The bar spacing of the trash rack in the Kaniere water race ranges from 60-70mm (Figure 4.22). The bars slope downstream away from the base at an angle of approximately 63 degrees and are at right angles to the flow with no bypass. Three measurements of water velocity were made approximately 1m in front of the trash rack and the maximum approach velocity was 0.81m/s. The water race was flowing near its full capacity of 1 cumec at the time of measurement.

Figure 4.22 Kaniere Water Race trash rack.

(ii) Spawning escapement of female longfin eels

In order to estimate the number of adult female longfin eels (length greater than 700mm) that might be expected to emigrate downstream from Lake Kaniere annually, the information contained within Graynoth *et al.* (2008) was used. Lake Kaniere is classified as a Class 2 eel fishery, which means that it is protected from fishing in its upper reaches but migrant eels could be fished further downstream (Graynoth *et al.* 2008). For comparison, Class 1 fisheries have not been commercially fished (e.g. National Parks) and also have safe downstream passage for migrating female eels (Graynoth *et al.* 2008). Graynoth *et al.* (2008) estimated the biomass of longfin eels in Lake Kaniere to be 12 tonnes. Large female longfin eels are estimated to comprise 74% of the total weight of longfin eels present in Class 2 waters (Graynoth *et al.* 2008). The biomass of female longfin eels in Lake Kaniere is therefore calculated to be 8.88 tonnes. Graynoth *et al.* (2008) estimated that only 8.3% of female longfin eels in Class 2 waters mature and migrate to sea each year, this equates to 0.737 tonnes or 737 kg in Lake Kaniere. The estimated mean weight of large female eels is 1.5kg (Jellyman *et al*. 2000 cited in Graynoth *et al.* 2008). Therefore 491 large female eels are estimated to migrate downstream from Lake Kaniere annually. Note that this estimate is heavily dependent on the mean weight and is a relatively rudimentary desktop calculation.

5. Summary of Existing Aquatic Ecosystem

There is limited information on water quality within the Kaniere River catchment; however, from the information available, and the moderate amount of development in the catchment, it is expected that water quality is good. Water temperatures in the residual river below McKays weir exceeded 20°C on several days during February 2010 and a maximum temperature of 23°C was recorded.

Periphyton was visible at all sites in the Kaniere River. Long filamentous green algae were present at all sites and cover slightly exceeded aesthetic/recreation guideline levels at one site. The flow in this reach was approximately 5 cumecs, having been reduced by the 1 cumec Kaniere intake upstream. It is unlikely that this small flow reduction would have caused algae cover to exceed guideline levels, and natural catchment features (including the presence of a lake upstream resulting in a relatively stable flow regime) and habitat conditions at the time would have had a greater influence. Thick algae mats were also present at all sites; however, aesthetic/recreation guideline cover levels for cyanobacteria/diatom mats were not exceeded at any sites. Periphyton biomass (chlorophyll *a*) did not exceed aesthetics/recreation guidelines at any sites.

The benthic macroinvertebrate community of the Kaniere River is comparable to that of similar habitats in the West Coast region. A total of 40 macroinvertebrate taxa were identified in our survey of six sites in the river. Within the limits of taxonomic resolution that were used for identification, two invertebrate species were identified as threatened: the freshwater mussel (kākāhi) and freshwater crayfish (koura), which are both ranked to be in 'gradual decline' (Hitchmough *et al.*

2007). Common macroinvertebrate taxa included, *Aoteapsyche* net-spinning caddisflies, *Potamopyrgus* snails, Elmidae beetles, *Oxyethira albiceps* cased caddisflies and *Deleatidium* mayflies. The dominant taxa varied somewhat depending on the distance of a site downstream from the lake. Macroinvertebrate community indices (%EPT taxa, and MCI and QMCI scores) were generally indicative of 'fair' to 'good' quality invertebrate habitat.

Seventeen fish species have been recorded in the Kaniere River catchment, 13 of these native and four introduced. Brown trout are common in both the lower Kaniere River and Lake Kaniere; however, angler use of the Kaniere River is low. The range of native fish species present in the Kaniere River catchment is similar to that of other West Coast rivers. There are obvious differences in fish communities upstream and downstream of McKays weir, and common bully and giant kokopu populations in Lake Kaniere both appear to be non-diadromous.

A threat ranking process has recently (June 2009) been applied to New Zealand freshwater fish (Allibone *et al.* 2010). These rankings supersede the rankings conducted under the system of Molloy *et al.* (2002), as listed in Hitchmough (2002) and Hitchmough *et al.* (2007). The rankings include all described species, and genetically distinct but undescribed taxa. Under the previous ranking system four species found in the Kaniere River catchment were classified as threatened; giant kokopu and longfin eel were both ranked as in 'gradual decline' and shortjaw kokopu and lamprey were ranked as 'sparse' (Hitchmough *et al.* 2007). Under the new ranking system these four species are all classified as 'declining', with the qualifiers of 'partial decline' for giant kokopu, and 'data poor' for lamprey and shortjaw kokopu (Allibone *et al.* 2010). A further five species are also now classified as 'declining'; bluegill bully ('data poor'), inanga ('conservation dependent', 'data poor'), koaro, redfin bully and torrentfish (Allibone *et al.* 2010).

6. Assessment of Effects

6.1 Background

TPL is considering upgrading and improving the efficiency of the scheme. The proposed enhancements to Kaniere Forks and McKays Creek are in brief (presented in detail in Section 1.1):

- Increase abstraction to Kaniere race to 8 cumecs (requiring deepening/heightening or widening of race) and construct new Kaniere Power Station at Wards Road (discharge to Kaniere River at this point).
- Increase abstraction to McKays race to 8 cumecs (requiring deepening/heightening or widening of race) and increase discharge from McKays power station to 9 cumecs.

Under the enhanced scheme flows will vary in different locations in the Kaniere River. As an indication as to how river flows will be altered relative to the existing situation Table 6.1 shows simulated minimum, median, mean and maximum flows for five locations under the existing and enhanced schemes for the January 2002-December 2008 period. The potential effect of these flow changes on fish passage, water quality, and instream habitat are discussed in the following sections. This analysis is based on the predicted flows provided to us by TPL and therefore its accuracy is dependent on the accuracy of the flow predictions.

Table 6.1 *Simulated 3-hourly minimum, median, mean and maximum flows (cumecs) for the period January 2002-December 2008 at five locations in the Kaniere River under the existing operating regime and the enhanced scheme (data provided by Lennie Palmer, TPL).*

Operating regime	Flow statistic	1. Downstream of lake outlet	2. At Wards Road Station	3. Downstream of McKays weir	4. Downstream of Kaniere Forks Station	5. Downstream of McKays Creek Station
Existing	*Minimum*	0.92	0.95	0.20*	0.26	0.82
	Median	5.5	5.8	1.4	2.9	7.5
	Mean	6.1	6.4	2.9	5.1	10.8
	Maximum	41	42	53	75	144
Enhanced	*Minimum*	0.30	0.40	0.30	0.38**	0.74
	Median	0.33	7.9	0.31	0.68	9.0
	Mean	0.56	7.4	1.2	2.4	11.4
	Maximum	25	34	38	73	160

* A minimum flow value of 0 cumecs has been derived from McKays Weir level record, but is likely to be an error (Palmer 2010). The consented minimum flow of 0.20 cumecs has therefore been used.

** Note that this minimum flow is calculated on the requirement to achieve a minimum flow of 0.5 cumecs downstream at McKays Ford.

6.2 Fish passage

6.2.1 Background

All of the native fish species found in the Kaniere River catchment are diadromous (except brown mudfish), requiring access to and from the sea to complete their lifecycle. Common bully and giant kokopu populations in Lake Kaniere are land-locked, however, juveniles of these species may still undergo downstream migration (Paterson and Boubee 2010). The two intake and control structures within the Kaniere River mainstem associated with the scheme (i.e., McKays weir and Lake Kaniere outlet control structure) could therefore limit upstream and downstream fish passage. There is also a weir associated with the intake structure in Blue Bottle Creek.

6.2.2 Intake screening

There are currently two locations where water is taken from the Kaniere River for the McKays Creek/Kaniere Forks scheme. Additional water is also taken into the McKays scheme from Blue Bottle Creek. At the intakes there is a risk that fish may become entrained within the intake races. Whether or not fish will be entrained into the races depends on the mesh size and approach velocities of the intake screen.

A recent review of screening requirements for juvenile native fish and salmonids at irrigation water intakes in Canterbury recommends that mesh sizes of approximately 3mm are necessary to exclude most juvenile fish (Jamieson *et al.* 2007) (Table 6.2). Screen mesh sizes of 20mm and approach velocities of less than or equal to 0.5m/s have been recommended to exclude the majority of female migrant eels (Charteris 2006, Paterson and Boubee 2010) (Table 6.2).

Table 6.2 *Screen mesh sizes required to exclude fish from water intakes. Information from Charteris (2006) and Jamieson et al. (2007).*

Group	Mesh size (mm)
Juvenile salmonids	3
Native larval fish	≤1
Whitebait (banded kokopu, inanga), common bully	3
Juvenile torrentfish	3
Glass eels and elvers	1.5-3
Adult eels	20-25

The Kaniere Forks water race intake at the lake outlet is currently unscreened; however, there is a trash rack located approximately 3km further downstream in the race. The McKays race intake at McKays weir also has a trash rack. The bar spacing of the McKays and Kaniere trash racks range from 60-70mm with approach velocities exceeding 0.5m/s. There is no screening at the Blue Bottle Creek intake.

The bar spacing of the trash racks in the Kaniere water race and at the intake to the McKays race are therefore not narrow enough to exclude any native fish species. Most fish would pass through the trash rack to enter the race, but approach velocities are such that adult eels may instead become impinged against the bars. Migrating adult eels, however, tend to move downstream during freshes or floods and it is likely that they would travel in the main flow of the river, towards the middle of the channel. They would therefore be less likely to encounter the intakes to the water races, but rather bypass over McKays weir and continue downstream. This is supported by the observation of TPL staff that they have never encountered dead eels on the trash racks during their regular maintenance (routinely every second day and more often during high river levels) (Jim McDermott, *pers. comm.*).

There is suitable fish habitat within the McKays/Blue Bottle Creek and Kaniere water races for some distance downstream of each intake and fish have been observed in each of these water races (Section 4.3). However, further downstream the water eventually enters penstocks to be conveyed to each power station. There is a second trash rack in the Kaniere race immediately upstream of the Kaniere Forks penstocks. It has a bar spacing of 45mm, which is also not sufficient to exclude native fish. The trash rack at the McKays Creek penstocks has a bar spacing of 25mm, which should be sufficient to exclude large adult eels, but not smaller fish. Most diadromous fish that enter the races as part of their active downstream migration will therefore ultimately encounter the power station turbines.

Under the enhanced scheme the capacity of the existing Kaniere Forks and McKays intakes and water races would be increased. Without adequate screening of the intake and the provision of a return flow, fish will be entrained into the scheme.

