624	0.974	1.324	1.965
Diatom habitat available compared to MALF	13.18%	31.75%	49.57%	67.38%	100 %
Didymo habitat (m^2/m)	*3.534*	*4.709*	*5.229*	*5.687*	*6.289*
Didymo habitat available compared to MALF	*56.19%*	*74.88%*	*83.15%*	*90.43%*	*100%*
Long green filamentous habitat (m^2/m)	*4.234*	*3.183*	*2.667*	*2.779*	*3.012*
Long green filamentous habitat available compared to MALF	*140.57%*	*105.68%*	*88.55*	*92.26%*	*100%*
Short filamentous habitat (m^2/m)	*2.464*	*4.011*	*4.471*	*4.702*	*4.941*
Short filamentous habitat available compared to MALF	*49.87%*	*81.18%*	*90.47%*	*95.16%*	*100%*
Phormidium habitat (m^2/m)	*5.056*	*6.325*	*6.741*	*7.194*	*7.881*
Phormidium habitat available compared to MALF	*64.15%*	*80.26%*	*85.55%*	*91.28%*	*100%*
General invertebrate habitat					
Food producing habitat	1.154	2.161	2.575	3.003	3.494
Food producing habitat available compared to MALF	33.03%	61.85%	73.70%	85.95%	100%
Invertebrate taxa – mayflies					
Deleatidium habitat	2.553	3.704	4.169	4.488	4.994
Deleatidium habitat available compared to MALF	51.12%	74.17%	83.48%	89.87%	100
Nesameletus habitat	2.331	2.921	3.099	3.126	3.161
Nesameletus habitat available compared to MALF	73.74%	92.41%	98.04%	98.89%	100
Invertebrate taxa – caddisflies					
Aoteapysche habitat	0.276	0.558	0.754	0.959	1.267
Aoteapysche habitat available compared to MALF	21.78%	44.04%	59.51%	75.69%	100%
Hydrobiosidae habitat	1.586	2.232	2.478	2.646	2.861
Hydrobiosidae habitat available compared to MALF	55.44%	78.01%	86.61%	92.49%	100
Olinga habitat	3.207	4.027	4.362	4.536	4.85
Olinga habitat available compared to MALF	66.12%	83.03%	89.94%	93.53%	100
Pynocentrodes habitat	2.037	3.03	3.397	3.595	3.871
Pynocentrodes habitat available compared to MALF	52.62%	78.27%	87.76%	92.87%	100
Native fish species					
Flathead habitat	3.9845	4.8415	5.138	5.2985	5.5555
Flathead habitat available compared to MALF	71.72%	87.15%	92.48%	95.37%	100%
Upland bully habitat	3.208	3.016	2.748	2.544	2.494
Upland bully habitat available compared to MALF	128.63%	120.93%	110.18%	102.00%	100%
Longfin eel >300 mm habitat	0.465	0.551	0.534	0.49	0.414
Longfin eel >300 mm habitat available compared to MALF	112.32%	133.09%	128.99%	118.36%	100%

Longfin eel <300 mm habitat	3.017	3.901	4.138	4.246	4.219
Longfin eel <300 mm habitat available compared to MALF	71.51%	92.46%	98.08%	100.64%	100%
Trout					
Brown trout spawning	0.744	0.996	0.918	0.865	0.787
Brown trout spawning habitat available compared to MALF	94.54%	126.56%	116.65%	109.91%	100%
Brown trout <100 mm habitat	4.188	5.691	6.253	6.596	6.975
Brown trout <100 mm habitat available compared to MALF	60.04%	81.59%	89.65%	94.57%	100%
Brown trout juvenile habitat	0.843	1.297	1.496	1.668	1.909
Brown trout juvenile habitat available compared to MALF	44.16%	67.94%	78.37%	87.38%	100%
Rainbow, brown trout juvenile habitat	1.428	2.473	2.94	3.385	4.076
Rainbow, brown trout habitat available compared to MALF	35.03%	60.67%	72.13%	83.05%	100%
Brown trout adult habitat (Hayes & Jowett)	0.068	0.15	0.185	0.215	0.226
Brown trout adult habitat available compared to MALF	30.09%	66.37%	81.86%	95.13%	100%
Rainbow, brown trout adult habitat (Wilding)	0.151	0.259	0.314	0.367	0.651
Rainbow, brown trout adult habitat available compared to MALF	23.20%	39.78%	48.23%	56.37%	100%
Brown trout adult habitat (Bovee, modified)	0.240	0.418	0.497	0.563	0.651
Brown trout adult habitat available compared to MALF	36.87%	64.21%	76.34	86.48%	100%

