Aquatic ecology considerations relating to Amuri Irrigation's proposed hydro-electric power scheme

Prepared for Amuri Irrigation Limited

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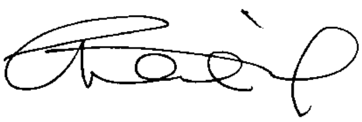	Reviewed by:	Cathy Kilroy
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Cover image: Looking downstream in the Pahau River from the proposed discharge location.

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Executive summary

Amuri Irrigation Company Limited (hereafter AIC) is the North Canterbury water supply company that operates the Amuri Irrigation Scheme (AIS) and delivers water to shareholders who irrigate over 28,000 ha in the Amuri Basin. In 2017, AIC upgraded most of the open race canal network on the Waiau and Balmoral sections of the AIS to a pressurised pipe network. AIC are now proposing to establish and operate two small hydro-electric power stations (HEPS) that would discharge into the Pahau River and Lowry Peaks Drain. At present, AIC's existing consents to take, use and discharge water during the irrigation season enable Amuri to generate hydroelectricity during the irrigation season at these sites but not outside the irrigation season. Following the submission of AIC's resource consent application, and subsequent discussions with Environment Canterbury (ECan), NIWA has been requested to provide a report examining the actual and potential effects on the flow regime of the Lowry Peaks and Pahau Rivers from the applicant's proposed activity.

Hydrological models for both the Pahau River and Lowry Peaks Drain were provided to NIWA by Amuri's hydrological consultant. The hydrological modelling of the HEPS is relatively straightforward because there is no water storage associated with either of the proposed HEPS; when consented water is not required for irrigation it is proposed to be used for electricity generation. For both waterways, summary hydrological statistics were available for approximately the last seven years. Three modelled scenarios were compared: (1) no bywash from the AIS, (2) historic or status quo bywash, and (3) proposed HEPS flows.

For the Pahau River, a flow of up to 3.35 m^3/s could be available for hydro-generation. Although the proposed HEPS would potentially operate year-round, imposed water restrictions during dry months may mean that hydro-generation would seldom operate at these times. Flow modelling indicates that under a hydro-generation scenario, the minimum flow (e.g., 7-day mean annual low flow) would be increased relative to a status quo and no bywash scenario. Examination of representative dry and wet year hydrographs for the Pahau River showed low flows can occur at varying times of the year. The Pahau River requires mid to high flows to prevent the accumulation of nuisance periphyton and fine sediment, and the addition of the HEPS discharge would increase the frequency of flow events exceeding three and five times the median flow (FRE3 and FRE5) but would not alter the frequency of flood events ten times the median flow (FRE10). The wide, shallow channel profile of the Pahau River suggests that increasing discharge from the HEPS will likely result in lateral channel expansion and inundate new habitat. Relative to the Lowry Peaks Drain, there is the potential for a larger varial zone (i.e., the area that is watered/dewatered) to occur in the Pahau River because of the channel morphology.

The maximum flow for hydro-power generation in the Lowry Peaks Drain is 2.78 m^3/s. Under the proposed hydro-generation scenario, the minimum flow in the Lowry would be equal or lower compared to the historic bywash scenario (pre-piping). Post-piping bywash flows have been limited to about 290 L/s (~10% of the pre-piping bywash), in part because most of the Waiau scheme bywash now occurs further up the AIS; the proposed hydrogeneration would increase the minimum flow in the drain during the irrigation season. Outside of the irrigation season the flow regime would markedly change, consistently staying above 2.8 m^3/s during dry and wet years in winter months. This catchment is dominated by groundwater inputs so the addition of the HEPS discharge increases the frequency of mid-range flow events. The more incised channel morphology of the Lowry Peaks Drain means that increased flow is likely to result in increased water depth and higher velocities rather than lateral channel expansion.

Effects of changing the flow regime on aquatic ecology

ECan have stated that the proposed HEPS will result in "very stable and flat-lined flow discharge periods particularly in the autumn, winter and spring", based on the analysis of the hydro-generation scenarios for both proposed HEPS there is limited evidence to support this statement, particularly for the Pahau HEPS. Installation of the proposed HEPS in the Pahau River is predicted to result in an overall increase in mean flow but will not alter underlying changes in flow variability. Whether or not extended periods of naturally low winter flow variability have an increased adverse impact on aquatic ecology at a higher base flow (as a result of the proposed HEPS) than at current base flows cannot be predicted based on available data.

Consequently, NIWA recommends:

- an adaptive winter monitoring programme to examine whether the scheme is having a detectable effect on aquatic ecology during the period of full HEPS discharge. This monitoring programme should consist of flow, water quality, periphyton, invertebrate and fish monitoring;
- sampling occurring no less than three times per year on the Pahau River: early March (prior to irrigation season shut-down), mid-May (approx. end of irrigation/start of full hydro-generation) and early September (approx. end of full hydro-generation/start of irrigation season). Results from this sampling programme should be reviewed annually to determine whether changes are needed. The monitoring should occur for at least three years with the duration of the monitoring dependent on the responses of the variables measured (e.g., fish are long-lived and may need to be monitored for longer than periphyton);
- a less intensive monitoring programme is considered appropriate for Lowry Peaks Drain but particular trigger levels would be set and any exceedances of these triggers would prompt increased monitoring.

ECan have also noted justified concerns that rapid increases and decreases in flow will have adverse effects on aquatic habitats and riverine biota. A large varial zone that is regularly watered/dewatered is a key consideration when examining the potential effects of hydro-generation on aquatic fauna (and will be examined by the monitoring proposed above); the channel profile of the Pahau River means this concern is particularly relevant to the Pahau HEPS. Based on the current 'water ordering' process for Amuri stakeholders, having rapidly changing varial zones over short time scales is unlikely and does not reflect how NIWA has been informed the proposed HEPS would operate. That noted, rapid flow reductions from HEPS have the potential to impact aquatic ecology, particularly if flows are reduced too quickly.

To mitigate this effect, NIWA recommends:

- a consent condition requiring a ramping rate restriction no faster than -3 cm/30 mins. For clarity, this ramping rate restriction only applies when reducing HEPS discharge.

Effect of flow regime change on salmonid spawning activity

The issue has also been raised about the potential for significant salmonid spawning activity in the Lowry Peaks Drain as a consequence of the proposed HEPS. This was examined by a salmonid spawning survey walk of the affected reach. Based on reach-scale observations and known salmonid spawning preferences and behaviour, increased salmonid spawning in the drain is not considered by NIWA to be an issue of concern.

To confirm this conclusion, NIWA recommends:

- in the first year of scheme operation, a survey walk be replicated during the brown trout spawning season to confirm there has not been increased salmonid spawning occurring downstream of the HEPS discharge.

Conclusion

The potential effects of the proposed HEPS on aquatic ecology, outside of the irrigation season, are likely to be *minor* (or less). The recommendations provided above are expected to provide certainty of this conclusion through either mitigating potential effects or monitoring to check for any adverse effects on aquatic ecosystems.

1 Introduction

Amuri Irrigation Company Limited (hereafter AIC) is the North Canterbury water supply company that operates the Amuri Irrigation Scheme (AIS). The scheme delivers water to its shareholders who irrigate over 28,000 ha in the Amuri Basin. In 2017, AIC upgraded the majority of the open race canal network on the Waiau and Balmoral sections of the AIS to a pipe network; the pipe network is approximately 130 km long. The key project driver was to deliver water under pressure to shareholders although there were a number of additional reasons for undertaking the upgrade (e.g., improving efficiency of water use, increasing accuracy of flow measurement and allocation). Pressurised water reduces shareholders' operating costs and safeguards against potential future energy cost increases but also provides AIC with an opportunity to generate hydroelectricity when there is surplus water available (i.e., when AIC's resource consent permits them to supply more water than their shareholders demand).

AIC are now proposing to establish and operate two hydro-electric power stations (hereafter HEPS) linked to the pressurised pipe network that would discharge into the Pahau River and Lowry Peaks Drain (Greaves 2020) (Figure 1-1). At present, AIC's existing consents to take, use and discharge water during the irrigation season enable Amuri to generate hydroelectricity during the irrigation season but not outside the irrigation season. Based on discussions with AIC, NIWA understands the irrigation season varies between years but could reasonably be expected to include August through to mid-May; outside this period there would rarely be a soil moisture deficit across the Culverden Plains.

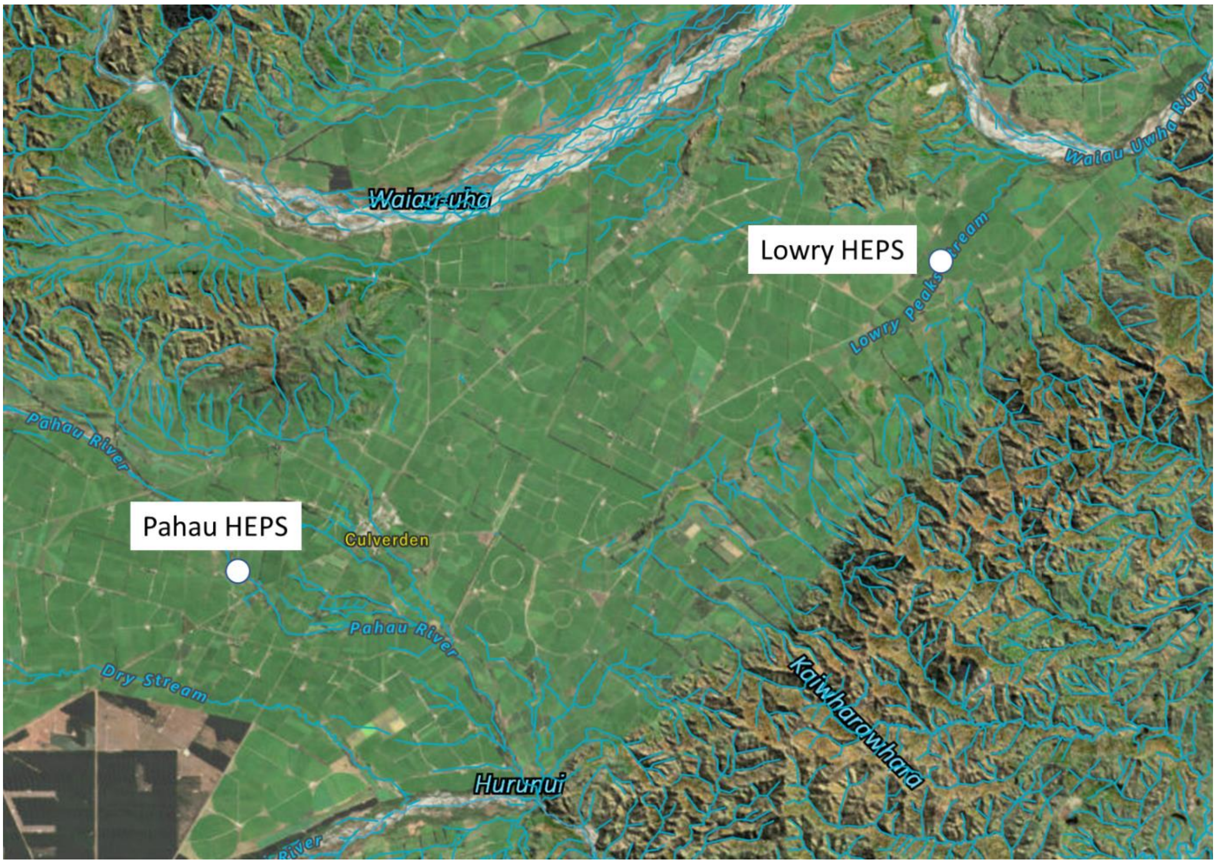

Figure 1-1: Location map for the two proposed hydro-electric power scheme (HEPS) discharges.