6.2.3 Turbine mortality

Downstream migrating fish that enter the water races will, without adequate screening, be drawn through the power station turbines. Fish mortality due to turbines has been well documented; as have results from impact (or 'strike'), pressure changes (associated with passing through high, then low pressure zones across the runner) and high shear stresses (close to fixed and moving surfaces and in the turbulent wake of the blade and in the draft tube) (Turnpenny *et al.* 2000). It is possible to estimate fish mortality during passage through turbines using various formulae (e.g., Larinier & Travade 1999; Turnpenny *et al.* 2000) and information on turbine design. Boubée (2003) estimated salmonid and eel mortality during passage through turbines for Project Aqua (lower Waitaki River) based on relatively low head (30m) Kaplan turbines. He estimated the mortality for trout fry (30mm long) to be 3–6% during each turbine transit. For fingerlings (115mm long) mortality during turbine passage was estimated to be 5–7%. In contrast, for migrant female longfin eel (1150mm long) the mortality during passage through just one turbine was estimated at about 55%.

Passage through the existing and proposed McKays Creek and Kaniere Forks power station turbines is therefore likely to result in mortality for some fish, particularly for larger individuals, which includes threatened native fish species (e.g., adult eels).

6.2.4 Instream barriers

There are currently two structures associated with the scheme within the Kaniere

River mainstem and one structure in Blue Bottle Creek that may hinder upstream fish passage.

Immediately downstream of the Blue Bottle Creek intake is a small weir approximately 1m high, formed by the placement of boulders across the channel (Figure 4.13). There is no minimum residual flow in the creek downstream of the intake, while the median flow is 0.06 cumecs (Table 5.6.1 Palmer 2010). At the intake the minimum flow is 0.002 cumecs and the median flow is 0.21 cumecs (Table 5.6.1 Palmer 2010). At low flows there is therefore very little water flowing over the weir and it appears that only climbing native fish species (e.g., eels, koaro, lamprey, and redfin bullies) would be able to pass, with poorer climbers (e.g. bluegill bullies and torrentfish) prevented from passing. However, existing fish distribution records and our recent survey confirm that all of the native fish present downstream of the intake weir are also present upstream (including brown trout, bluegill and redfin bully, koaro and longfin eels) and passage must therefore be possible at higher flows. Densities of bluegill and redfin bullies are higher downstream of the weir than upstream though, possibly indicating that passage is limited although not completely prevented. The presence of a concrete ford in the lower reaches may also limit fish passage somewhat (Figure 4.15). There will be no change from the existing situation under the enhanced scheme.

In the Kaniere River mainstem there are two structures that may hinder upstream fish passage: McKays weir (Figures 1.5 and 6.1), which is located approximately 9km upstream of the confluence of the Kaniere and Hokitika Rivers, and the Lake Kaniere outlet control structure (Figure 1.2), which is located a further 7km upstream.

McKays weir is a low concrete weir, which at typical flows is overtopped. At lower water levels no water flows over the weir and the current residual flow (0.2 cumecs) is maintained through an underwater notch on the true left side of the weir. The drop from the crest of the weir to the river downstream varies depending on how much water is spilling over the weir, but typically ranges from 0.5-0.9m. When the weir is spilling, upstream passage should be possible for large salmonids (i.e. trout and salmon) and climbing native fish species; however, poorer climbers may be prevented from passing.

Figure 6.1 Left: McKays weir spilling. Right: McKays weir with no spill.

There are two channels at the Lake Kaniere outlet (Figure 6.2). The true right channel leads directly to the intake and control gates for the Kaniere water race. The control gates are adjusted to manipulate the flow passing down the Kaniere River. As the gates are adjusted from the top continuous passage is available to the lake provided that fish are able to swim upstream against the high water velocity through the gates. The second channel has a concrete weir and control boards between the river and the lake outlet (Figure 1.2). Depending on the lake level there is a drop of approximately 0.5m from the lake over the weir and control boards into this channel (Figure 6.2, right). Lake level records indicate that under the existing situation the lake spills over the concrete weir greater than 40% of the time, more so during October to January (Palmer 2010). As at the McKays weir this overflow should allow upstream passage for fish species that are good climbers; however, poorer climbers may be prevented from passing. At lower lake levels, however, there is no surface discharge from the lake to the true left channel. Under the existing scheme the lake spills for greater than 40% of the time. Under the enhanced scheme this will reduce to only 8% of the time (Table 6.2.1 Palmer 2010). This reduction in spill will reduce opportunities for upstream fish passage from the river to the lake.

Figure 6.2 *Left: Two channels at the Lake Kaniere outlet. Right: Control boards and concrete weir at Lake Kaniere outlet to true left channel.*

Whether upstream fish passage is possible at the control structures in the Kaniere River is therefore dependent on the flows in the river (and over the structures) during the upstream migration period for each fish species. Historical flow records can be examined to determine if flows during migration periods are sufficient to allow upstream passage. Alternatively, the existing distribution of fish in the catchment can be examined to assess how existing fish distribution is related to the presence of the structures.

To assist with understanding fish distribution FWFDB records for the catchment have been divided into four groups (Table 6.3):

1. Below McKays weir.
2. McKays weir upstream to Lake Kaniere outlet.
3. Lake Kaniere.
4. Lake Kaniere tributaries.

A map showing the location of fish records within the Kaniere River catchment has also been prepared (Figure 2.2).

Table 6.3 *Distribution of native and introduced fish species in the Kaniere River catchment, based on FWFDB (wetlands and forest pools omitted) and our February 2010 sampling. Numbers indicate the number of FWFDB records for the species and a tick indicates that the species was recorded during sampling in February 2010.*

Fish species	**Location**			
	Below McKays weir	**McKays weir upstream to Lake Kaniere outlet**	**Lake Kaniere**	**Lake Kaniere tributaries**
Brown mudfish*				
Banded kokopu	5		2	2 ✓
Giant kokopu	7		5	4 ✓
Inanga	7			
Koaro	32 ✓	2 ✓		10 ✓
Shortjaw kokopu	33	2 ✓		
Galaxiid species	4		4	1
Bluegill bully	11 ✓			
Common bully	10 ✓		5	7 ✓
Redfin bully	41 ✓	2 ✓		1
Bully species	1			
Longfin eel	36 ✓	2 ✓	1	11
Shortfin eel	2 ✓	✓	1	2
Eel species	8		3	
Lamprey	2			
Torrentfish	17 ✓			1
Brown trout	14 ✓	2		12
Rainbow trout				1
Trout species			3	
Chinook salmon	1			1
Perch			6	
Total # of species**	**14**	**6**	**6**	**11**

* confined to wetlands and forest pools
** total number of fish taxa identified to species level

It is apparent from Table 6.3 and Figure 2.2 that a greater number of species are found downstream of McKays weir than upstream. Three native fish species, lamprey, inanga and bluegill bullies, have only been recorded below McKays weir (Table 6.3, Figure 2.2). Inanga rarely penetrate far inland so their absence from upstream areas may not be due to the presence of the weir, however, bluegill bullies and lamprey could be expected further inland. Torrentfish are another native species that is common in tributaries below the weir, but only a single individual has been recorded upstream in a lake tributary (Figure 2.2). Likewise redfin bullies are common below the weir, but appear to be less common above the weir, although they were found in Butchers Creek upstream of the weir during our February survey.

Shortjaw kokopu have been recorded from tributaries below McKays weir and also from Butchers Creek (Figure 2.2). They have not been found above the lake outlet, however, shortjaw kokopu are cryptic and seldom abundant, and so they may be present but have gone undetected in the upper catchment.

Five native species are found in reasonable numbers throughout the catchment (Table 6.3 and Figure 2.2). Longfin and shortfin eels, koaro and banded kokopu are known to be excellent climbers so it is likely that they are able to negotiate the structures in the Kaniere River mainstem. Common bullies and giant kokopu are also found both downstream of the weir and in Lake Kaniere; however, it appears that populations of both species in the lake are land-locked.

To summarise, it appears that McKays weir is hindering upstream passage, and therefore limiting the distribution, of bluegill bullies, lamprey and torrentfish in the middle and upper reaches of the Kaniere River catchment. Upstream passage of common bully and giant kokopu is also hindered, but both species have developed land-locked populations in Lake Kaniere. Redfin bullies and shortjaw kokopu have been recorded upstream of the weir; however, it appears they are not present, or present only in low numbers, in the upper catchment. Under the enhanced scheme there will be no change to the Lake Kaniere control structure and Blue Bottle Creek intake. The Lake Kaniere intake gates will be modified and minor changes will be made to McKays weir, however, these changes are unlikely to improve fish passage and any existing effect of these structures on upstream passage will therefore continue unless mitigated.

6.2.5 Flow reductions and connectivity

(i) Kaniere River

The enhanced scheme will result in flow reductions in some sections of the Kaniere River mainstem relative to the existing situation (although in other sections flows will increase) (Table 6.1). This may affect fish passage in two ways: by reducing the average river flow and making instream barriers more difficult to negotiate and by reducing the frequency and magnitude of freshes and floods.

As previously noted, many of the fish species in the Kaniere River are diadromous, migrating to and from the sea to complete their lifecycle. The timing of downstream spawning migrations for some native species (e.g., eels and shortjaw kokopu) is associated with floods or elevated flows (Charteris 2006). Sufficient flow is also required during periods of upstream migration to ensure that connectivity is maintained to allow upstream passage within the mainstem and also to access tributaries. This is also important for brown trout, which undertake their upstream spawning migration during autumn and winter.

The main upstream migration period for most diadromous native fish species found in the Kaniere River catchment is spring and early summer (Table 6.4). Existing fish distribution records indicate that under the current operating regime longfin and shortfin eels, banded kokopu, koaro and probably to some extent shortjaw kokopu and redfin bullies are able to travel upstream in the river. Bluegill bullies and torrentfish do not appear to be able to negotiate McKays weir; however, this is most likely due primarily to their poor climbing ability and changes in flow are unlikely to improve passage for these species. Downstream migration is occurring for at least one species in most months of the year (Table 6.4). However, the main species of concern is the longfin eel (a threatened species), which migrates downstream in autumn and does so during freshes or floods.

Flow simulations have been undertaken to predict how flows in several locations in the Kaniere River will change under the enhanced scheme relative to the existing situation. Comparing flows between the existing and enhanced schemes during the peak periods for upstream and downstream fish migration allows the potential effect of flow changes on fish passage to be determined.

Table 6.4 Upstream and downstream migration periods of some native fish species found in the Kaniere River catchment. Adapted from Environment Waikato (2007).