Water abstraction reliability

The analysis of the modelled Cardrona River flow series indicates the water take restrictions will be uncommon if the minimum flow is set at 300 L/s. At this flow the minimum flow would result is partial water take restrictions but some water would be available on all days even during very dry years (e.g., 1978, see Figure 1). At the higher minimum flow rates partial and complete restriction of water takes occurs (Table 2). In addition, the duration of complete restriction can exceed 60 days in dry years for the 900 L/s and natural 7dMALf minimum flow scenarios. This analysis has considered the full calender year rather than just the irrigaiton season. It is noteable that during some winter periods river flows are low and abstraction would also be restricted (e.g., 1992, Figure 2). There are also wet years were water abstraction is rarely restricted by the minimum flow at any level and/or the level of partial retriction is small when present (e.g., 2005 Figure 3).

Table 2: Days of irrigation restriction at four minimum flows and a primary allocation of 350 L/s. For flows from 1976 to 2018 model from Lindis Peak flow record.

Minimum flow	Days of complete restriction	Days of partial restriction	Maximum number of sequential days of full restriction	Complete restriction days (%)	Partial restriction days (%)
Natural flow regime days under 300 L/s	0	64	0	0	0.41%
Natural flow regime days under 600 L/s	40	538	11	0.07%	3.47%
Natural flow regime days under 750 L/s	170	1369	28	1.10%	8.83%%

Natural flow regime days under 900 L/s	413	1782	62	2.68%	11.50%
Natural flow regime days under 1150 L/s	1369	2880	66	8.82%	18.58%