1.1 Project scope

Following the submission of AIC's resource consent application (Greaves 2020), we understand that Environment Canterbury's Section 92 response requested additional information in seven technical areas associated with 'Actual and potential adverse effects on surface water quality and aquatic ecology'. NIWA understands that AIC's planning (Enspire) and ecology (Ryder) consultants have progressed discussions with Environment Canterbury (ECan) to a point where there are two issues outstanding for AIC to address[1]. NIWA have been requested to provide a report examining one of these issues:

- *Actual and potential effects on the flow regime of the Lowry Peaks and Pahau Rivers*.

ECan's report states that the proposed hydro will result in "very stable and flat-lined flow discharge periods particularly in the autumn, winter and spring". ECan also has concerns that rapid increases and decreases in flow will have adverse effects on aquatic habitats and riverine biota.

In a subsequent discussion between NIWA and ECan, the opinion of the regulator (ECan) was that the current consents permit hydropower discharges during the irrigation season. For the use and discharge of water for hydro-electric generation outside of the irrigation season, Greaves (2020) considered that a new resource consent was required (and was sought). AIC contend that in seeking a new consent any effects associated with hydro-electricity generation in the irrigation season are permitted under their existing consents and ECan must limit their evaluation to effects outside of the irrigation season. Because of this, the focus of this report is predominately on the period from May to August (outside of the irrigation season) but does provide some interpretation outside of these months, where appropriate.

1.2 Approach

A potential pathway forward was discussed with ECan around the usefulness of additional hydrological analyses that provided annual hydrographs illustrating flow regime variability under contrasting climate conditions. The low rainfall and lack of north-westerly-driven floods during the most recent irrigation season (September 2020 to May 2021) were noted as representative of a potentially extreme irrigation year. Such extreme years illustrate high natural variability in flow regimes. An analysis of hindcast modelled discharge combined with expected discharge from the proposed HEPS in both "dry" and "wet" years would provide more transparent information about the effects of the HEPS on flow regimes than the table of summary flow statistics currently provided. Moreover, coupling additional hydrological analyses with an interpretation of the implications of the modified flow regime for aquatic ecology was identified as being needed.

Furthermore, AIC (Andrew Barton) organised a meeting between AIC, NIWA (Phil Jellyman) and North Canterbury Fish and Game (NCFG, Rasmus Gabrielsson) on 15 December 2021 to hear any concerns that NCFG might have so that these could also be included in the NIWA assessment. The principal concern that arose during that discussion related to NCFG wanting NIWA to provide an evaluation of the likelihood of increased salmonid spawning potential — for both brown trout and Chinook salmon — in the Lowry Drain as a result of the proposed HEPS activity. AIC subsequently expanded the scope of this report to include an evaluation on this issue in response to the concern raised by NCFG.

[1] With the permission of AIC CEO Andrew Barton, Phil Jellyman contacted Adrian Meredith (Principal Scientist – Water Quality and Ecology) from ECan on 21/6/21 and confirmed that only two issues needed additional work.

2 Hydrological models

2.1 Pahau River model

The hydrological model of the Pahau River was first described in Brown (2019) and has been extended by three years in Brown (2021a). The model includes inflows from hill runoff, groundwater, and bywash, as well as losses from irrigation abstraction and sub-surface flow; for further model description see Brown (2021a). Brown (2021a) modelled three flow scenarios in the Pahau River (at Dalzells Bridge[2]):

1. Status quo irrigation bywash.
2. Proposed hydro-electric power scheme (HEPS) flows.
3. No bywash.

The first scenario of status quo irrigation bywash is markedly different at present compared to pre-piping for the AIS. Brown (2021a) noted that AIC bywash has contributed a significant portion of the Pahau River flow since the scheme (i.e., the open race canal network) was installed approximately 40 years ago. Pre-piping bywash flows were higher than at present because of bywash from both the Balmoral and Waiau schemes; bywash provided, on average, 33% of mean flow in the Pahau River (Brown 2021a). Since the 2017 piping upgrade, bywash has primarily been from the Balmoral Scheme only, although Waiau Scheme discharges do still occur (Appendix A). Since the upgrade, bywash has comprised an average of 14% of mean flow in the Pahau River (Brown 2021a) (Appendix B).

Under scenario two, the HEPS flows would replace the race bywash flow since both come from the same source (i.e., any bywash would be lost generation flow). Brown (2021a) assumed a maximum hydro-generation flow of 3.35 m^3/s. The flow model for scenario two was the most complex because flows were generated from an integrated catchment and infrastructure model which considers Hurunui River restrictions, AIC scheme irrigation demand and pipeline capacity constraints.

The third scenario of no bywash was modelled by Brown (2021a) from 1961–2021. Note that this scenario should not be considered a 'naturalised flow record' because it incorporates irrigation recharge of groundwater which significantly influences the surface water flow regime. Brown (2021a) notes that in the absence of this irrigation recharge in the model, prior to irrigation on the Amuri Plains the Pahau River (at Dalzells Bridge) would at times have been predicted to have no surface flow, with a seven-day mean annual low flow (7DMALF) of close to zero.

The hydrological statistics generated for each of these models are presented in Table 2-1 and analysed/interpreted in Section 3. Example hydrographs for both dry (Figure 2-1) and wet (Figure 2-2) years are also shown to illustrate how hydro-generation would have likely altered the flow regime during those years relative to the other scenarios outlined above.

[2] The Dalzells Bridge site is an ECan operated site located on private farmland (Dalzell's Farm). The location is approximately 1 km upstream of the confluence with the Hurunui River (and 750 m upstream of the confluence with St Leonards Drain).

Table 2-1: Summary of key hydrological statistics for Pahau River. Statistics are for the period 1 January 2014–31 May 2021. Frequency (FRE) *x* calculations assume a minimum of 10 days between independent events. Data source: Brown (2021a).

Flow measure		Status quo irrigation bywash	Hydro-generation	No bywash
1D-MALF		0.64	0.86	0.49
7D-MALF		0.70	1.02	0.53
30D-MALF		1.02	1.55	0.66
1D-MALF/Mean		0.20	0.18	0.21
BFI (7D-MALF/Mean)		0.22	0.21	0.22
30D-MALF/Mean		0.32	0.33	0.28
Mean		3.18	4.76	2.38
Median		2.20	4.21	1.30
1%ile		0.50	0.91	0.32
5%ile		0.87	1.30	0.52
95%ile		7.23	9.58	6.28
99%ie		22.64	25.99	22.64
CV of Flow		1.45	1.04	1.94
FRE1	Status quo median used for all scenarios	7.29	3.91	7.83
FRE2		8.77	6.75	7.02
FRE3		6.48	7.15	4.99
FRE5		3.91	4.72	3.51
FRE10		1.89	1.89	1.89

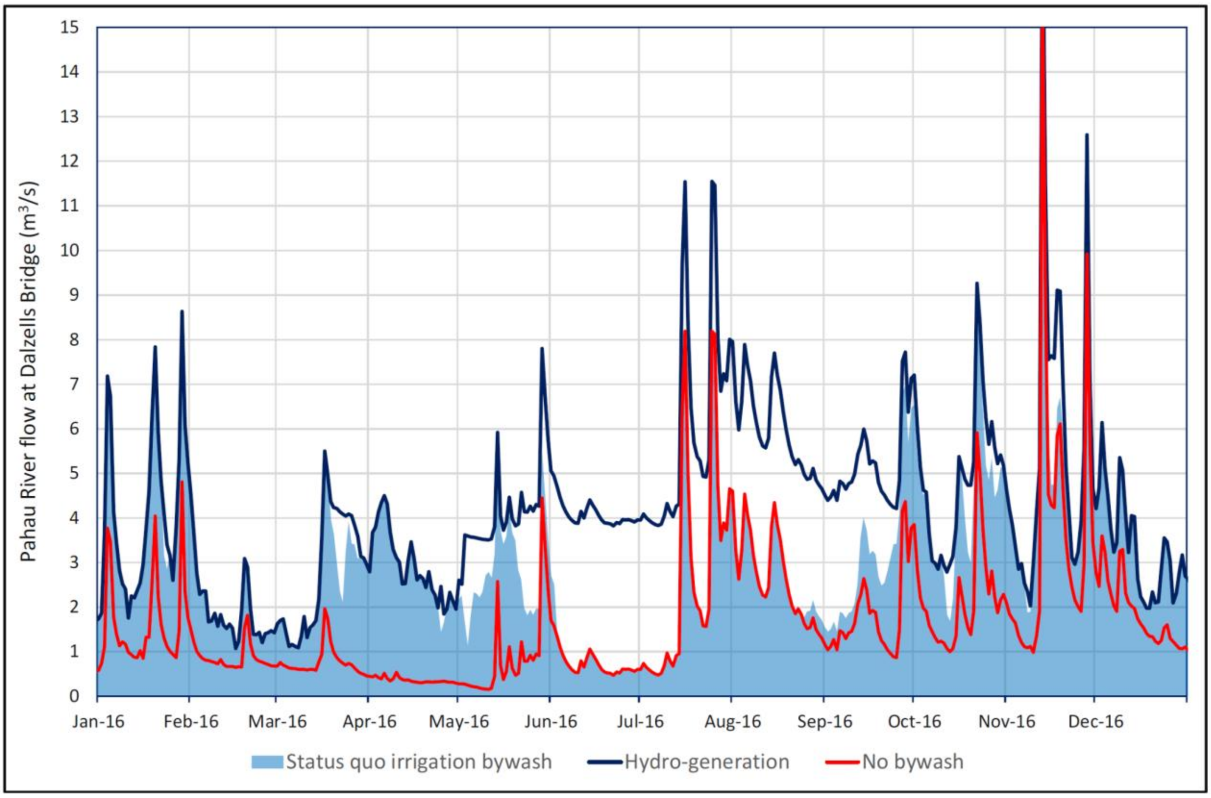

Figure 2-1: Modelled results for a representative dry year in the Pahau River. Source: Brown (2021a).