Species	**Summer**			**Autumn**			**Winter**			**Spring**		
	D	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Upstream												
Lamprey (adult)							✓	✓	✓	✓		
Bluegill and redfin bully (juvenile)	✓											✓
Common bully (juvenile)	✓	✓	✓								✓	✓
Banded kokopu (juvenile)									✓	✓	✓	✓
Giant kokopu (juvenile)	✓										✓	✓
Shortjaw kokopu and koaro (juvenile)										✓	✓	✓
Shortfin and longfin eels (juvenile)	✓	✓	✓	✓	✓							✓
Torrentfish (juvenile)	✓	✓	✓									✓
Downstream												
Lamprey (juvenile)					✓	✓	✓	✓	✓			
Bluegill bully (larvae)	✓	✓	✓							✓	✓	✓
Common bully (larvae)											✓	✓
Redfin bully (larvae)									✓	✓	✓	✓
Banded kokopu (larvae)						✓	✓	✓				
Giant kokopu (larvae)						✓	✓	✓	✓			
Koaro (larvae)					✓	✓	✓					
Shortjaw kokopu (larvae)						✓	✓					
Longfin eel (adult)					✓	✓						
Shortfin eel (adult)			✓	✓	✓							
Torrentfish (larvae)			✓	✓	✓	✓						

From the flow distributions for the river it is apparent that in most reaches of the river the enhanced scheme will result in reduced flows relative to the existing situation (Figures 6.3 to 6.7). For example, under the existing scheme, flows less than 0.5 cumecs occur for less than 1% of the time in the Kaniere River at the lake outlet (Figure 6.3). Such low flows will increase to approximately 92% frequency under the enhanced scheme (Figure 6.3). The frequency of flows below 0.5 cumecs will be greater than 50% under the enhanced scheme downstream of McKays weir (Figure 6.5). Under the existing scheme, flows below 1 cumec occur for 4% of the time in the Kaniere River downstream of the Kaniere Forks station discharge (Figure 6.6). Such low flows will have a frequency of approximately 66% under the enhanced scheme (Figure 6.6). In the same reach flows less than 0.5 cumecs will occur for 27% of the time under the enhanced scheme (Figure 6.6).

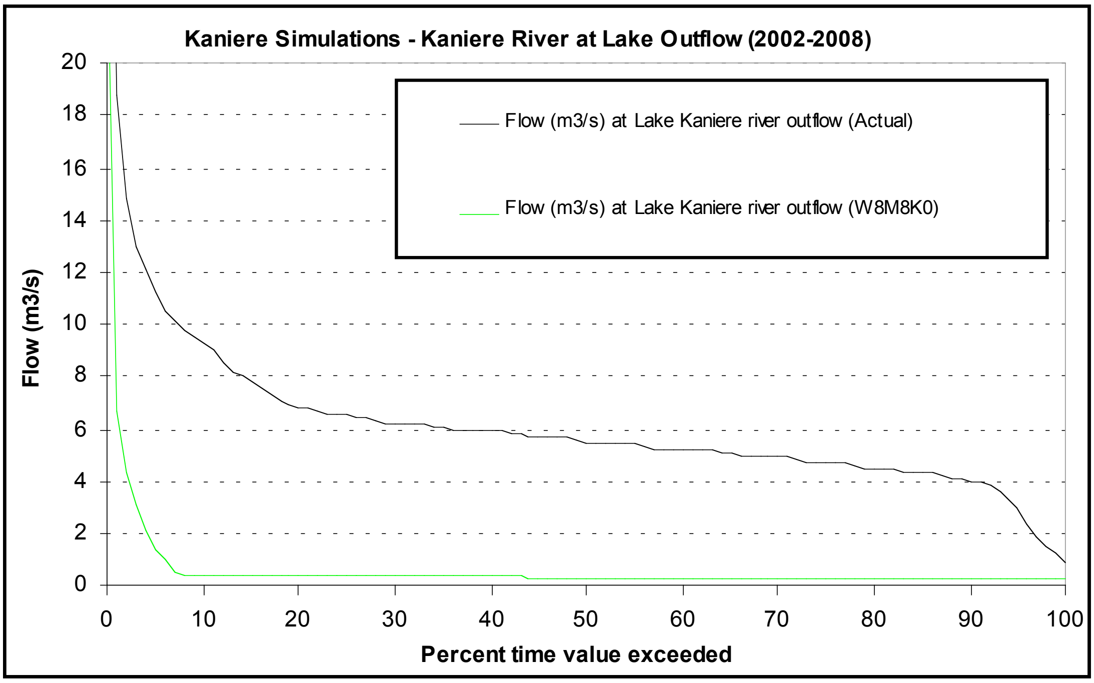


Figure 6.3 *Kaniere River flow distribution at the lake outlet under the existing (Actual) and enhanced (W8 M8 K0) schemes (graph provided by Lennie Palmer, TPL).*

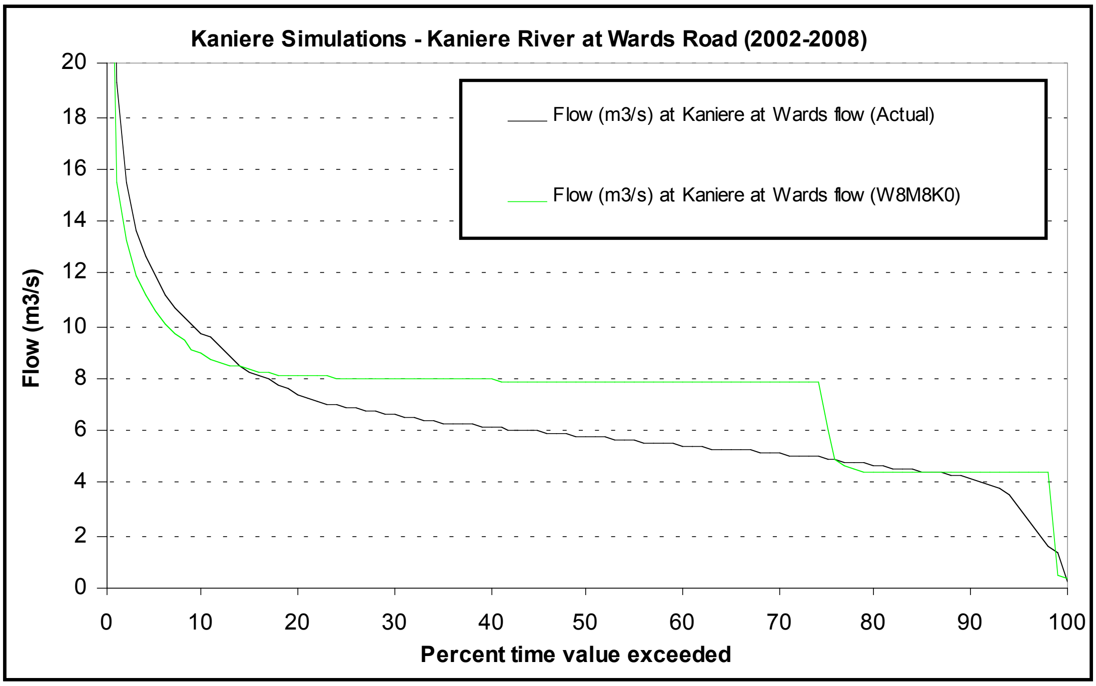


Figure 6.4 *Kaniere River flow distribution at Wards Road under the existing (Actual) and enhanced (W8 M8 K0) schemes (graph provided by Lennie Palmer, TPL).*

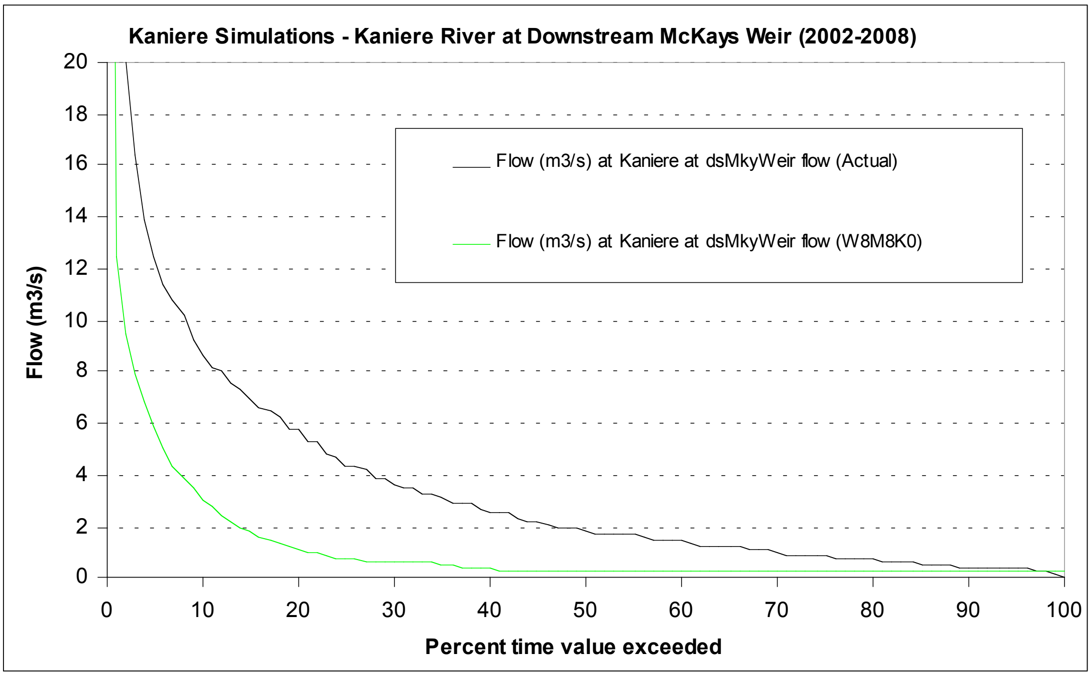


Figure 6.5 Kaniere River flow distribution downstream of McKays weir under the existing (Actual) and enhanced (W8 M8 K0) schemes (graph provided by Lennie Palmer, TPL).

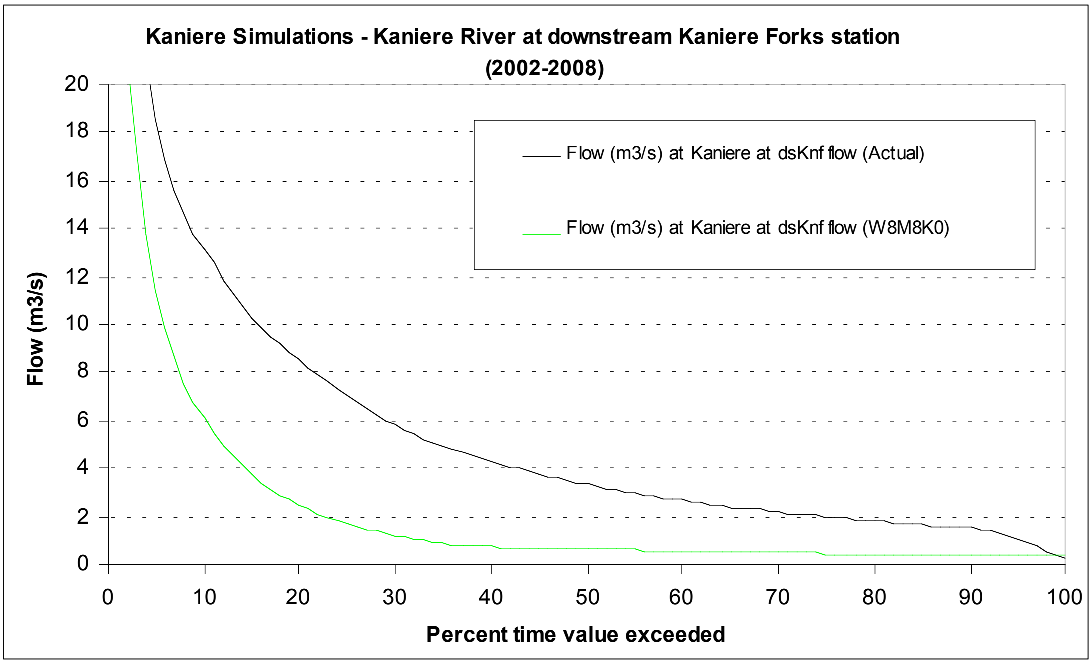


Figure 6.6 Kaniere River flow distribution downstream of Kaniere Forks station under the existing (Actual) and enhanced (W8 M8 K0) schemes (graph provided by Lennie Palmer, TPL).