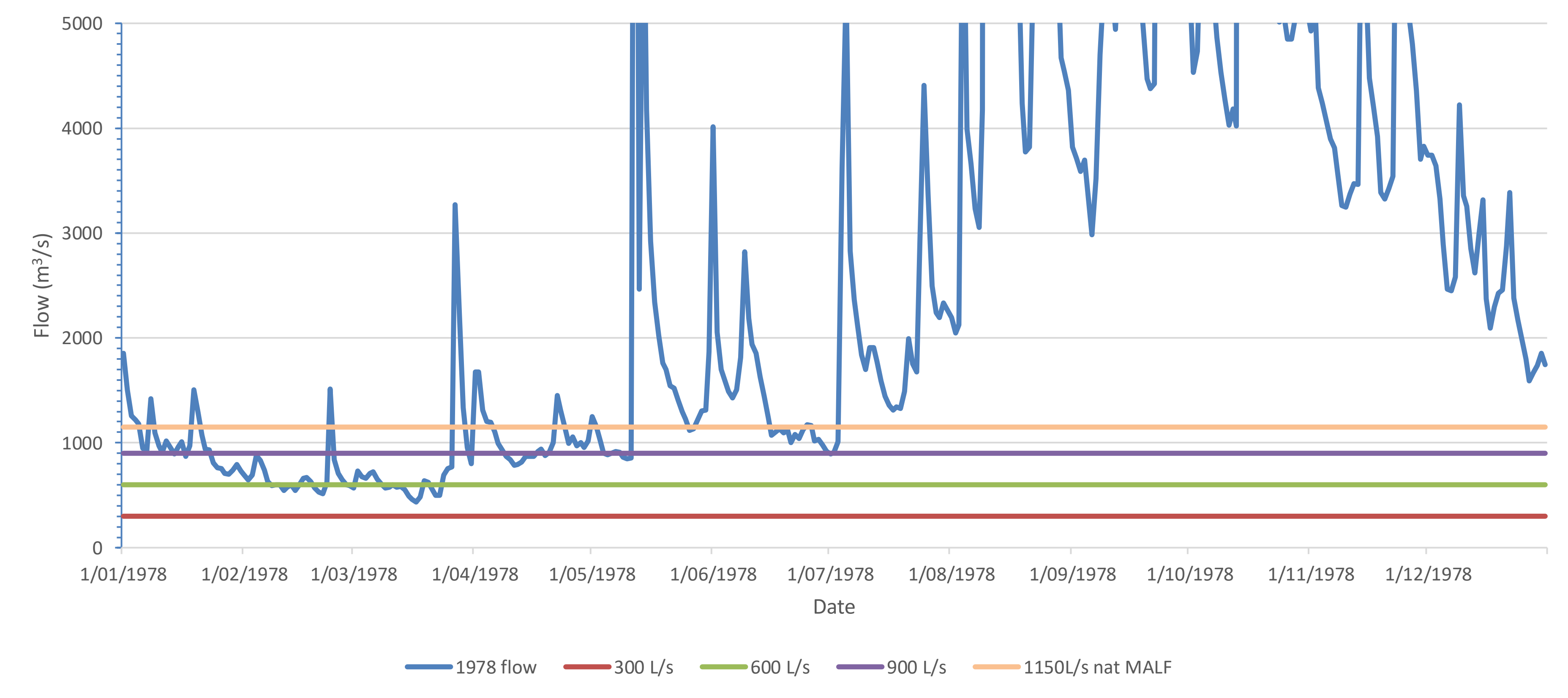

Figure 1: The Cardrona River flow for 1978 and example minimum flows.