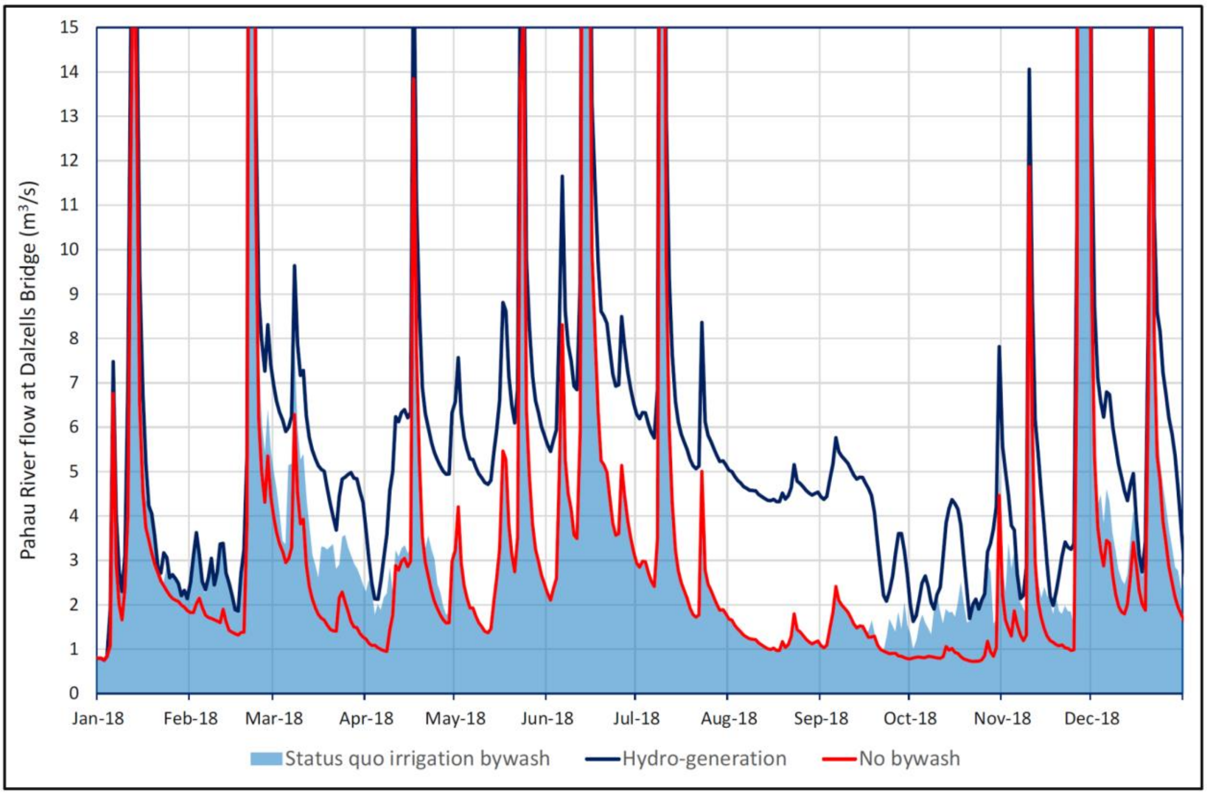

Figure 2-2: Modelled results for a representative wet year in the Pahau River. Source: Brown (2021a).

2.2 Lowry Peaks Drain model

The hydrological model of the Lowry Peaks Drain was first described in Brown (2019) and has been extended by three years in Brown (2021b). The model includes inflows from hill runoff, groundwater, and bywash, as well as losses from irrigation abstraction and sub-surface flow; for further model description see Brown (2021b). Brown (2021b) modelled three flow scenarios in the Lowry Peaks Drain (at Longbrook Dairy Bridge[3]):

1. Historical irrigation bywash.

2a. Proposed HEPS flows (integrated model).

2b. Proposed HEPS flows (simple model – measured flow less bywash plus hydro).

3a. No bywash (integrated model).

3b. No bywash (simple model – measured flow less bywash).

The first scenario of historical irrigation bywash has used the historic bywash inflow timeseries for the period June 2015 to May 2017 and used these to simulate historical bywash for June 2017 to May 2021 when the network was piped. Pre-piping bywash flows were significantly higher than at present. Post-piping bywash flows have been limited to about 290 L/s which is approximately 10% of the pre-piping bywash flow (Brown 2021b), in part because most of the Waiau scheme bywash now occurs further up the AIS. Historic bywash contributed, on average, 43% of mean flow in the Lowry Peaks Drain, and groundwater 55%, the remainder being hill runoff (Brown 2021b) (Appendix B).

Under scenario two, a maximum hydro-generation flow of 2.78 m^3/s is assumed. The HEPS modelled flows for scenario two were from an integrated catchment and infrastructure model which considers Waiau River restrictions, AIC scheme irrigation demand and pipeline capacity constraints (Brown 2021b).

The third scenario of no bywash was modelled by Brown (2021b) from 1961–2021. As noted for the Pahau River, this scenario should not be considered a naturalised flow record because it incorporates irrigation recharge of groundwater which significantly influences the surface water flow regime. Brown (2021b) notes that in the absence of this irrigation recharge in the model, prior to irrigation on the Amuri Plains that Lowry Peaks Drain would be predicted to be dry at Longbrook Dairy bridge for extended periods of time, during a dry year.

For each of scenario two and three, there is an additional model (simple model) that was not used in the Pahau River. Brown (2021b) noted that the model fit of the integrated model with measured data was not particularly good because of uncertainties in the bywash inflows and irrigation abstractions from private water rights. Because bywash and irrigation abstraction can account for a large proportion of the drain flow, uncertainties in these numbers have a significant impact on the predicted flows. Therefore, a simple surface water only model is provided for comparison, which takes the measured flow, subtracts the estimated bywash flow, and adds the modelled hydro-generation flow (the latter only occurs in scenario two). For the simple model Brown (2021b) notes it "provides very poor low flow predictions because it fails to account for the significant flow buffering that the groundwater system provides. This model also does not account for changes in irrigation abstraction and land surface recharge."

[3] The Longbrook Dairy Bridge site is an ECan operated site located approximately 1 km upstream of the confluence with the Waiau River.

The hydrological statistics generated for each of these models are presented in Table 2-2 and analysed/interpreted in Section 3. Example hydrographs for both dry (Figure 2-3) and wet (Figure 2-4) years are also shown to illustrate how hydro-generation would have likely altered the flow regime during those years relative to the other scenarios outlined above.

Table 2-2: Summary of key hydrological statistics for Lowry Peaks Drain. Note, statistics are for the period 18 August 2015–15 May 2021. FRE *x* calculations assume a minimum of 10 days between independent events and a constant median flow has been applied across all scenarios for comparative purposes. Statistics from the two simple models are highlighted in blue. See note below. Data source: Brown (2021b).

Flow measure		S1 (historic bywash)	S2a (hydro)	S2b (hydro & simple model)	S3a (no bywash)	S3b (no bywash & simple model)
1D-MALF		0.20	0.20	-0.21	0.08	-0.23
7D-MALF		0.28	0.25	-0.12	0.10	-0.14
30D-MALF		0.39	0.34	0.11	0.17	0.00
1D-MALF/Mean		0.13	0.09	-0.09	0.18	-0.45
BFI (7D-MALF/Mean)		0.18	0.11	-0.05	0.22	-0.27
30D-MALF/Mean		0.25	0.16	0.05	0.37	0.00
Mean		1.54	2.17	2.21	0.46	0.50
Median		1.51	2.78	2.74	0.29	0.37
1%ile		0.12	0.10	-0.50	0.00	-0.61
5%ile		0.26	0.18	-0.16	0.04	-0.33
95%ile		2.76	4.02	4.20	1.36	1.59
99%ie		3.47	4.70	6.02	2.08	3.27
CV of Flow		0.48	0.64	0.72	0.97	1.51
FRE1	Scenario 1 median used for all scenarios	8.20	5.23	5.23	1.92	2.44
FRE2		2.27	4.88	5.58	0.52	1.22
FRE3		0.35	1.40	2.09	0.17	1.05
FRE5		0.00	0.17	0.87	0.00	0.35
FRE10		0.00	0.00	0.00	0.00	0.00

Note, Brown (2021b) states "Simple modelling results are included only for reference. I do not recommend these be used in further analysis due to the inferior low flow model performance. Furthermore, in scenario analysis the simple model should not be mixed with the integrated model, since to do so would not be an 'apples with apples' comparison".

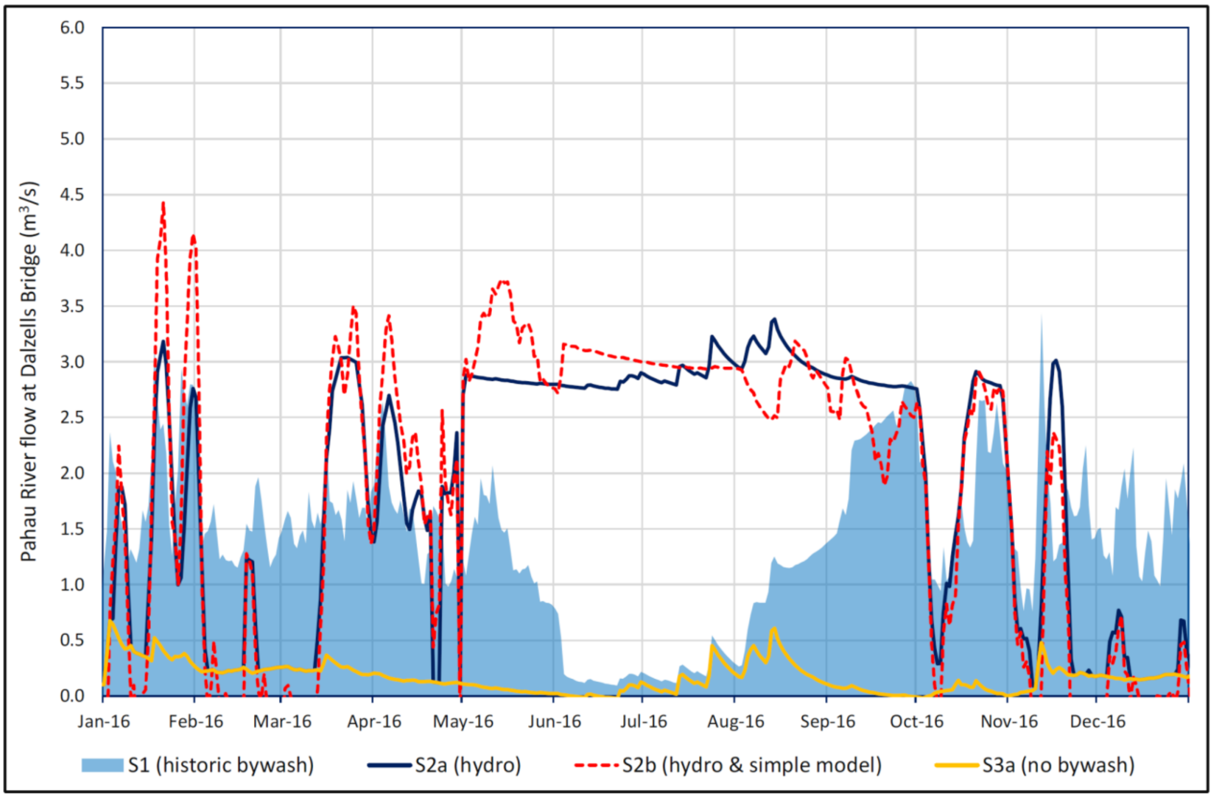

Figure 2-3: Modelled results for a representative dry year in the Lowry Peaks Drain. Source: PZB consulting.