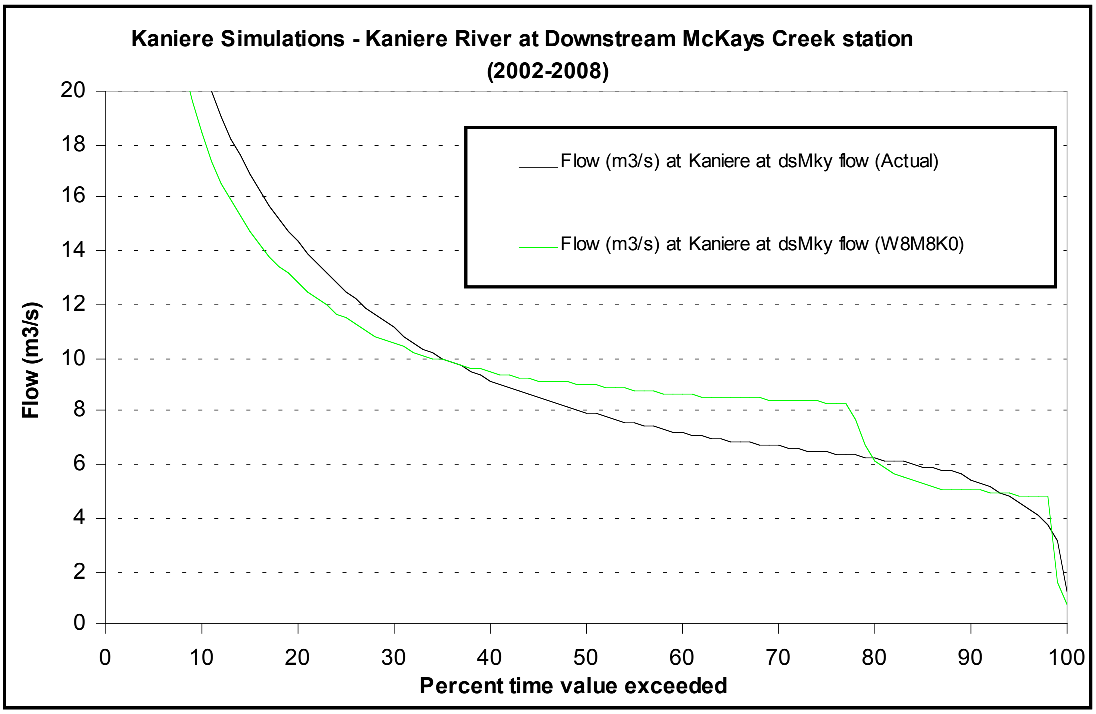


Figure 6.7 *Kaniere River flow distribution downstream of McKays Creek Station under the existing (Actual) and enhanced (W8 M8 K0) schemes (graph provided by Lennie Palmer, TPL).*

As an example of how fish passage may be affected during the main native upstream migration period, monthly median river flows are shown in Figure 6.8 for six locations in the Kaniere River under the enhanced scheme. The month of November is an upstream migration period for the majority of native fish found in the Kaniere River catchment, including bluegill, common and redfin bullies, banded, giant and shortjaw kokopu, koaro, longfin and shortfin eels and torrentfish (Table 6.4). It is apparent that a juvenile koaro migrating upstream in the Kaniere River in November will experience wide variation in flows as it progresses from the lower end of the scheme below the McKays Creek station discharge to the lake outlet (Figures 6.8). In contrast, flows in an unmodified river would be relatively constant as the koaro progressed upstream, with the only variation perhaps being a decrease in flow upstream due to fewer tributary inflows.

In general, the enhanced scheme will reduce flows and increase flow variation between most river reaches relative to the existing situation (Table 6.1). For example, the sequence of *median* flows that a juvenile koaro might currently encounter as it migrated upstream in November would be approximately 7.4, 2.4, 1.1, 5.5, and 5.4 cumecs (Palmer 2010). Under the enhanced scheme this would become approximately 9.6, 0.7, 0.3, 7.9, and 0.3 cumecs (i.e., median flow reductions in three of five reaches) (Figure 6.8).

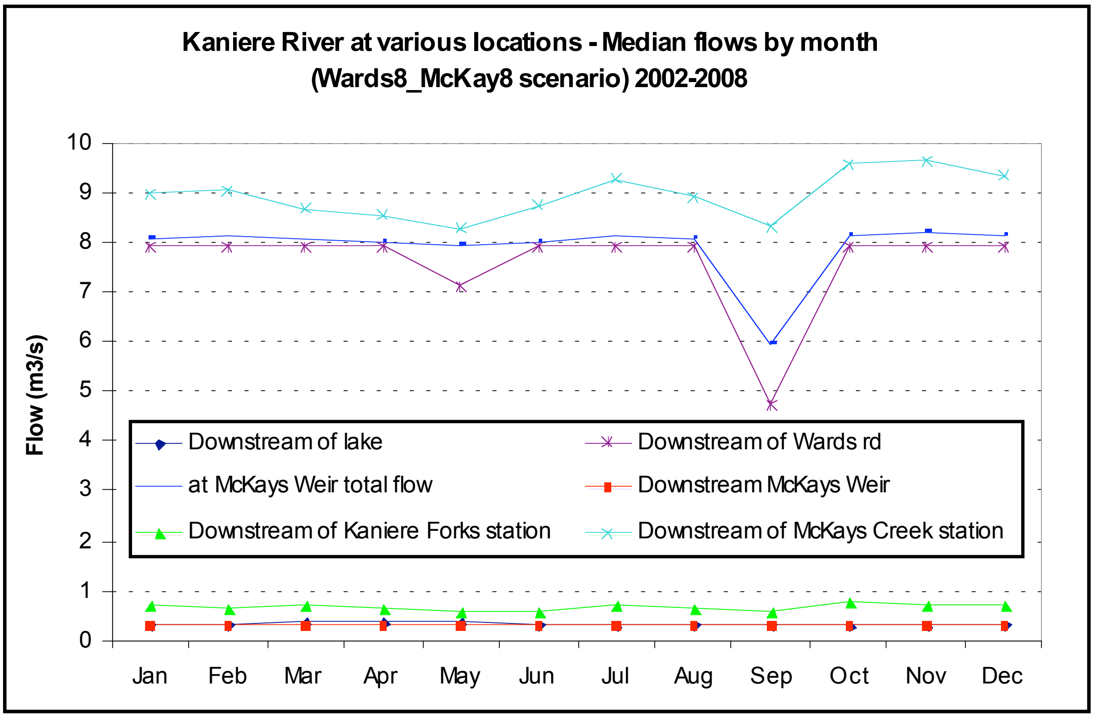


Figure 6.8 *Monthly median flow (cumecs) at six locations in the Kaniere River under the enhanced scheme (graph provided by Lennie Palmer, TPL).*

The major flow variations between reaches are due to water intakes and water discharges above and below power stations. A major variation in flow currently occurs upstream and downstream of the McKays power station discharge (median flow variation 4.6 cumecs), and this variation increases under the enhanced scheme (8.3 cumecs). As the discharge from the McKays power station is currently larger than the median flow in the river mainstem upstream, migrating fish may be encouraged to continue up the discharge channel towards the power station during generation rather than up the river mainstem. This effect is likely to be exacerbated under the enhanced scheme. The discharge from the proposed new Wards Road station would also exceed median flows in the river mainstem so upstream migrating fish, unless prevented from doing so, may also enter the station tailraces during generation.

Aside from upstream migrating fish potentially being attracted to the power station tailraces during generation, reductions in flow may also affect connectivity within the mainstem and access to tributaries. In order to allow identification of areas in the river where this may be a problem TPL reduced flows at the lake outlet (within existing consent conditions) to 0.2 cumecs on 26 May 2010. The flow in the river was supplemented downstream of here by surface inflows such that, at Wards Road, the flow had increased to 0.65 cumecs. Our inspections of the river at several points at this flow did not identify any connectivity issues. A similar flow reduction trial was undertaken in the lower river on 11 August 2010. Discharge from the Kaniere Forks power station was stopped and flow in the river downstream of McKays weir was maintained at 0.22 cumecs. This resulted in a flow of approximately 0.8 cumecs at McKays Ford, flows increased downstream with tributary inflows. The entire river reach from McKays weir downstream to the McKays power station tailrace discharge (approximately 3.8km long) was inspected under these flow conditions. Several sections were identified where maximum water depths at these flows ranged from 20-30cm (e.g. Figure 6.9). The length of these shallow sections ranged from only 1-2m to greater than 10m. Native fish passage is unlikely to be affected by the shallow water depths observed, however, passage for larger salmonids may be. Flows in some reaches under the enhanced scheme would also be lower than that which was observed on 11 August (e.g. 0.50 not 0.8 cumecs at McKays Ford).

Figure 6.9 Kaniere River below McKays weir to McKays Ford (left to right, upstream to downstream) at flows of approximately 0.22 cumecs (top photos) and 0.8 cumecs (bottom photos). Under the enhanced scheme the minimum flow throughout this reach would range from 0.3 to 0.5 cumecs.

May and June are likely to be important months for downstream fish migration in the Kaniere River, as it is during these months that adult longfin eels and larval galaxiids migrate downstream (Table 6.4), although this can be dependent on a number of environmental variables such as rainfall and temperature (Ryder 2006). Downstream eel migration typically peaks during periods of elevated flow so as an example maximum flows during May and June were therefore examined for the enhanced scheme (Figure 6.10). In May maximum flow in the reach downstream of the lake outlet is only 0.39 cumecs. This is due to 8 cumecs being taken into the new Wards Road race at the lake outlet. Freshes and floods above 8 cumecs will, however, pass down the river, as observed in June (Figure 6.10), and as downstream migrating eels most likely take their cue to migrate from increased inflows to the lake it is possible that operation of the scheme will not affect the cue for downstream migration. Flow simulations indicate that daily inflows to Lake Kaniere exceed 8 cumecs approximately 27% of the time in May and 40% of the time in June (Figure 5.2.7 Palmer 2010).