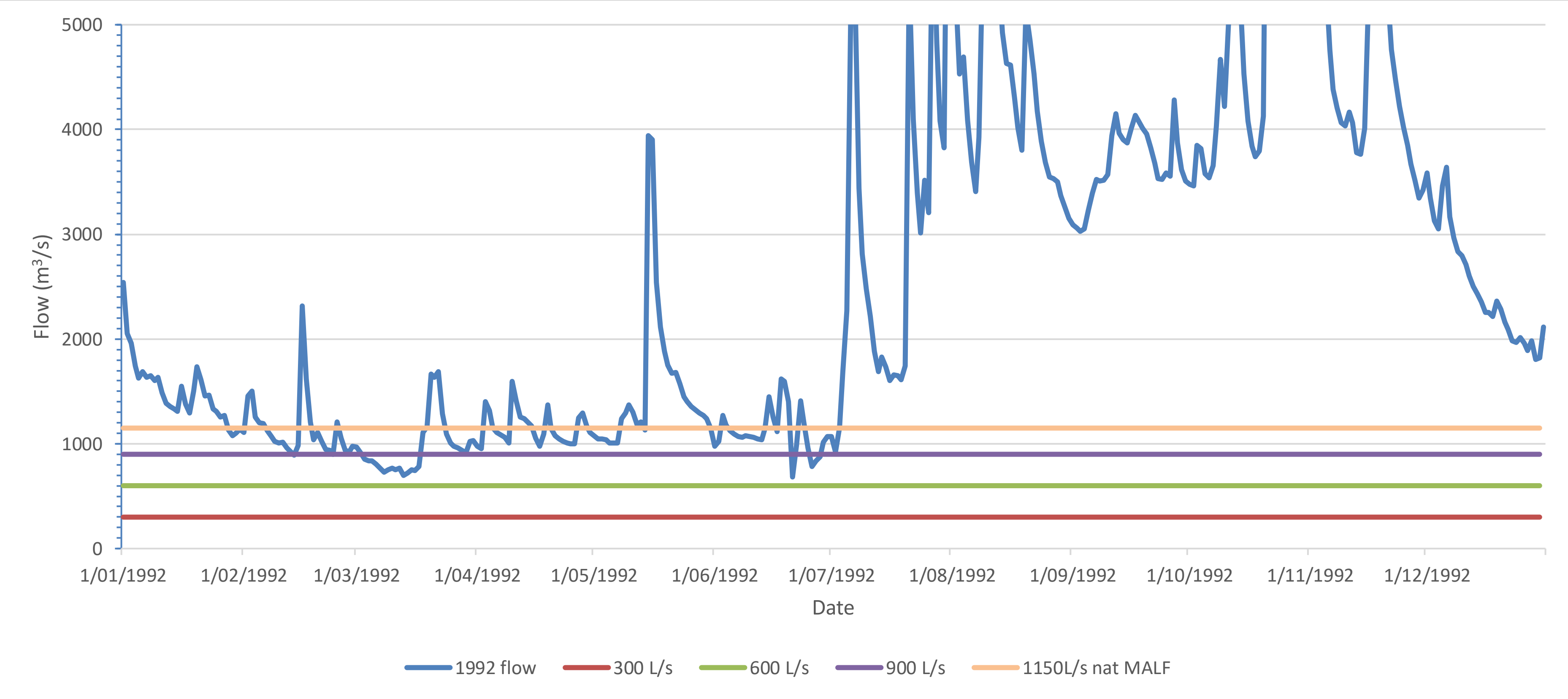

Figure 2: The Cardrona River flow for 1992 and example minimum flows.

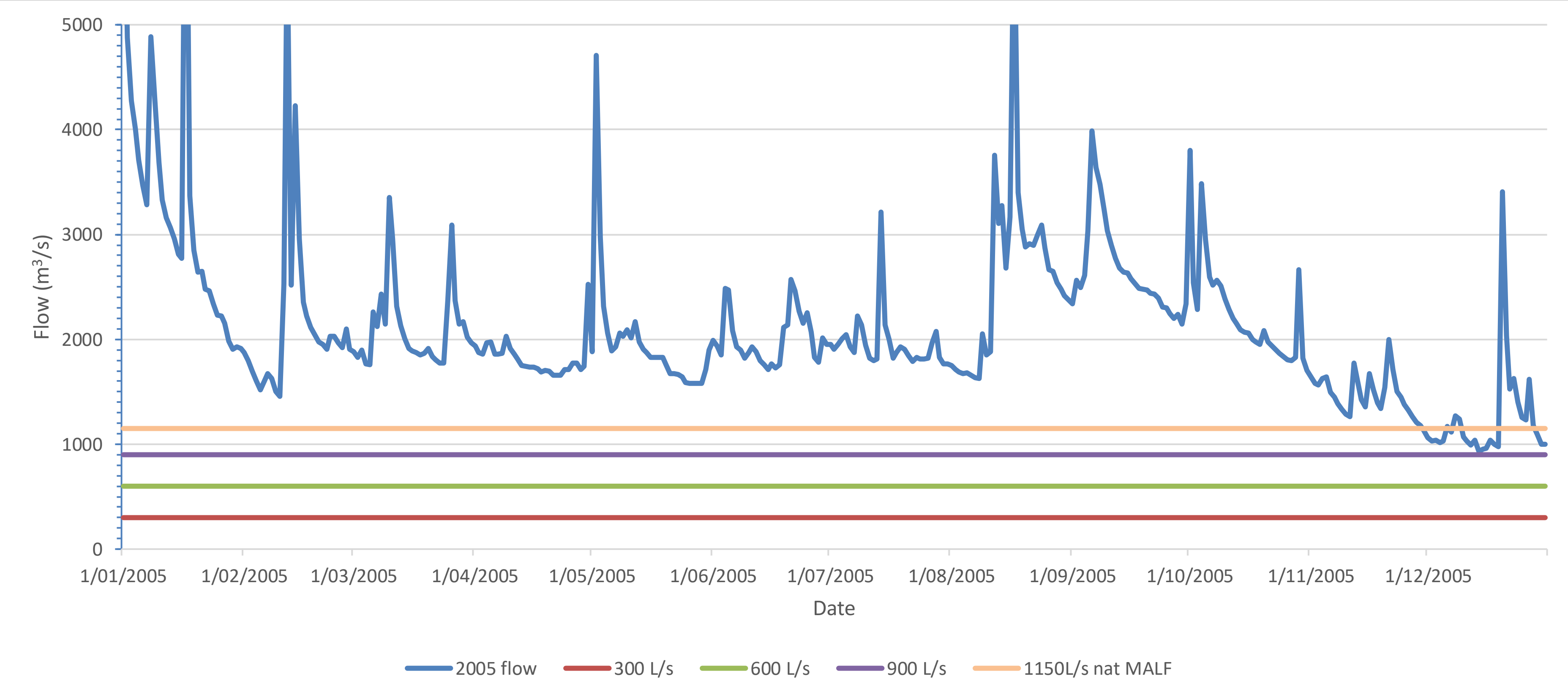

Figure 3: The Cardrona River flow for 2005 and example minimum flows.