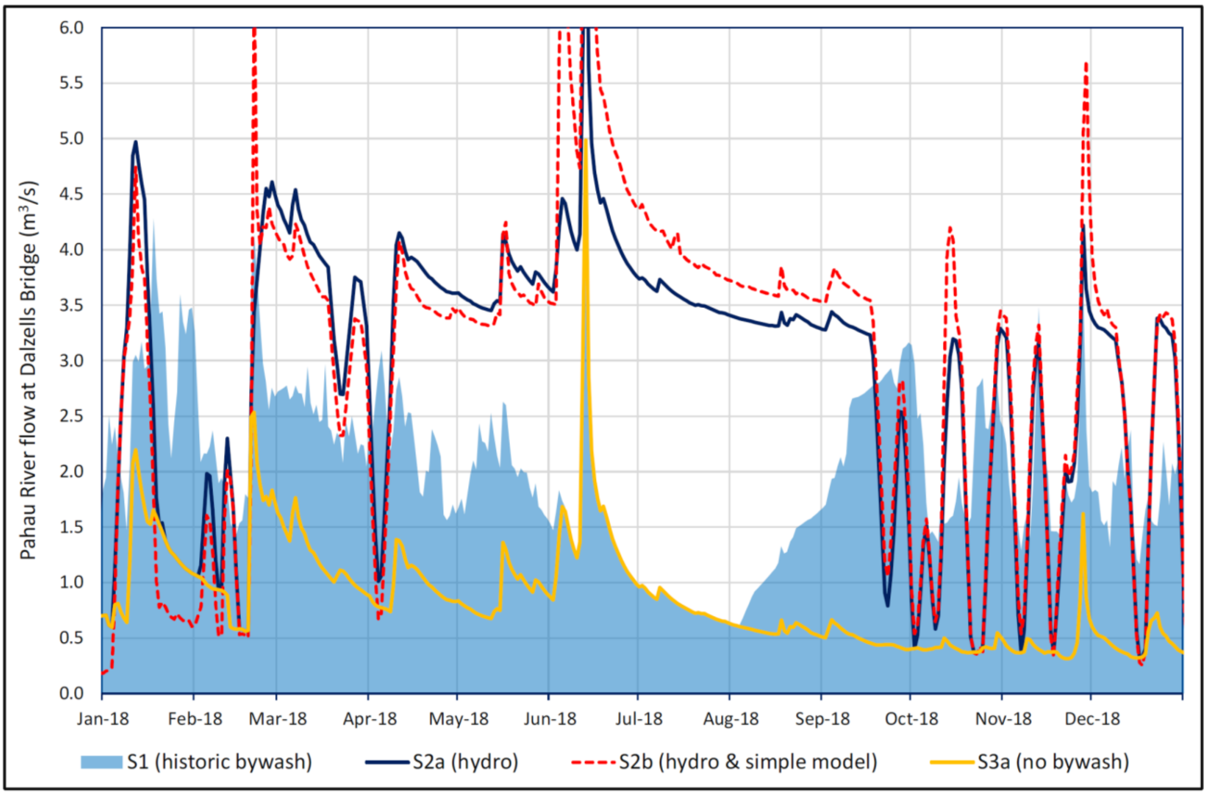

Figure 2-4: Modelled results for a representative wet year in the Lowry Peaks Drain. Source: PZB consulting.

3 Flow regime effects on aquatic ecology for the Pahau and Lowry HEPS

Below I outline and evaluate four aspects of the flow regime that are typically considered when examining how a proposed HEPS could impact the aquatic ecology of receiving waterways.

From the discussion below, it should be apparent that several of the effects on flow regimes that would be considered for an 'on river' HEPS are of lower relevance for the 'end-of-pipe' HEPS scheme proposed by Amuri. End-of-pipe HEPS differ from on-river HEPS in the following ways: (1) the water is typically sourced from a mainstem river so the receiving waterways are receiving additional water, not having surface waters consumed for hydro-generation, (2) the absence of a storage reservoir in end-of-pipe schemes means freshes and floods are not captured for later release as is common for many on-river HEPS, (3) the absence of a dam means upstream passage is not directly impacted by the HEPS. An end-of-pipe HEPS will still modify the flow regime in the receiving waterways, so it is still appropriate to consider all four aspects of the flow regime, but it is pertinent to be aware of these differences when evaluating the relative importance in terms of effects on the aquatic ecosystem.

In subsequent sections, the general rationale for examining each flow regime effect is explained and then the possible consequences for aquatic ecology in the two receiving waterways are evaluated separately. This separate analysis is in part because the receiving waterways for the two proposed hydro-power stations have contrasting hydrology; flow in the Pahau River is primarily influenced by runoff/hydrology in the Tekoa and Culverden ranges whereas groundwater availability determines the flow regime of the Lowry Peaks Drain (see Figure 3-1). Thus, effects of hydropower generation on the flow regime and aquatic biota are also likely to differ between these waterways.

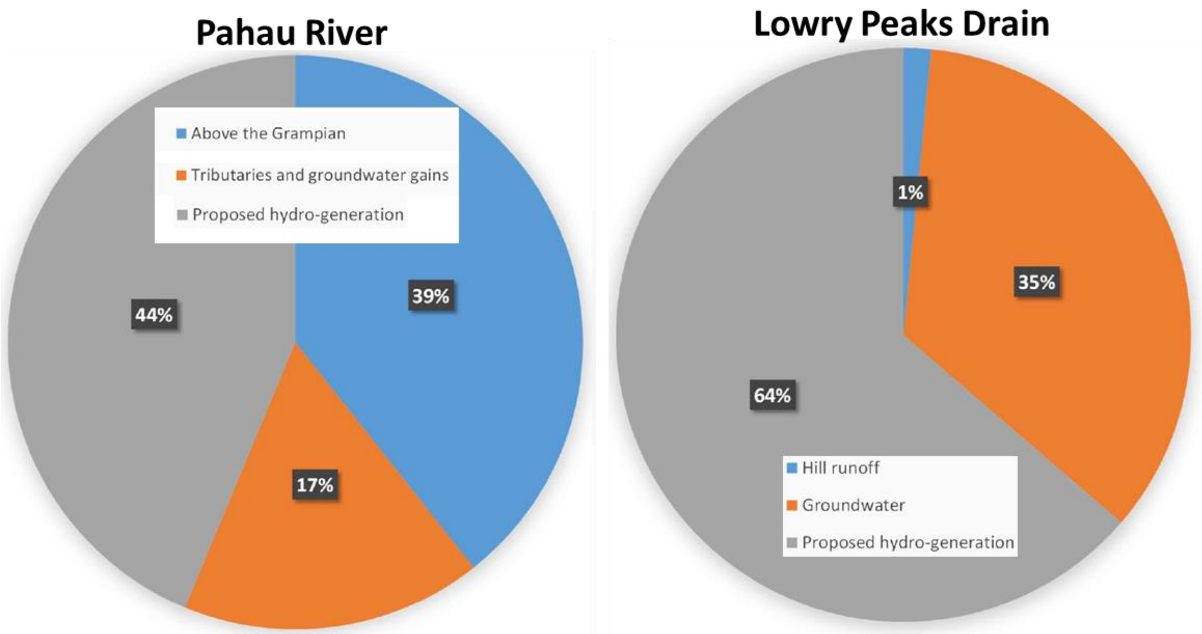

Figure 3-1: A comparison of the predicted flow contributions for the Pahau River and Lowry Peaks Drain. Figures redrawn from Brown (2021a,b).

3.1 Minimum flows

Low flows can limit the amount of available physical habitat in a waterway and it is often assumed that frequently occurring low flows will limit fish populations and other stream communities. For example, Jowett et al. (2005) reported that fish abundances in the Waipara River (Canterbury) were affected by the magnitude and duration of low flows. The setting of minimum flows to prevent a serious decline in habitat (i.e., avoids the flow falling to a level below which physical habitat sharply declines) is often a key consideration for consenting (or reconsenting) a HEPS to reduce adverse outcomes for aquatic communities.

The proposed end-of-pipe HEPS differs from storage-based schemes because it does not take or capture any water from the waterway it discharges to. Therefore, the minimum flow is not controlled by the HEPS as it is on storage-based schemes with dams (e.g., Roxburgh Dam on the Clutha River). However, the operation of an end-of-pipe HEPS has the ability to influence the minimum flow in the receiving waterway. For both the Pahau and Lowry HEPS, there are minimum flows set on the source rivers (e.g., Waiau and Hurunui) which restrict, at certain times, the quantity of water available to the HEPS.

3.1.1 Pahau HEPS

Flow modelling indicates that under a hydro-generation scenario the minimum flow would be increased in the Pahau River relative to a status quo and no bywash scenario (Table 2-1). The 1, 7 and 30-day MALF flows are approximately 50% higher than the status quo scenario and double the flow of the no bywash scenario. Higher minimum flows result in a greater wetted habitat area for aquatic species and will be most beneficial to aquatic fauna during summer when the aquatic ecosystem is under the greatest stress (Jowett and Biggs 2006).

The dry and wet year hydrographs for the Pahau River showed naturally occurring low flows (i.e., no bywash scenario) can occur at varying times of the year. In the example dry year, the lowest flows in the status quo scenario occurred during February/March and June/July whereas in the example wet year they were during late winter and most of spring (August to mid-October; Figure 2-1, Figure 2-2). In other years low flows will occur in summer suggesting that in a given year it is possible that the lowest flows could occur during almost any month. Although the proposed HEPS would potentially operate year-round, imposed water restrictions during dry months may mean that hydro-generation is seldom operating at these times. For the majority of the irrigation season, Brown (2021a) stated "hydrogeneration flows are likely to be comparable to pre-piping bywash flows". This is relevant to note because hydro-generation may largely be increasing the lowest minimum flows (i.e., 1-day MALF) during the winter months outside of the irrigation months when aquatic communities are not under stress from abiotic factors such as high water temperature. If higher winter flows are coupled with increasing invertebrate production, which would be assumed in the absence of frequent flooding (such as occurred during the representative wet year in Figure 2-2), then there could be more food available for fish communities compared to no bywash and status quo scenarios (Figure 2-1, Figure 2-2).

3.1.2 Lowry Peaks Drain HEPS

The proposed hydro-generation scenario in the Lowry Peaks Drain has an equal or lower minimum flow compared to the historic bywash scenario for the 1, 7 and 30-day MALF statistics (Table 2-1); the hydro scenario has double the minimum flow of the no bywash scenario across these statistics.

Compared to the Pahau hydrographs where bywash and hydro-generation scenarios were highly correlated during the irrigation season, the Lowry Peaks Drain hydro scenario shows a marked departure from the historic bywash scenario in both dry and wet year examples (Figure 2-3, Figure 2-4). However, as previously noted, this decoupling has already occurred following the piped network becoming operational because post-piping bywash flows have been limited to approximately 10% of the pre-piping bywash flow. As illustrated in the dry year example, abstraction restrictions related to minimum flows could mean there are still several periods of one to three consecutive weeks with no water available for generation during a 12-month period (Figure 2-3).

Outside of the irrigation season the flow regime would markedly change, consistently staying above 2.8 m^3/s during dry and wet years in winter months. This elevated and stable winter flow has resulted in concerns from ECan that it could result in increased trout attraction into Lowry Peaks Drain for spawning rather than having them spawn in potentially more suitable locations in the Waiau catchment. This issue is addressed in Section 3.5.

3.2 Flow variability, flat lining, and flood flows

Flow variability is considered necessary to maintain a healthy aquatic environment. The quantity of flow and timing of low flows in a stream are critical components of water supply, water quality and ecological integrity (Poff et al. 1997). Historically, the protection of stream ecosystems has been limited to one aspect of water quantity — minimum flow — but there is now a much better understanding around the importance of flow variability in maintaining functional stream ecosystems (i.e., flow requirements for streams that support critical physical, chemical, and biological processes). The ecological processes in a stream are regulated by five critical components of the flow regime: the magnitude, frequency, duration, timing, and rate of change of hydrologic conditions (Poff and Ward 1989). These five components can be used to characterize the entire range of flows or specific hydrological events (e.g., floods or low flows) that are critical to stream ecosystem integrity.