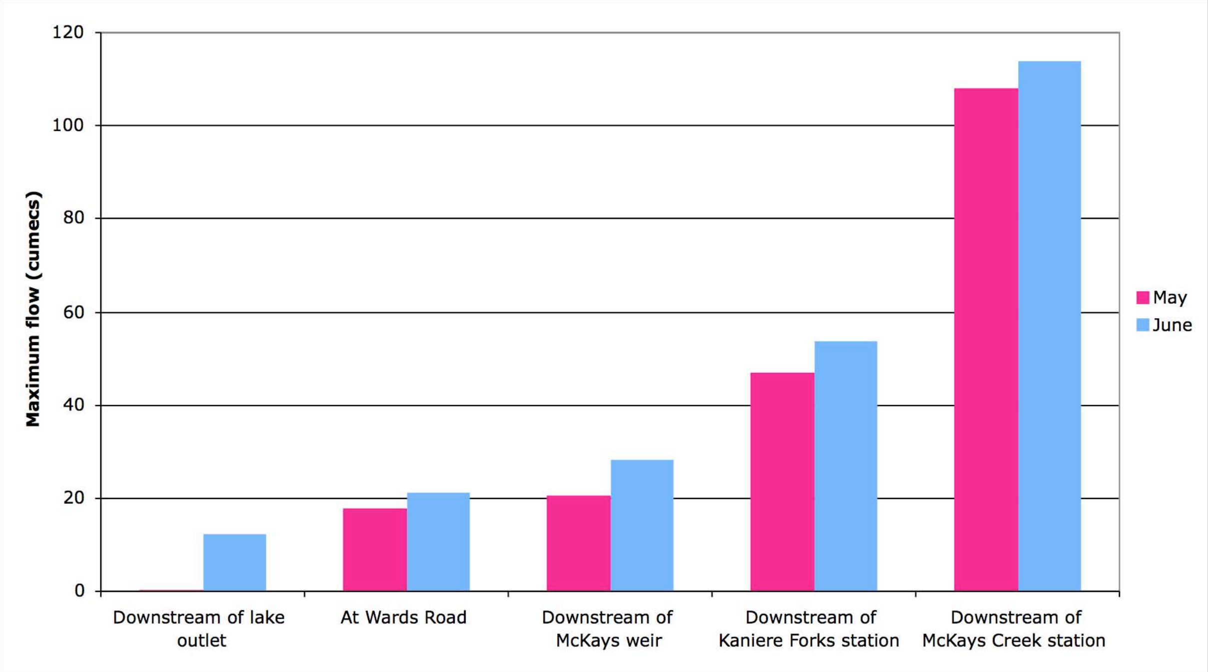


Figure 6.10 *Simulated 3-hourly maximum flows (cumecs) in the Kaniere River, May and June 2002-2008 under the enhanced scheme.*

(ii) Blue Bottle Creek

The existing take from Blue Bottle Creek to the McKays race is up to 1 cumec and this will not change under the enhanced scheme. The median flow at the Blue Bottle Creek intake is 0.21 cumecs (Table 5.6.1 Palmer 2010). The intake captures approximately 80-90% of the flow in Blue Bottle Creek at flows below 0.5 cumecs and approximately 20% at flows above 1 cumec (Palmer 2010). No minimum residual flow is provided below the intake in Blue Bottle Creek and the median residual flow is 0.06 cumecs (Palmer 2010). Under low flow conditions the creek channel has been observed to have no surface flow for at least 100m downstream of the intake (V. Keesing, *pers. comm.*). Further downstream, surface and groundwater inflows contribute water so there is surface flow, although connectivity is limited under these conditions. Despite this existing situation, fish distribution records indicate that fish can and do move freely throughout the creek at higher flows, although fish densities indicate instream structures may limit this movement somewhat (refer to Section 6.2.4).

6.3 Water quality

6.3.1 Background

Water quality in the Kaniere River is good due to the limited development in the catchment and the large amount of native riparian vegetation that remains as a consequence of this. There are no major discharges to the river so reduced flows in the river under the enhanced scheme will have no effect on potential contaminant dilutions, however, water temperatures may be affected.

6.3.2 Water temperature

A maximum water temperature of 23°C was recorded in the Kaniere River during monitoring from November to April this year. Sustained periods of reduced flow under the enhanced scheme could cause temperature variation in the river, particularly during summer months. Substantial increases in water temperature coupled with an absence of safe retreats can result in fish and invertebrate stress and potential mortality. While flow does not have a large effect on daily mean temperatures, a reduction in flow will increase diurnal variation by increasing temperatures in the afternoon and decreasing them in early morning. An increase in diurnal maximum temperatures has less effect on aquatic invertebrates than the same change in daily mean temperature (Cox and Rutherford 2000).

There is detailed information available on the effects of water temperature on river invertebrates. Water temperature can affect abundance, growth, metabolism, reproduction, and activity levels of aquatic insects. A detailed analysis of 88 New Zealand rivers (Quinn and Hickey 1990) identified water temperature as one of the important variables affecting species distribution. Stoneflies (Plecoptera) were largely confined to rivers between 13 and 19°C, and mayflies (Ephemeroptera) were less common in rivers with maximum temperatures of >21.5°C (Quinn and Hickey 1990). The common mayfly *Deleatidium* has an LT_{50} (the temperature at which 50% of individuals will die) of 22.6°C (Table 6.5).

Table 6.5 Upper lethal temperatures (based on an LT_{50} standard, the temperature at which 50% of individuals will die) for the common invertebrate taxa.

Taxa	Life stage	Upper lethal temperature (°C)	Source
Deleatidium spp.	Mid-late instar	22.6-26.8	Quinn *et al.* 1994 Cox & Rutherford 2000
Aoteapsyche spp.	Mid-late instar	25.9-27.8	Quinn *et al.* 1994
Elmidae	Mid-late instar	32.6-34.0	Quinn *et al.* 1994
Potamopyrgus antipodarum	Unknown	31.0	Cox and Rutherford 2000
Zelandobius spp.	Mid-late instar	28.0	Quinn *et al.* 1994

There is the potential at high temperatures for *Deleatidium* to be replaced by the grazing snail *Potamopyrgus antipodarum*, which has a much higher LT_{50} (31.0°C). *Potamopyrgus* can be considered a less desirable taxa as it is a less attractive prey item for trout and native fish. Some recent research has suggested that *Deleatidium* may be able to survive short periods of high temperatures, provided they have experienced a summer acclimation period (Cox and Rutherford 2000). There are already some existing differences in the invertebrate community of the Kaniere River among sites, with *Potamopyrgus* snails more common than *Deleatidium* mayflies at sites upstream of McKays weir, and the opposite pattern downstream of McKays weir (refer to Section 4.1.4). Due to the limited amount of water temperature data available it is not possible to determine from existing information if this is due to water temperature differences among sites or to greater flow stability and periphyton accrual associated with the lake outlet.

The effects of water temperature on New Zealand native fish have been summarised by Richardson *et al.* (1994). In general the tolerances for native fish species are much higher than for trout (Table 6.6), and lethal temperatures are unlikely to ever be achieved in flowing sections of most rivers. Trout, therefore, remain the species that if protected against temperature increases will result in protection of other river fish species.

The effect of the flow reduction on water temperatures in rivers is typically predicted using the WAIORA model (Jowett *et al.* 2004). However, as under the enhanced scheme flows will vary markedly in different locations in the river often over short distances (e.g. 2km), depending on how much water is being diverted, the WAIORA model is difficult to apply.

Surface water temperature is driven by climatic and geographic conditions including air temperature, radiation and shade. The high water temperatures in Kaniere River in late summer are driven by the lake outlet water temperature as lakes act as heat stores. The Arnold River, which flows out of Lake Brunner, is a good example of this on the West Coast (see Jowett 2010; Ryder 2010). However, when the flow of a river reduces it becomes more sensitive to radiation because it is shallower and flows more slowly. As a result of day heating and night cooling, daily fluctuations in water temperature increase, but there is little change in the daily mean temperature.

Table 6.6 *Upper lethal temperatures (based on an LT_{50} standard, the temperature at which 50% of individuals will die) and preferred temperatures for a range of fish species. Superscripts match temperature values to the reference source.*

Species	Life stage	Upper lethal temperature	Preferred temp (and quartiles)	Source
Short-finned eel (*Anguilla australis*)	Elver Adult	35.7[1] 39.7[1]	26.9 (25.6-28.5)[1] 26.0[2]	[1]Richardson *et al.* 1994 [2]Todd 1981
Long-finned eel (*A. dieffenbachii*)	Elver Adult	34.8[1] 37.3[1]	24.4 (22.6-26.2)[1] 24.0[2]	[1]Richardson *et al.* 1994 [2]Todd 1981
Common bully (*Gobiomorphus cotidianus*)	All	30.9	20.2 (18.7-21.8)	Richardson *et al.* 1994
Torrentfish (*Cheimarricthys fosteri*)	Adult	30.0	21.8 (20.1-22.9)	Richardson *et al.* 1994
Inanga (*Galaxias maculatus*)	Juvenile Adult	33.1[1] 30.8[2]	18.7 (17.2-20.0)[2] 18.1 (17.2-19.1)[2]	[1]Simons 1986 [2]Richardson *et al.* 1994
Common smelt (*Retropinna retropinna*)	Adult	28.3	16.1 (15.1-17.4)	Richardson *et al.* 1994
Brown trout (*Salmo trutta*)	Adult Juvenile	24.7[1] 29.6[2] 17.4-17.6[3]	13-14[1]	[1]Elliott 1994 [2]Elliott and Elliott 1995 [3]Collier *et al.* 1995
Quinnat salmon (*Oncorhynchus tshawytscha*)	Adult Juvenile	21.0[1] 25.1[2] 25.0[1]	11.3-13.3[1] 14.8[1] 12-13[3]	[1]Armour 1991 [2]Elliott 1994 [3]McCollough 1999

6.4 Instream habitat

6.4.1 Background

The relationship between instream habitat and flow for key aquatic species in the Kaniere River was estimated with habitat hydraulic mapping using instream flow incremental methodology (IFIM). This approach enables an assessment to be made of the effects of flow alterations on physical habitat for fish, invertebrates and periphyton.

Two reaches of the river were surveyed: an upper reach (Wards Road, Figure 6.11) representing the narrower, steeper gradient section of the river from the lake outlet to upstream of McKays weir, and a lower reach (McKays Ford, Figure 6.12) representing the wider and less steep section downstream of McKays weir.

Figure 6.11 Wards Road instream habitat assessment reach, flow 1.1 cumecs.

Figure 6.12 McKays Ford instream habitat assessment reach, flow 1.5 cumecs.

The two components of an IFIM analysis are the hydraulic simulations of a stream reach and habitat suitability criteria for the taxa of interest (e.g. fish, macroinvertebrates, and periphyton). Hydraulic simulation is used to describe the area of a stream having various combinations of depth, velocity and substrate type as a function of flow. This information is used to calculate the Weighted Useable Area (WUA) of the stream segment from suitability information based on field sampling of various aquatic species. Habitat suitability criteria are a way of describing what is considered to be 'good' habitat (Jowett 1996). Once habitat suitability criteria are defined they can be applied to habitat survey data and the amount of suitable habitat with varying flow calculated.