The proposed HEPS, on both waterways, would primarily alter flow magnitude (quantity) and duration of low flows. There are also changes to the frequency of flood flow statistics but, because there is no storage of water, and the maximum increase in discharge across both HEPS is 3.35 m^3/s, large 'flood flows' (FRE10 events) are not strongly influenced by HEPS discharges. Based on the example hydrographs in Section 2, changes to the rate of flow change in the Pahau hydro-generation scenario generally parallel the rising and falling limb of the hydrograph. In contrast, generation-related flow changes in Lowry Peaks Drain appear less predictable and the rate of flow change for the receiving waters could have effects on aquatic ecology.

3.2.1 Pahau HEPS

In the Pahau River, mid to high flows are needed to prevent the accumulation of nuisance periphyton as well as fine sediment in low velocity areas. Periphyton data from ECan monitoring at Dalzells Bridge has previously identified that both cyanobacteria and the invasive alga didymo (*Didymosphenia geminata*) are present, albeit with limited coverage. As noted at the start of Section 3, the end-of-pipe HEPS does not capture/store water so does not impact flood flows. The addition of up to 3.35 m^3/s results in a higher FRE3 and FRE5 count relative to the other scenarios but the FRE10 count (i.e., very large floods) is identical for all three scenarios (Table 2-1). The hydrological statistics for the Pahau hydro-generation scenario could be misinterpreted as resulting in fewer freshes because the counts for FRE1 and FRE2 events are lower when compared with the status quo and no bywash scenarios. However, this occurs because an 'event' is recorded by how many times the flow decreases below the median and then increases above the median. The count of exceedance events is reduced for the hydro-generation scenario because the flow does not drop below the median for the status quo scenario (2.2 m^3/s) from May to October (Figure 2-1, Figure 2-2).

The no bywash scenario was the most variable flow regime (i.e., CV of flow = 1.94) which is almost double the variability of the hydro-generation scenario (1.04). The less variable hydro-generation scenario will in part be influenced by lower flow variability in winter months. The winter months, during both dry and wet years, show that the flow variability under the hydro-generation scenario reflects the flow patterns of the no bywash scenario but with an altered flow magnitude due to the addition of the HEPS discharge (Figure 2-1, Figure 2-2). Under a wet year scenario there would not be concerns about either the flow variability or the additional water. During a dry year, stable flows could occur for extended periods of time (as they would have without the HEPS). Whilst the day-to-day changes in flow are not altered by the HEPS (e.g., the river might decrease by 5 m^3/s in a day during a flood recession regardless of generation discharge), flow variability as a percentage of mean daily flow is markedly reduced due to the magnitude of the generation discharge when compared to what the flow would be in the no bywash scenario. In the absence of water storage and additional pipeline capacity there would be limited flow-mitigation options. In the author's opinion, rather than consider flow variability conditions, it would be more appropriate to design an adaptive winter biological monitoring programme (e.g., periphyton, macroinvertebrates and fish) to examine whether the scheme was having a detectable effect during the period of full HEPS discharge. A simple paired monitoring design could be used comparing above and below the discharge location.

3.2.2 Lowry Peaks Drain HEPS

The hydro scenario in Lowry Peaks Drain results in a higher number of FRE2, FRE3 and FRE5 events relative to the historic bywash and no bywash scenarios. No scenarios result in FRE10 events given the flow regime is dominated by groundwater inputs. The inherent lack of flow variability in this waterway is apparent when comparing the no bywash scenario in Lowry Peaks Drain to the Pahau River; FRE3 is 4.99 in Pahau compared to 0.17 in Lowry (Table 2-1, Table 2-2).

Similar to the Pahau River, the no bywash scenario was the most variable flow regime although the most variable scenario in Lowry Peaks Drain had lower flow variability than the least variable flow in the Pahau River. Whilst the hydro-generation scenario had higher flow variability than the historic bywash scenario, it is apparent from Figure 2-3 that during dry years there could be periods of more than a month without flow variability. For a typical HEPS, extended periods of highly stable flows are considered 'flat lining' because the scheme is storing water and artificially releasing a very constant discharge. For waterways that, pre-HEPS, were adapted for flow variability, this flat lining has a number of negative impacts on aquatic biota. Because Lowry Peaks Drain is groundwater-dominated and naturally has a stable flow regime year-round, these effects are likely to be weaker/less detectable compared to a run-off dominated waterway such as the Pahau. Thus, although the flow regime in Figure 2-3 has extensive 'flat lining' from May to October because of the HEPS discharge, the hydro-generation scenario overall reflects the characteristic lack of flow variability of the drain (as represented by the no bywash scenario) plus the additional HEPS discharge. Similar to the Pahau, an adaptive winter biological monitoring programme is recommended to examine whether the discharge is having a detectable effect during the period of full HEPS discharge.

3.3 Flushing flows and periphyton growth

'Flushing flows' are flows that remove the fine sediments and periphyton accumulations from stream substrates. Flushing flows are a necessary part of maintaining a healthy ecosystem in most streams because they restore interstitial space (i.e., habitat) in gravel substrates. In the short-term, large flushing flows can have a detrimental effect on streams because they result in a loss of productivity but in the longer term, they benefit aquatic species through improved habitat quality. There are various guidelines that specify limits for periphyton cover or biomass below which a range of instream ecological values are likely to be maintained (Biggs 2000, Wood et al. 2009, Matheson et al. 2012, NPS-FM 2020). For example, cover of less than 30% by filamentous green algae, or biomass of less than 35 g/m^2 periphyton ash-free dry mass (a measure of organic content), is considered necessary to maintain values for aesthetics and recreation (Biggs 2000). Excessive periphyton accrual is the result of a lack of flow variability, specifically higher flows, and the problem is exacerbated for HEPS that release a constant discharge. For storage based HEPS, ensuring both surface and deep flushing flows are provided for is increasingly recognised in decision-making processes but as previously mentioned, the proposed HEPS do not store flows. The proposed HEPS will increase the magnitude of flushing flows but is unable to generate flows in excess of 3.35 m^3/s to assist with the removal of nuisance periphyton. It is noted that flow variability and high flows are not markedly unchanged under the hydro-generation scenarios, compared to the status quo, particularly in the irrigation season (summer) when periphyton accumulations are likely to be greatest.

3.4 Hydrological connectivity for aquatic communities

Hydrological connectivity can be changed by a HEPS in two ways: (1) variation in lateral connectivity and (2) variation in longitudinal connectivity.

3.4.1 Lateral connectivity

On a daily basis, lateral connectivity determines the availability of wetted habitat for freshwater communities. Consequently, a key consideration when examining the potential effects of hydro-generation on aquatic fauna is the extent of the varial zone; the varial zone is the area of the river that is frequently inundated with water as discharges increase and are then left dry as flows decrease. HEPS that hydropeak (i.e., sporadically generate in response to peak energy demand) change the size of the varial zone several times a day (see Greimel et al. 2018 for a review of associated impacts) and HEPS on some New Zealand rivers regularly have extensive daily changes of the varial zone (e.g., Waitaki River). As is evident from the hydrological modelling results in Section 2, the proposed HEPS on Pahau and Lowry will not be operated using a hydropeaking approach but the rate of flow change that the HEPS will use is currently unknown.

Controlling ramping rates to reduce impacts on aquatic ecology

Rapid changes in water level or flow in streams (ramping rate) can result in stranding and mortality of fish. NIWA is not aware of specific ramping rate restrictions on HEPS in New Zealand (note, consent conditions are difficult to systematically search) but dams such as Roxburgh (Contact Energy) are permitted to alter the flow of the lower Clutha River by hundreds of cumecs very rapidly. When flows drop quickly, fish may become isolated in pools or become stranded in the interstices of exposed gravel or cobble substrate (Irvine et al. 2014), for this reason ramping rates are regulated in some countries to reduce the impacts on aquatic ecology. The likelihood of fish stranding during ramping events is dependent on fish life stage (i.e., younger life stages are more vulnerable), species, wetted history of the habitat, rate of stage change (i.e., ramping rate), magnitude of stage change, substrate characteristics, bank slope, channel morphology, water temperature, time of day, and other biotic and abiotic factors (Nagrodski et al. 2012, Irvine et al. 2014). There is limited government-level regulation of ramping rates but the Department of Fisheries and Oceans in Canada have specified ramping rate criteria to protect fish. These rates are specific to life stages present: -2.5 cm/hr when fry are present and -5.0 cm/hr when fry are not present.

These criteria are specifically designed to protect salmonids from ramping issues (specifically flow reductions) associated with HEPS that produce electricity using hydropeaking (i.e., generate electricity during times of peak demand). Ramping rate effects on aquatic ecology have not been tested in New Zealand, and the direct application of the salmonid rates from large Canadian HEPS to a small-scale HEPS is marginal, but the same risk is relevant to mitigate. Using the Canadian criteria as a guideline, and specifically examining the stage-discharge relationship of the Pahau for reference, it is recommended that the ramping rate be no faster than -3 cm/30 mins with best efforts made to ramp down at -1 cm/10 mins. Setting a rate based on an hour for a small stream is problematic because an operator would still be compliant on a -6 cm/hr rate if they dropped all 6 cm in the first minute and then did not alter the flow for the remainder of the hour; reducing the time step reduces that risk but it needs to be at a time-step that is operationally achievable to meet (hence 30 mins).

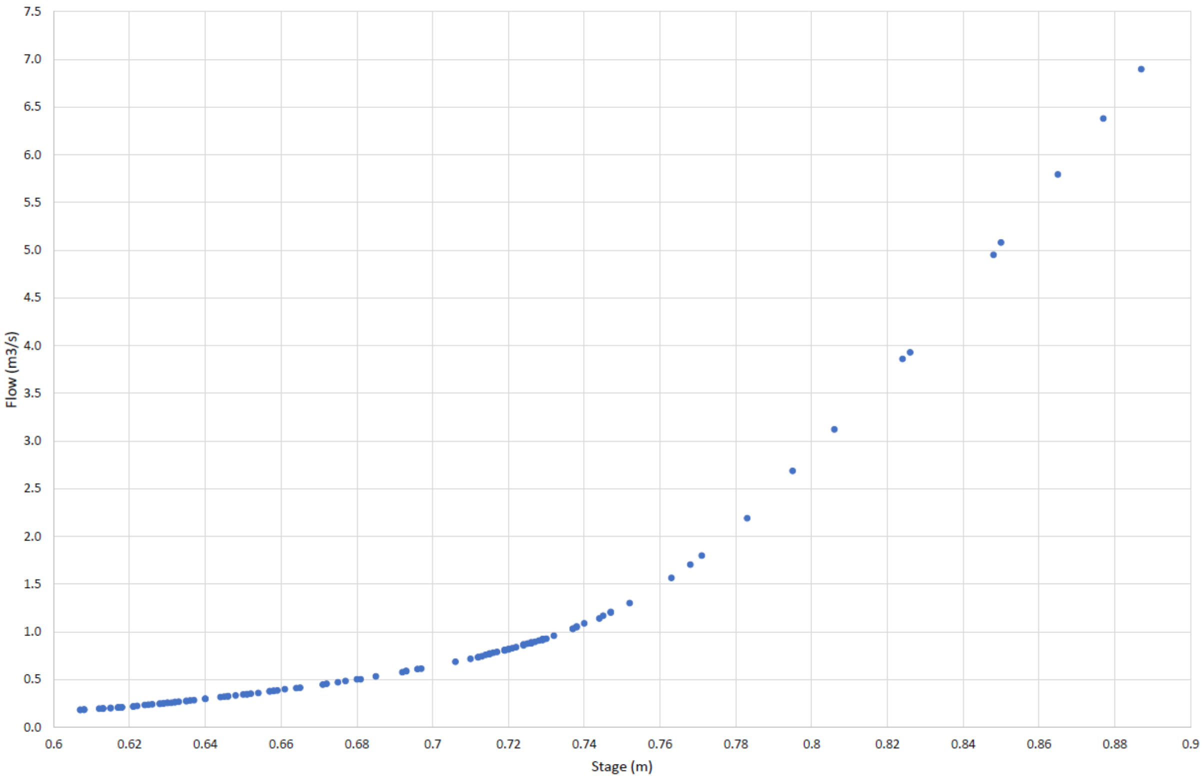

Figure 3-2: Stage-discharge relationship for the Pahau River. Source: AIC.

3.4.2 Longitudinal connectivity

Longitudinal connectivity determines the extent to which aquatic organisms, particularly fish, can move upstream and downstream within a waterway. As indicated by the review of conditions when fish migrate (e.g., Jellyman et al. 2018), increased flows are an almost universal factor in promoting fish movement, especially for the key species such as longfin eel and Chinook salmon. Fish species move in both directions in the main channel and tributaries at different times of the year (Table 3-1). What is less well understood are the threshold levels that trigger migrations, and whether increasing flows beyond the threshold then causes a temporary cessation in upstream migration until flows drop to a level that can be negotiated by fish. The species requiring the most flow for habitat connectivity between the Pahau and Lowry catchments and the mainstem rivers will be brown trout, Chinook salmon (very occasionally) and longfin eel. Of these three species, longfin eels require the least water and provided there is sufficient water depth for them to be fully submerged[4] as they move downstream through run and pool habitat at low flow (noting they may not be fully submerged in all riffle zones), they should be able to migrate. That noted, for several reasons they tend to migrate during high flow events when water depth is less of a critical factor.

[4] Longfin eels that are 1 m in length generally have a body height of 8-9 cm (NIWA unpubl. data).

Table 3-1: Probable fish migration (black bars) in the affected reaches of the Hurunui and Waiau Rivers over a year. For reference, the timing of freshwater entry for kōaro whitebait, glass eels, juvenile bullies and torrentfish is based on when they migrate from the sea into fresh water (i.e., the river mouth). Progressive colonisation upstream is represented by green bars; dark green over the warmer periods when active upstream movement occurs, and light green for cooler periods when less movement occurs.

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Longfin eel	glass eel	from sea												
	elver	gradual upstream												
	adult	downstream												
Shortfin eel	glass eel	from sea												
	elver	gradual upstream												
	adult	downstream												
Koaro	whitebait	from sea												
	post-whitebait	upstream												
	larvae	downstream												
Lamprey	adult	upstream												
	ammocete	gradual downstream												
	macropthalmia	out to sea												
Torrentfish	juvenile	from sea												
	growing adult	gradual upstream												
	larvae	downstream												
Bluegill bully	juvenile	from sea												
	growing adult	gradual upstream												
	larvae	downstream												
Common bully	juvenile	from sea												
	growing adult	gradual upstream												
	larvae	downstream												
Chinook salmon	adult	upstream												
	juvenile	downstream												
Brown trout	adult	upstream												
	juvenile	downstream												

3.4.3 Pahau HEPS

The morphology of the Pahau River is that of a hard-bottomed, run-off fed river in inland Canterbury. The wide, shallow channel profile (Appendix A) suggests that increasing discharge from the HEPS will likely result in lateral expansion and inundate new habitat. Relative to a no bywash scenario, the dry and wet year hydrological modelling indicate that under a hydro-generation scenario there would consistently be more flow in the river which would result an increase in aquatic habitat for periphyton, macroinvertebrates and fish. During the dry-year example in the Pahau River, the no bywash scenario shows the river flow almost reaches zero by mid-May (Figure 2-1). On all the occasions where these extreme low flows are occurring in the no bywash scenario, the hydro-generation scenario is discharging water and markedly increasing the flow.

To examine fish communities, two locations on the Pahau River were sampled by NIWA on three occasions from November 2018–March 2019 (Hogsden et al. 2019). Five fish species were caught comprising two non-migratory native species (Canterbury galaxias and upland bully) and three species that can undertake large-scale movements during their life cycle (longfin eel, shortfin eel, and brown trout). Flows are consistently low during the outmigration periods for migrant eels under the no bywash scenario but more water would be available for downstream migrations under the hydro-generation scenario. That said, as previously noted there is a tendency for migrant eels to wait for high flow events before migrating downstream.

North Canterbury Fish and Game (2010) noted that whilst the Pahau River has never been a productive fishery in its own right, it does have some significance as a spawning stream in the lower reaches where the flow is increased with the addition of other spring fed streams. The lower section is considered to probably hold trout but it is difficult for anglers to access. The authors are also aware of Chinook salmon occasionally spawning in the Pahau River although whether this is a regular occurrence is not known. The availability of sufficient passage depth is mainly an issue identified for adult Chinook salmon moving upstream as they try to migrate back to their natal spawning grounds. A depth of 25 cm is the generally agreed minimum depth required for salmon passage (Mosley 1982). Hydraulic modelling has not been conducted to examine to what extent water depth might be increased under the HEPS but higher winter flows could increase the likelihood of salmonids (brown trout and Chinook salmon) spawning in the river. Given salmonid spawning already occurs this may not be an issue of concern for North Canterbury Fish and Game.

3.4.4 Lowry HEPS

Based on observations of channel morphology made during site visits by the author, it is predicted that HEPS discharges will likely result in an increase in water height and velocity but the channel profile of Lowry Peaks Drain (downstream of the proposed discharge location) means there is minimal lateral habitat to inundate. Relative to a no bywash scenario, the hydro-generation discharge is therefore unlikely to result in markedly more aquatic habitat during winter and early spring. However, as noted in Section 3.4.1, it is still relevant to control the ramping rates in these waterways, particularly flow reductions, to provide some protection for aquatic values and minimise the potential for any fish stranding events.

3.5 Salmonid spawning in Lowry Peaks Drain

The increased attractiveness of the Lowry Peaks Drain for salmonids is an issue that has been raised by both ECan and NCFG. To investigate this issue NIWA examined available salmonid spawning information for the catchment and conducted a stream walk survey along the length of the drain to examine the potential for it to be utilised by both Chinook salmon and brown trout.

3.5.1 Salmonid fishery and spawning information

During the last National Angler Survey (NAS)[5], Unwin (2016) reported that 49% of total angling effort in 2014/15 (86,060 ± 7,350 angler-days; Table 3-2) in North Canterbury was from salmon fishing. Of the four main salmon-producing rivers in North Canterbury (Waiau, Hurunui, Waimakariri, and Rakaia), the Waiau River has the least angler effort targeting salmon (2.7% of all NCFG salmon angler days) (Table 3-2). The Waiau River is the only river with a salmon fishery to have higher angler effort for trout than salmon (Table 3-2). Unwin (2006) identified the Waiau Uha River as a *locally significant* salmon fishery due, in part, to a relatively low angling effort on the river at the time but based on angler usage in 2014/15 being over 2,000 angler days it would likely now be classified as a *regionally significant* fishery (i.e., the tier below the four 'nationally significant' rivers of Waimakariri, Rakaia, Rangitata and Waitaki that receiver over 10,000 angler days).

NCFG are undertaking helicopter-based salmon spawning counts this season, this will be the first salmon spawning data available for several years for the catchment. Anecdotal evidence for the 2021/22 salmon season suggests that across the major rivers there have been the best catch numbers for several years, although NIWA is not aware of Waiau-specific information for the past season. NCFG staff noted last season that very few salmon were seen around the key spawning sites/reaches (Appendix C), all of which are upstream of the Hope-Waiau River confluence (see Schedule 17 of the Canterbury Land and Water Regional Plan). The main salmon spawning reaches in the Waiau catchment are upstream of the Henry-Waiau River confluence which is more than 100 km further upstream than Lowry Peaks Drain.

Table 3-2: Estimated annual effort (angler-days + 1 standard error) expended in 2014/15 on eight east coast South Island rivers sustaining recognised salmon fish. Figures for the Hurunui River are based on the assumption that anglers fishing in the upper and lower reaches, i.e., above and below the Mandamus confluence, are targeting trout and salmon, respectively. Source: Unwin (2016).

FGNZ region	River	Total effort	Effort (salmon)	Effort (trout)	% salmon
Nelson/Marlborough	Clarence River (below Acheron)	1,030 ± 350	430 ± 190	600 ± 290	42%
North Canterbury	Waiau River	4,780 ± 1,270	2,320 ± 1,010	2,460 ± 770	49%
	Hurunui River	11,540 ± 2,250	6,810 ± 1,750	4,730 ± 1,420	59%
	Waimakariri River	59,520 ± 5,250	42,750 ± 4,750	16,760 ± 2,230	72%
	Rakaia River	46,260 ± 5,930	34,180 ± 5,230	12,080 ± 2,790	74%
Central South Island	Rangitata River	28,540 ± 3,690	19,880 ± 2,900	8,650 ± 2,290	70%
	Waitaki River (lower)	26,250 ± 3,230	9,560 ± 2,200	16,680 ± 2,370	36%
Otago	Clutha River (below Roxburgh)	23,520 ± 3,870	6,760 ± 2,700	16,760 ± 2,770	29%
Total, all regions		201,440 ± 10,420	122,690 ± 8,630	78,720 ± 5,820	61%

3.5.2 Salmonid spawning survey walk

The survey walk was undertaken in late June because: (1) this is the approximate mid-point of the non-irrigation season when the proposed HEPS would be altering flows, (2) any Chinook salmon

[5] These surveys are undertaken every seven years and NIWA (and subcontractors) are currently conducting the survey on behalf of Fish and Game that will supersede these data.

spawning would be completed, and (3) the majority of the brown trout spawning should have occurred (based on detailed spawning run timings from nearby catchments). Given the water clarity in the drain and the consistent periphyton coverage on the river bed, evidence of spawning redds (fish nests) was expected to be readily apparent.

Habitat preference curves were used to define the spawning habitat requirements for brown trout and Chinook salmon (Figure 3-3). The stream walk survey focussed on identifying gravel substrate (8–64 mm) in the drain because this is the preferred spawning substrate for both species (Figure 3-3).