Habitat suitability was modelled against flow using RHYHABSIM software (River Hydraulics and Habitat Simulation, Jowett 1996). References for habitat suitability criteria are given in Table 6.7. Nine fish species and five macroinvertebrate taxa were included in the model. Food producing habitat, which brown trout abundance is related to (Jowett 1992), was also modelled. Three periphyton groups: diatoms, and short and long filamentous algae, were included to evaluate the potential for nuisance algae growths.

Table 6.7 *Habitat suitability criteria used for the Kaniere River instream habitat assessment.*

Species/life stage	**Reference**
Native fish	
Bluegill bully	Jowett and Richardson 2008
Common bully	Jowett and Richardson 2008
Redfin bully	Jowett and Richardson 2008
Koaro	Jowett and Richardson 2008
Shortjaw kokopu	McDowall *et al.* 1996
Longfin eel (<300mm and >300mm)	Jowett and Richardson 2008
Shortfin eel (<300mm and >300mm)	Jowett and Richardson 2008
Torrentfish	Jowett and Richardson 2008
Trout	
Brown trout, <100mm	Jowett and Richardson 2008
Brown trout, adult	Hayes and Jowett 1994
Food producing habitat	Waters 1976
Macroinvertebrates	
Aoteapsyche species	Jowett *et al.* 1991
Deleatidium species	Jowett *et al.* 1991
Elmidae	Jowett *et al.* 2003
Orthocladiinae	Jowett *et al.* 2003
Potamopyrgus species	Jowett *et al.* 2003
Periphyton	
Diatoms	Rhyhabsim v5.0
Long filamentous	Rhyhabsim v5.0
Short filamentous	Rhyhabsim v5.0

Representative cross-sections for hydraulic measurements were randomly chosen within each of the three general habitat types: pool, run, and riffle. Twelve cross-sections were surveyed at each reach, with the number of cross-sections within each habitat type calculated according to the proportion of each habitat type within the reach. This was determined by general visual assessment of the river habitat and detailed measurement of the amount of each habitat within an approximate 1km reach.

Cross-sections were marked across the river using a level line strung between survey pegs. To allow measurement of the degree of water level variation at each cross-section with flow a steel water-level gauging rod was hammered into the riverbed or alternatively a point was marked on the river edge. Water velocity, depth and bed substrate-type was measured at a series of points across the river (approximately every 0.5-1m), and bank profile was described to a height of approximately 1m above the water level.

Survey and calibration flows for each reach are shown in Table 6.8. Water level and hydraulic measurements were made at each cross-section at the survey flow. At the two (McKays Ford) or three (Wards Road) calibration flows water level was measured at each cross-section and the discharge at a representative cross-section determined.

Table 6.8 *Survey and calibration flows for the Wards Road and McKays Ford IFIM sites. 'NA' = not applicable.*

	Wards Road flow (cumecs)	**McKays Ford flow (cumecs)**
Survey flow	1.1	1.5
Calibration flow 1	3.3	2.4
Calibration flow 2	5.5	2.1
Calibration flow 3	0.7	NA

6.4.2 Proposed minimum flows

Under the enhanced scheme flows will vary in different locations in the river (Table 6.1). The Wards Road IFIM model can be used to predict available instream habitat for aquatic taxa at locations upstream of McKays weir under these flow conditions, and the McKays Road IFIM is representative of locations downstream of McKays weir.

(i) Physical characteristics

Mean water depth, velocity and channel and wetted perimeter width generally increased gradually with increasing flow in both survey reaches in the Kaniere River (Figures 6.15 and 6.16). As expected, water velocities are higher and increase more quickly with increasing flow at the Wards Road site relative to the McKays Ford site, reflecting the difference in the channel gradient between the sites (Figures 6.13 and 6.14). Channel and wetted perimeter widths are also narrower at the Wards Road site (Figures 6.13 and 6.14).

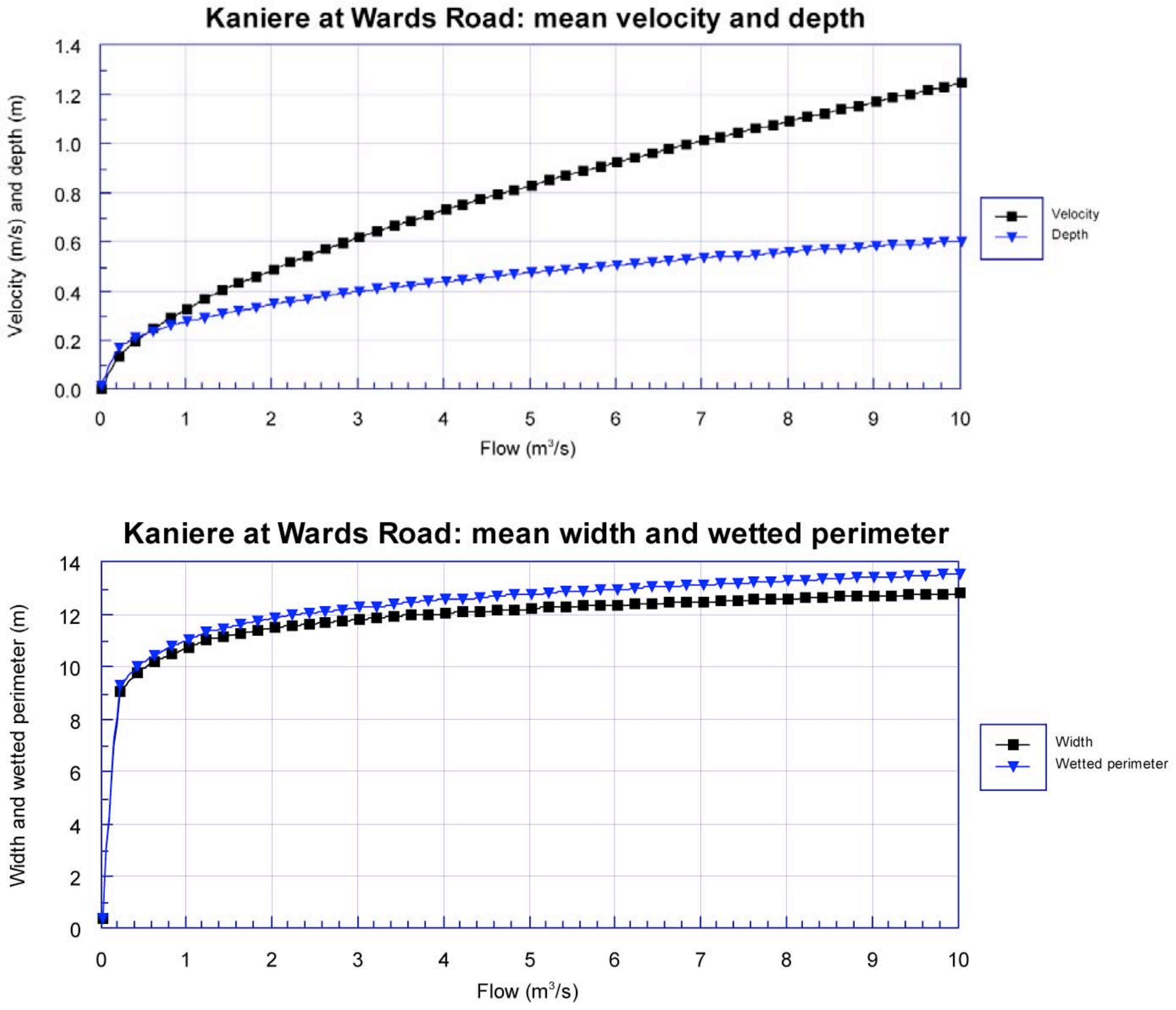
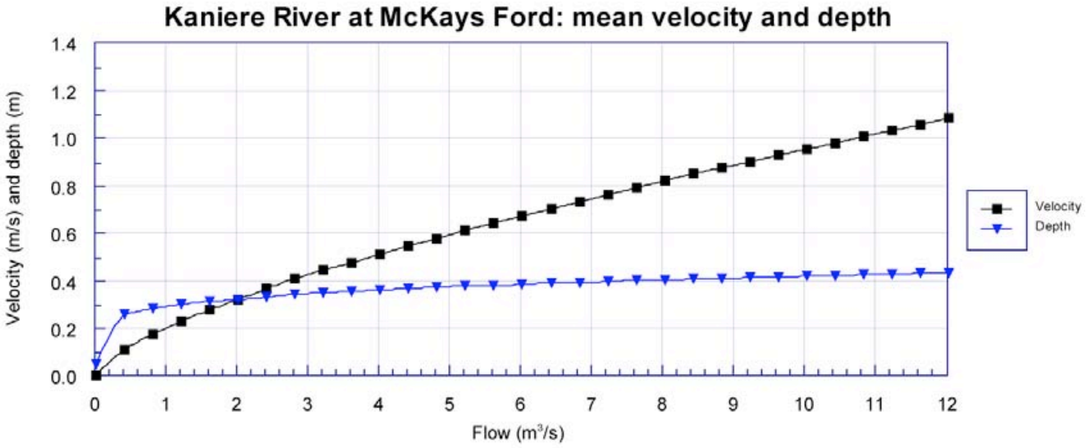


Figure 6.13 Variation of average velocity, depth, width and wetted perimeter with flow in the Kaniere River Wards Road IFIM reach.



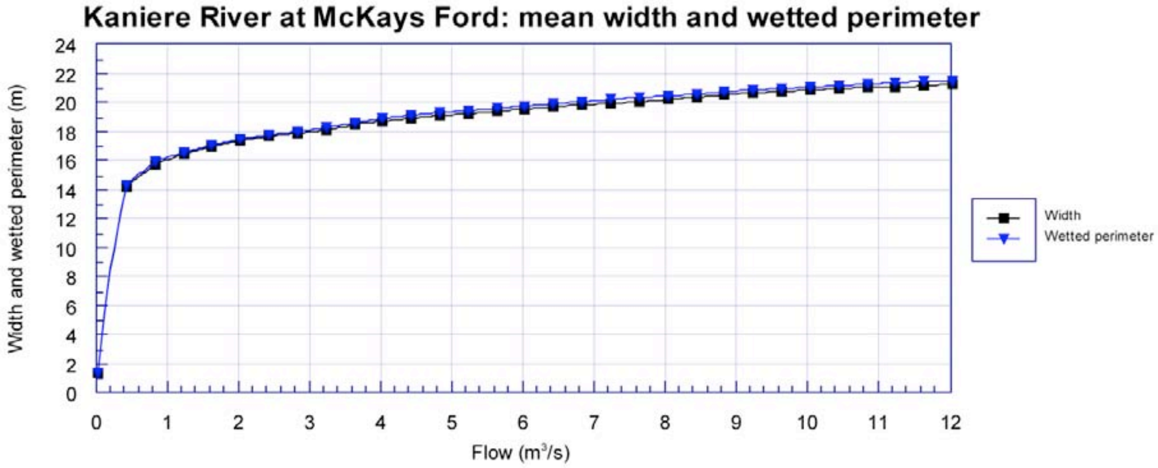


Figure 6.14 *Variation of average velocity, depth, width and wetted perimeter with flow in the Kaniere River McKays Ford IFIM reach.*

Mean physical characteristics at five locations in the Kaniere River at predicted minimum and median flows under the existing situation and the enhanced scheme are shown in Tables 6.9 and 6.10. Water depth and velocity are particularly important characteristics of the river as any changes may affect the quantity and quality of instream habitat for aquatic communities. Changes in channel width and wetted perimeter also affect the quantity of available instream habitat.

In the river upstream of McKays weir (i.e. sites 'downstream of lake outlet' and 'at Wards Road'), the enhanced scheme will result in reductions in mean water velocity, depth, width and wetted perimeter relative to the existing situation (Table 6.9). Velocities will be reduced by approximately 41-48% and depths by approximately 25-30% (Table 6.9). Channel width and wetted perimeter will be reduced by approximately 0.9-1.2m (Table 6.9). At two of the three river reaches downstream of

McKays weir ('downstream of McKays weir' and 'downstream of Kaniere Forks station') mean water velocities, depth and widths under the enhanced scheme will be slightly higher than the existing minimum flow situation (Table 6.9). Downstream of McKays Creek station, mean velocities, depths and widths will be slightly lower than the existing situation (Table 6.9).

Table 6.9 *Mean physical characteristics at the minimum flow as predicted from the relevant IFIM model (Wards Road or McKays Ford) at five locations in the Kaniere River under the existing situation and the enhanced scheme.*

Operating regime	**Physical characteristic**	**1. Downstream of lake outlet**	**2. At Wards Road Station**	**3. Downstream of McKays weir**	**4. Downstream of Kaniere Forks Station**	**5. Downstream of McKays Creek Station**
Existing	*Minimum flow (cumecs)*	0.92	1.0	0.20	0.26	0.82
	Velocity (m/s)	0.31	0.32	0.07	0.07	0.17
	Depth (m)	0.27	0.28	0.23	0.24	0.28
	Width (m)	10.6	10.7	12.9	12.9	16.0
	Wetted perimeter (m)	10.9	11.0	13.0	13.0	16.1
Enhanced	*Minimum flow (cumecs)*	0.30	0.40	0.30	0.38	0.74
	Velocity (m/s)	0.16	0.19	0.09	0.10	0.16
	Depth (m)	0.19	0.21	0.25	0.26	0.27
	Width (m)	9.5	9.8	13.5	14.0	15.5
	Wetted perimeter (m)	9.7	10.0	13.6	14.3	15.7

At median flows the enhanced scheme results in reductions in velocity, depth and width at three of the five locations relative to the existing situation: 'downstream of lake outlet', 'downstream of McKays weir', and 'downstream of Kaniere Forks Station' (Table 6.10). At the remaining two sites, 'at Wards Road' and 'downstream of McKays Creek Station' the enhanced scheme would result in slightly increased velocities, depths and widths at the median flow (Table 6.10).

Differences in the physical characteristics of the river under the enhanced scheme will result in differences in the available instream habitat for aquatic taxa at each location depending on their particular habitat requirements, as discussed in the following sections.

Table 6.10 Mean physical characteristics at the median flow as predicted from the relevant IFIM model (Wards Road or McKays Ford) at five locations in the Kaniere River under the existing situation and the enhanced scheme.

Operating regime	**Physical characteristic**	**1. Downstream of lake outlet**	**2. At Wards Road Station**	**3. Downstream of McKays weir**	**4. Downstream of Kaniere Forks Station**	**5. Downstream of McKays Creek Station**
Existing	*Median flow (cumecs)*	5.5	5.8	1.4	2.9	7.5
	Velocity (m/s)	0.88	0.90	0.25	0.41	0.78
	Depth (m)	0.49	0.50	0.30	0.34	0.40
	Width (m)	12.3	12.3	16.7	17.9	20.0
	Wetted perimeter (m)	12.9	12.9	16.8	18.1	20.2
Enhanced	*Median flow (cumecs)*	0.33	7.9	0.30	0.68	9.0
	Velocity (m/s)	0.16	1.1	0.09	0.16	0.89
	Depth (m)	0.19	0.55	0.25	0.27	0.41
	Width (m)	9.5	12.6	13.5	15.5	20.5
	Wetted perimeter (m)	9.7	13.3	13.6	15.7	20.8

(ii) Instream habitat

There are two measures of instream habitat that can be used to assess minimum flow requirements of aquatic taxa. WUA (m^2/m, WUA) can be regarded as a measure of the quantity of potentially available habitat provided by the flow, and the average habitat suitability index (HSI) is a measure of the quality of the habitat. HSI is numerically equivalent to WUA divided by the wetted river width (Jowett *et al.* 2008). Both measures of instream habitat are presented below for fish, invertebrates, macrophytes and periphyton at the two IFIM locations in the Kaniere River.

1. Wards Road

Native fish

Available habitat for eight native fish species (bluegill bully, common bully, redfin bully, koaro, shortjawed kokopu, longfin eel, shortfin eel and torrentfish) was modelled. Habitat for most native fish species is maximised at flows below 1 cumec; however, habitat for bluegill bully, koaro and torrentfish is greater at higher flows due to their higher velocity preferences (Figure 6.15).

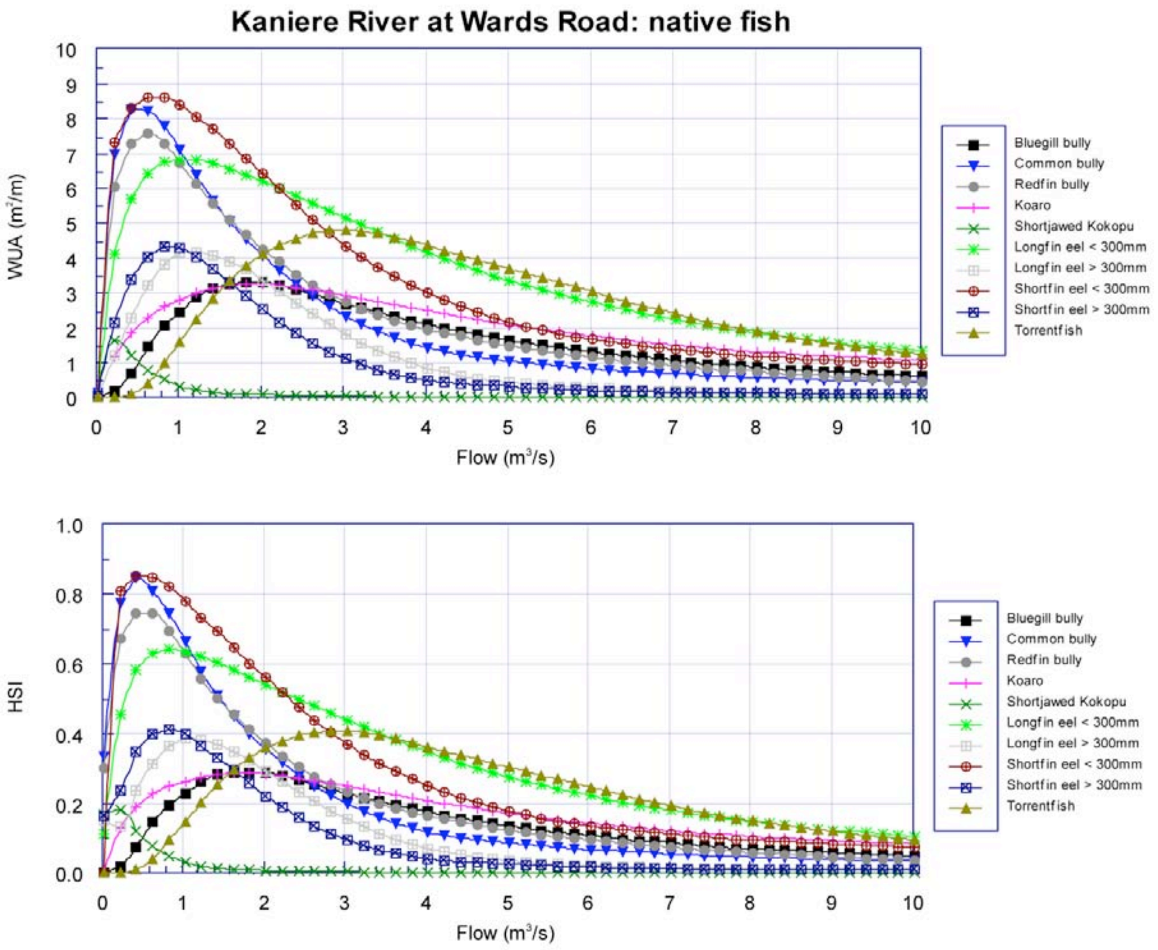


Figure 6.15 *Variation of WUA (m²/m) and HSI with flow for bluegill bully, common bully, redfin bully, koaro, shortjawed kokopu, longfin and shortfin eels (<300mm and >300mm) and torrentfish in the Kaniere River at Wards Road.*

Brown trout

Habitat for adult brown trout and food producing is maximised at flows of 2.7 and 3.7 cumecs respectively at the Wards Road IFIM reach (Figure 6.16). Smaller trout (<100mm) have lower flow requirements and their habitat is maximised at flows of around 1 cumec (Figure 6.16).