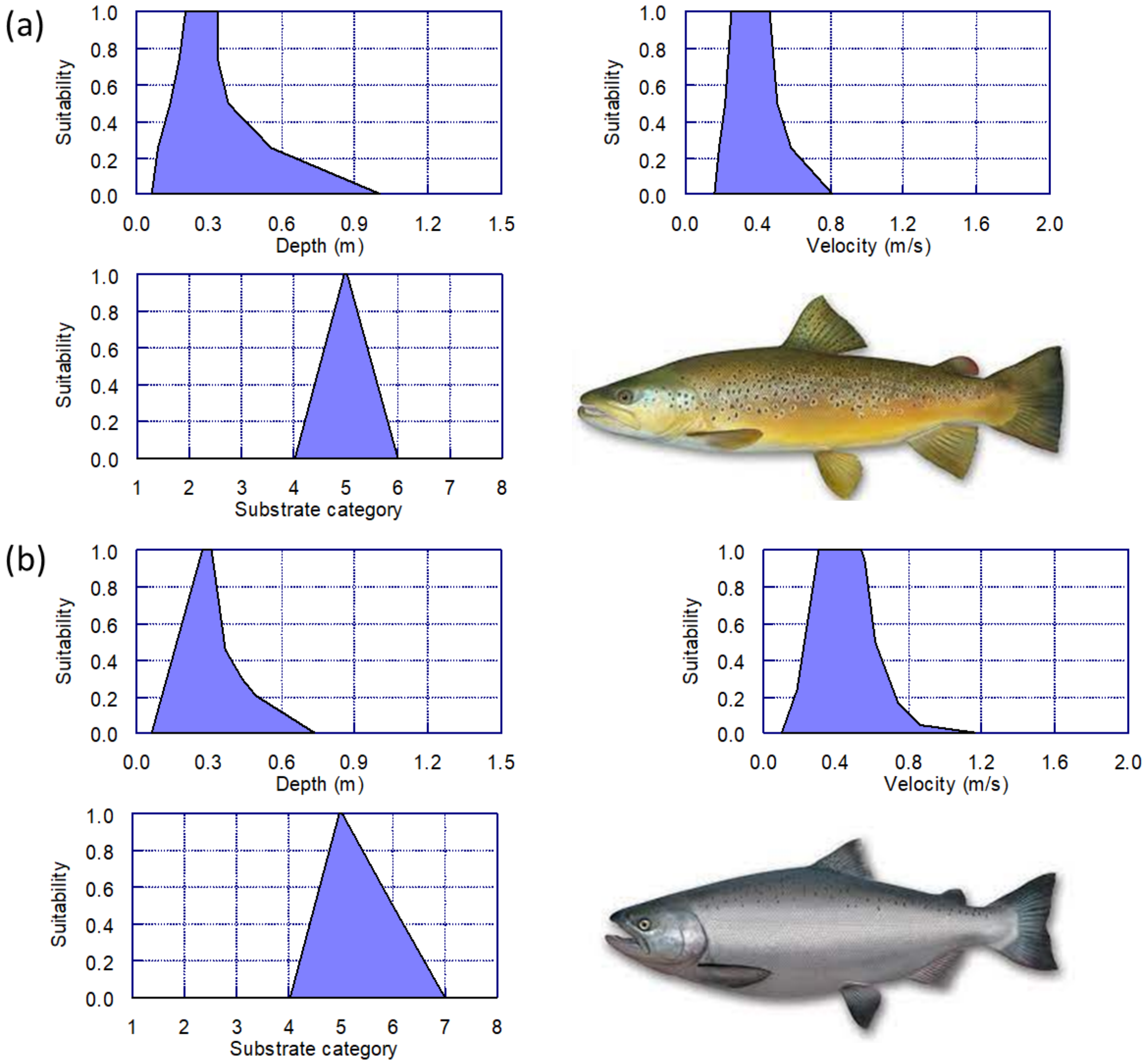

Figure 3-3: Spawning habitat suitability curves for (a) brown trout and (b) Chinook salmon. Substrate categories are: 4, fine gravel (2–8 mm); 5, gravel (8–64 mm); 6, cobble (64–256 mm). Source: SEFA.

Both water clarity and overhead light conditions were near optimal for examining the bed of the drain for substrate size analysis and evidence of salmonid spawning (Figure 3-4). No redds were seen anywhere along the walked reach and no salmonids (juvenile or adult) were observed in the drain (Figure 3-5). The walked reach had extensive macrophyte beds throughout (Appendix D). Whilst macrophyte beds can be associated with soft-bottomed beds (high deposited sediment), the drain was much clearer of fine sediment than expected (often a spawning deterrent) and this enabled the bed substrate to be highly visible. Cobbles were the dominant substrate size class present throughout the reach and patches of spawning gravel were almost non-existent throughout the entire walked reach.

The lower section of Lowry Peaks Drain flows down a terrace before joining the Waiau-Uha and there was almost no ‘holding water’ (i.e., pools) present. There was a significant amount of vegetation and fallen trees that prevented walking access to the confluence with the Waiau and it appeared as though this quantity of debris could potentially be a barrier for the upstream movement of adult Chinook salmon[6]. The lack of holding water as well as potentially the extent of clogging from woody debris means it is considered unlikely that salmon would attempt to move into the drain under higher flows (but it is acknowledged that partial channel clogging could be a temporary state). In addition, most salmon spawning redds are laid down in April and May (Unwin 1986), when irrigation is still occurring to some extent. AIC’s current consent would already permit the HEPS discharge regime during this spawning period, but given it may not differ markedly from the historic flow regime in some years (e.g., Figure 2-3) and salmon have never been seen in the drain before, it is considered unlikely that the altered flow regime will be an attractant for salmon. For Chinook salmon, a fish species that typically exhibits homing behaviour to their natal waters to spawn (as opposed to straying into small tributaries), we consider it highly unlikely that they will be entering the drain based on the rationale outlined above and suitable spawning substrate would not be readily available in the drain.

Unlike Chinook salmon, almost all brown trout in the Waiau catchment will complete their entire life cycle within fresh water. Consequently, this species could potentially have fish of any size entering Lowry Peaks Drain provided they are of sufficient size to swim upstream against the downstream flow. Brown trout have been recorded in the drain before and relative to salmon, the drain will be more accessible to brown trout since they can enter year-round and at a smaller size (i.e., debris clusters are less of a barrier). That noted, no trout were observed during the spawning survey walk and there was no evidence of any spawning redds in the walked reach. A lack of redds is consistent with the substrate size composition that was examined at each location in Figure 3-5. Even if occasional trout spawned in the drain this would only be problematic if there was a lack of juvenile fish rearing habitat; based on the walked reach this is considered unlikely. Given no adult trout were observed after more than 5 km of the drain was walked during trout spawning season it does not appear that the drain is a spawning stream and given the channel morphology it is not expected that the drain would become a markedly more attractive spawning proposition for brown trout under the proposed flow regime of the HEPS.

[6] The life cycle of migratory Chinook salmon involves fry/juvenile fish migrating out to sea, growing/maturing in the ocean and then re-entering freshwater rivers as adults to migrate back upstream to spawn (and then die).

Figure 3-4: An example of the extent of macrophyte coverage in Lowry Peaks Drain. Photo is from the longitudinal stream survey (Site LD8) on 23 June 2022.

Figure 3-5: Longitudinal salmonid spawning survey walk. Site pictures associated with each GPS location are provided in Appendix D.

4 Conclusions

As outlined in the scope for this work (Section 1.1), ECan's report states that the HEPS proposed by AIC will result in "very stable and flat-lined flow discharge periods particularly in the autumn, winter and spring". This concern is relatively common with HEPS because generators with sufficient capacity to store water, either through altering/creating lakes or off-line storage of diversions, often release a constant discharge for an extended duration resulting in impacts on aquatic ecology (as outlined in Section 3). Analysis of the hydrogeneration scenarios for proposed HEPS does not support this view, particularly for the Pahau HEPS. Installation of the HEPS in the Pahau River is predicted to result in an overall increase in mean flow but will not alter underlying changes in flow magnitude. That noted, the magnitude of the constant HEPS discharge will mean that flow variability — as a percentage of mean daily flow — is markedly reduced. Whether or not extended periods of naturally low winter flow variability have more of an adverse impact on aquatic ecology at a higher base flow than at the lower baseflows of the status quo scenario cannot be predicted based on available data. Thus, it would be appropriate to consider an adaptive winter monitoring programme to examine whether the scheme is having a detectable effect on aquatic ecology during the period of full HEPS discharge.

NIWA proposes that this monitoring programme should consist of flow, water quality, periphyton, invertebrate and fish monitoring. A more detailed monitoring programme/sampling methodology would be developed but would have no less than sampling occurring three times per year on the Pahau River: early March (prior to irrigation season shut-down), mid-May (approx. end of irrigation/start of full hydro-generation) and early September (approx. end of full hydro-generation/start of irrigation season). Our conclusion is that a less intensive monitoring programme is appropriate for Lowry Peaks Drain but that particular trigger levels would be set and any exceedances of these triggers would prompt increased monitoring. The initial monitoring programme would last for three years (but total duration would depend on the outcomes) and provided no trigger levels had been exceeded (at either site) during the three years, Amuri would provide a report to the Council identifying the results and potential recommendations.

ECan have also noted concerns that rapid increases and decreases in flow will have adverse effects on aquatic habitats and riverine biota. As noted in Section 3.4, the extent of the varial zone and how often it is watered/dewatered is a key consideration when examining the potential effects of hydro-generation on aquatic fauna. None of the modelling provided to NIWA indicates that either of the two proposed HEPS will be operated this way. Whilst modelling is at a daily time step, most of the generation discharge will occur during the winter and on the 'shoulder months' of the irrigation season and a relatively consistent HEPS discharge would be assumed under these conditions (i.e., not rapidly increasing/decreasing). Moreover, water restrictions during the irrigation season are relatively consistent from day-to-day and are not reduced until there is sufficient catchment rainfall to increase mainstem flows. Therefore, water is often unlikely to be available for generation during summer months and the demand from AIC's shareholders for irrigation water will exceed AIC's supply; as a water supply company AIC will continue to prioritise the irrigation requirements of shareholders over hydro generation. Based on the operational requirements outlined, the 'water ordering' process for AIC's shareholders and the information supplied to NIWA, a hydropeaking HEPS with rapidly changing varial zones over short time scales does not reflect how NIWA has been informed the proposed HEPS would operate. That noted, flow reductions from HEPS still have the potential to impact aquatic ecology, particularly if flows are reduced too quickly. To mitigate this risk it is recommended that a ramping rate no faster than -3 cm/30 mins be required.

As outlined in Section 3.5, NIWA does not hold concerns about significant salmonid spawning activity in the Lowry Peaks Drain as a consequence of the proposed HEPS. With an existing baseline salmonid spawning survey walk of the affected reach now completed, it would be appropriate in the first year of scheme operation for this be replicated during the brown trout spawning season to confirm there was not an issue (the approximate timing of when that walk should be undertaken should be discussed and agreed with NCFG).

5 References

Biggs, B.J.F. (2000) New Zealand Periphyton Guideline: detecting, monitoring and managing enrichment of streams. Ministry for the Environment, Wellington.

Brown, P. (2019) Amuri Plains Tributaries: Hydrological modelling overview. Report prepared by PZB Consulting for Amuri Irrigation Company. December 2019. Report ID 2004/1.

Brown, P. (2021a) Pahau River updated hydrological model. DRAFT. Memo prepared by PZB Consulting for Amuri Irrigation Company. July 2021. 18 p.

Brown, P. (2021b) Lowry Peaks Drain updated hydrological model. DRAFT. Memo prepared by PZB Consulting for Amuri Irrigation Company. July 2021. 17 p.

Goldsmith, R. (2019) Proposed hydroelectric power scheme: Instream ecological assessment - Lowry Peaks Drain, St Leonards Drain and Pahau River. Prepared for Amuri Irrigation Company. 71 p.

Greaves, D. (2020) Resource Consent Application to Establish and Operate Two Hydro-Electric Power Stations. Prepared for Amuri Irrigation Company. 51 p.

Greimel F., Schülting, L., Graf, W., Bondar-Kunze, E., Auer, S., Zeiringer, B., Hauer C. (2018) Hydropeaking Impacts and Mitigation. In: Schmutz S., Sendzimir J. (eds) Riverine Ecosystem Management. Aquatic Ecology Series, vol 8. Springer, Cham.

Hogsden, K., Jellyman, P.G., Sinton, A.M.R., Daly, O., Kilroy, C. (2019) Assessment of water quality and aquatic ecology of the Hurunui and Waiau Rivers: October 2018–April 2019. Prepared for Amuri Irrigation Company. NIWA Client Report 2019150CH. 73 p.

Irvine, R.L., L. Thorley, R. Wescott, D. Schmidt, D. DeRosa (2014) Why do fish strand? An analysis of ten years of flow reduction monitoring data from the Columbia and Kootenay Rivers, Canada. River Res. Appl. 31: 1242-1250. doi:10.1002/rra.2823.

Jellyman, P.G., Kilroy, C., Jellyman, D. (2018) Review of water quality and aquatic ecology of the Hurunui and Waiau Rivers. Prepared for Amuri Irrigation Company. 119 p.

Jowett, I.G., Biggs, B.J.F. (2006) Flow regime requirements and the biological effectiveness of habitat-based minimum flow assessments for six rivers. International Journal of River Basin Management 4: 179–189.

Jowett, I.G., Richardson, J., Bonnett, M.L. (2005) Relationship between flow regime and fish abundances in a gravel-bed river, New Zealand. Journal of Fish Biology 66: 1419–1436.

Matheson, F., Quinn, J., Hickey, C. (2012) Review of the New Zealand instream plant and nutrient guidelines and development of an extended decision-making framework: Phases 1 and 2 final reports. NIWA Client Report, HAM2012-081.

Mosley, M.P. (1982) Critical depths for passage in braided rivers. New Zealand Journal of Marine and Freshwater Research 16: 351-357.

Nagrodski, A., G.D. Raby, C.T. Hasler, M.K. Taylor, and S.J. Cooke (2012) Fish stranding in freshwater systems: sources, consequences, and mitigation. Journal of Environmental Management 103: 133-141.

North Canterbury Fish and Game (2010) A fisheries overview of the Hurunui Waiau Zone. Prepared for Hurunui-Waiau Zone Committee. September 2010.

Poff, N.L., Allan, J.D., Karr, J.R. (1997) The Natural Flow Regime: A paradigm for river conservation and restoration. Bioscience 47: 769-784.

Poff, N.L., Ward, J.V. (1989) Implications of streamflow variability and predictability for lotic community structure: a regional analysis of streamflow patterns. Canadian Journal of Fisheries and Aquatic Sciences 46: 1805-1817.

Unwin, M.J. (1986) Stream residence time, size characteristics and migration patterns of juvenile chinook salmon (*Oncorhynchus tshawytscha*) from a tributary of the Rakaia River, New Zealand. New Zealand Journal of Marine and Freshwater Research 20: 231-252.

Unwin, M.J. (2006) Assessment of significant salmon spawning sites in the Canterbury region. NIWA Client Report, CHC2006-097. 64 p.

Wood, S.A., Hamilton, D.P., Paul, W.J., Safi, K.A., Williamson, W.M. (2008) New Zealand guidelines for Cyanobacteria in recreational fresh waters: interim guidelines. Publication, 981. Ministry for the Environment, Wellington.

Appendix A Photos

Figure A-1: The proposed Pahau River power station discharge location.

Figure A-2: The Waiau scheme bywash discharging into the Pahau River c. 50 m downstream of the power station discharge location.

Figure A-3: The proposed Lowry Peaks power station discharge location.

Appendix B Flow contributions: Pre-piping vs. post-piping

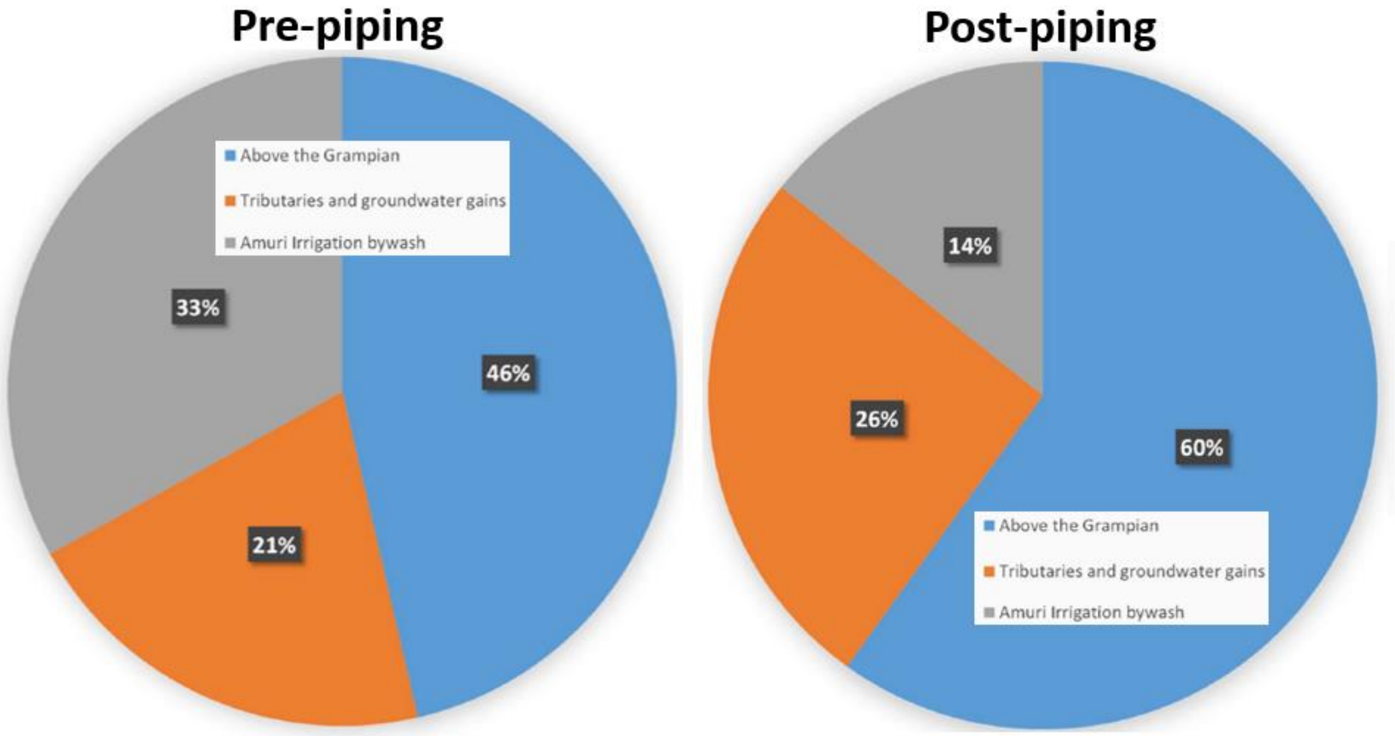

Figure B-1: Comparison of mean flow contribution to Pahau River from pre-piping (left) and post-piping (right) sources. Flow recorder at Dalzells Bridge. Source: Brown (2021a).

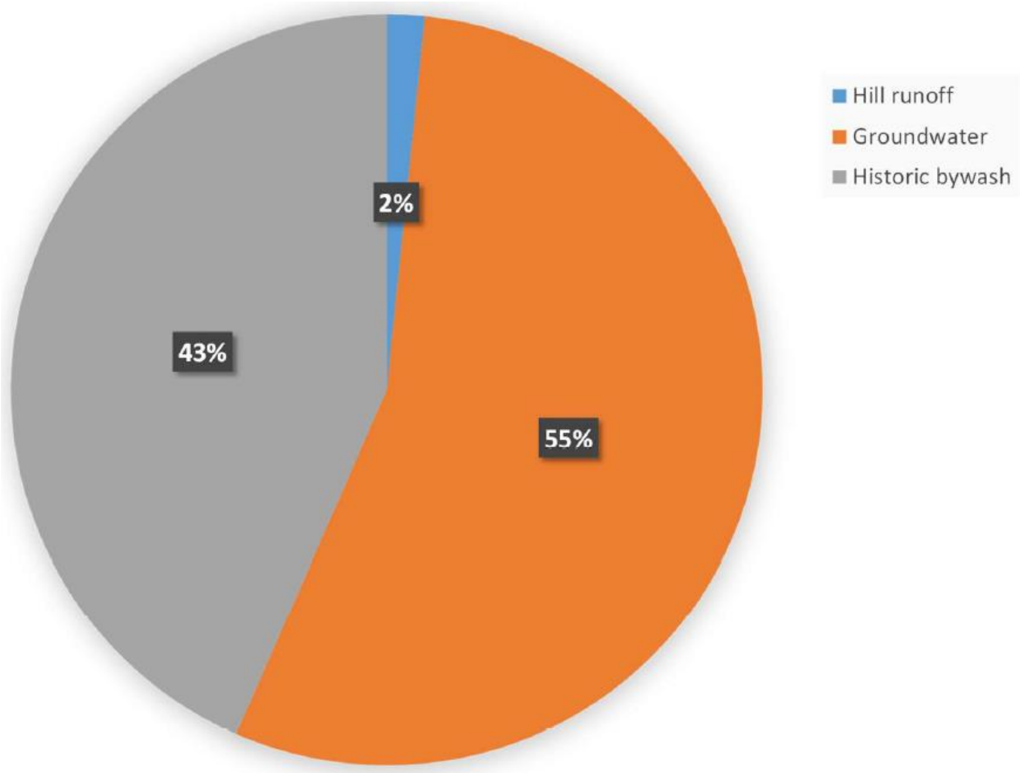

Figure B-2: Comparison of mean flow contribution to Lowry Peaks Drain from pre-piping (left) and post-piping (right) sources. Flow recorder at Longbrook Dairy Bridge. Source: Brown (2021b).

Appendix C Salmon catch data 2020/21 (Fish and Game)

Below are the salmon catch data for the 2020/21 season. These data are based on a summary of email and phone survey respondents. Fish and Game noted the following regarding these data “The Hurunui and Waiau rivers were not as comprehensively surveyed this season, however the key spawning areas were visited a few times throughout the spawning season to collect tissue samples for salmon DNA analysis for the Winnemum Wintu research project. Very few salmon were seen.”

	Total anglers ± 95 CI			Succesful anglers ± 95 CI			Salmon caught ± 95 CI			Finclips caught ± 95 CI		
Hurunui	499	±	139	64	±	55	89	±	84	20	±	37
Kaiapoi	302	±	99	30	±	37	42	±	38	13	±	5
Rakaia	1,207	±	183	204	±	63	434	±	229	86	±	80
Tentburn	5	±	2	3	±	-	5	±	-	-	±	-
Waiau	214	±	92	11	±	2	19	±	6	3	±	3
Waimakariri	1,883	±	233	191	±	67	261	±	69	55	±	8

Appendix D Salmonid spawning survey

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