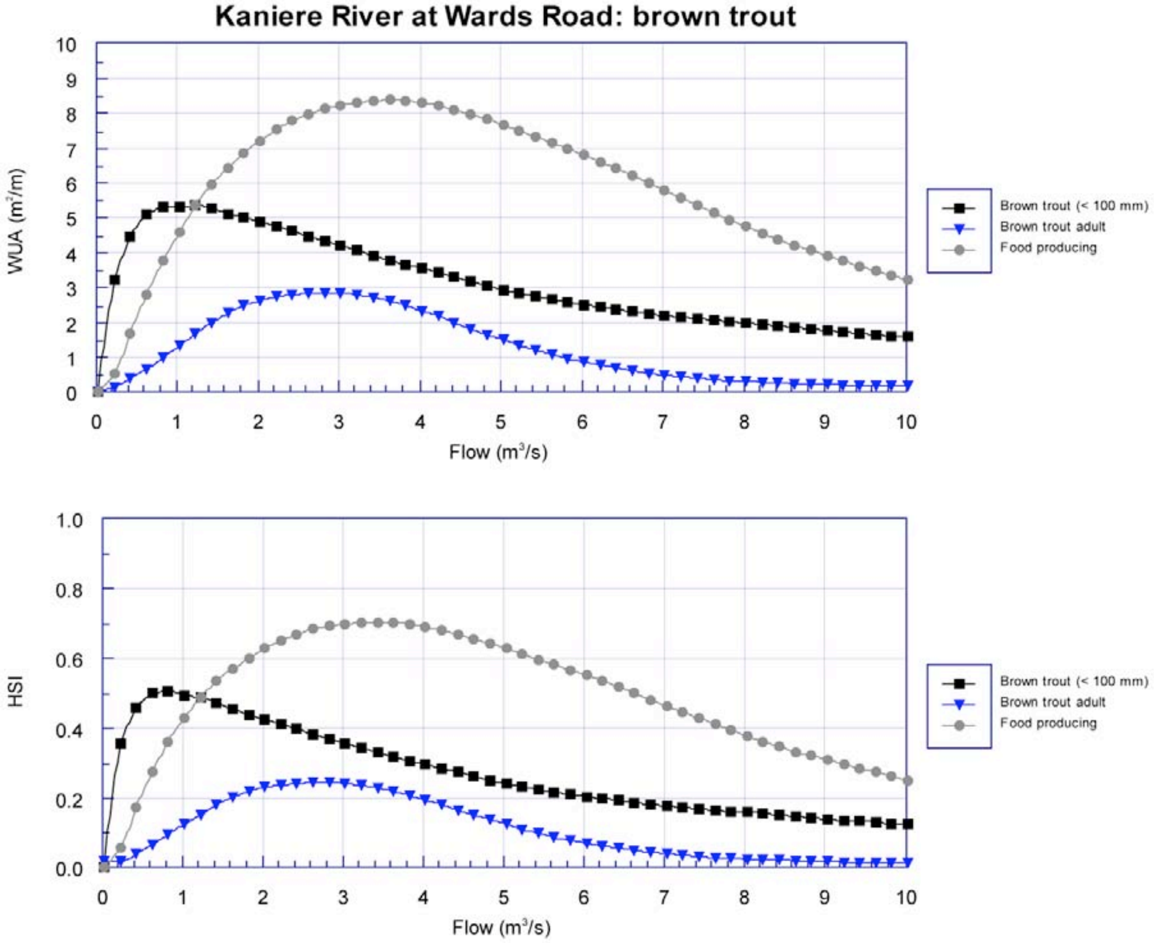


Figure 6.16 *Variation of WUA (m^2/m) and HSI with flow for brown trout and food producing habitat in the Kaniere River at Wards Road.*

Benthic macroinvertebrates

Available habitat for the five macroinvertebrate taxa modelled show differing responses to decreasing flow (Figure 6.17). Both the quantity (WUA) and quality (HSI) of habitat increases for Elmidae (beetles) and *Potamopyrgus* species (snail) as flows decrease; however, for *Aoteapsyche* (net spinning caddisfly) habitat improves as flows increases (Figure 6.17). Habitat for *Deleatidium* mayflies is maximised at

2.8 cumecs (Figure 6.17).

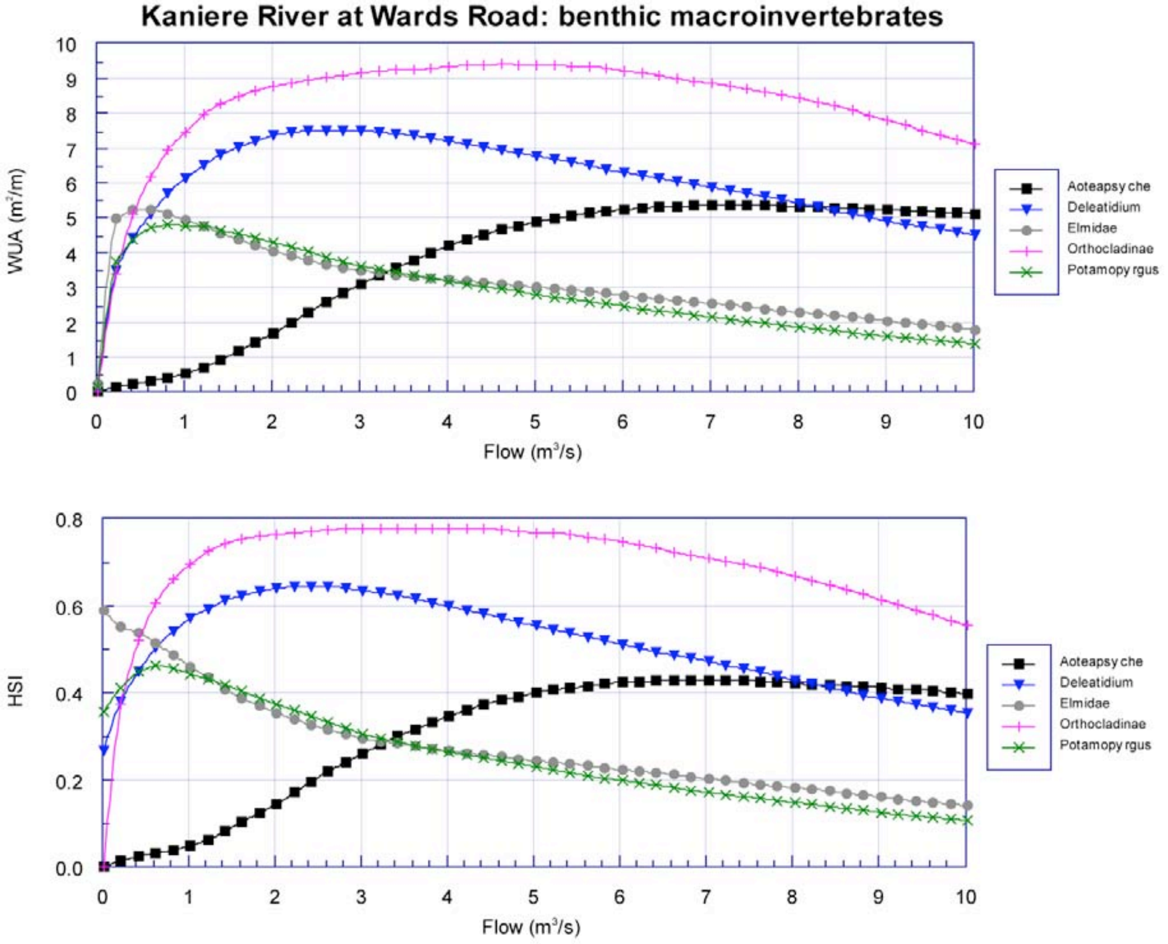


Figure 6.17 *Variation of WUA (m^2/m) and HSI with flow for five benthic macroinvertebrate taxa in the Kaniere River at Wards Road.*

Periphyton

The growth of long filamentous algae in a river can result in changes to invertebrate communities and in the availability of invertebrates as food for fish. As flows decrease in the river, the amount of potential habitat for both short and long filamentous algae increases (Figure 6.18). The quantity (WUA) and quality (HSI) of habitat for long filamentous algae is high at flows of 0.2-0.4 cumecs (Figure 6.18). In contrast, as flows decrease the habitat becomes less suitable for diatoms (Figure 6.18).

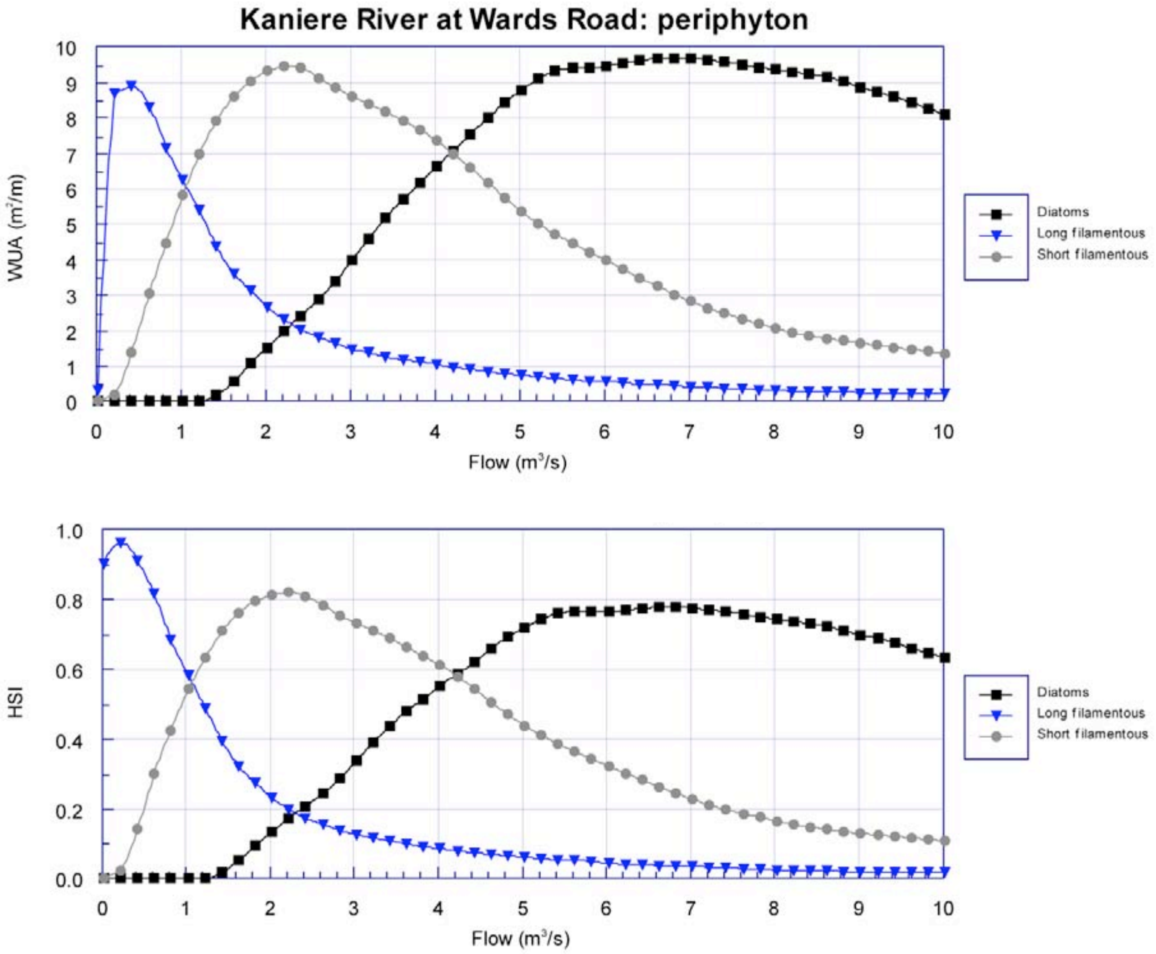


Figure 6.18 *Variation of WUA (m^2/m) and HSI with flow for periphyton (diatoms, short and long filamentous algae) in the Kaniere River at Wards Road.*

2. McKays Ford

Native fish

Available habitat for eight native fish species (bluegill bully, common bully, redfin bully, koaro, shortjawed kokopu, longfin eel, shortfin eel and torrentfish) was modelled. Habitat for most native fish species is maximised at flows between 0.5-2 cumecs; however, habitat for bluegill bully, koaro and torrentfish is greater at higher flows due to their higher velocity preferences (Figure 6.19).

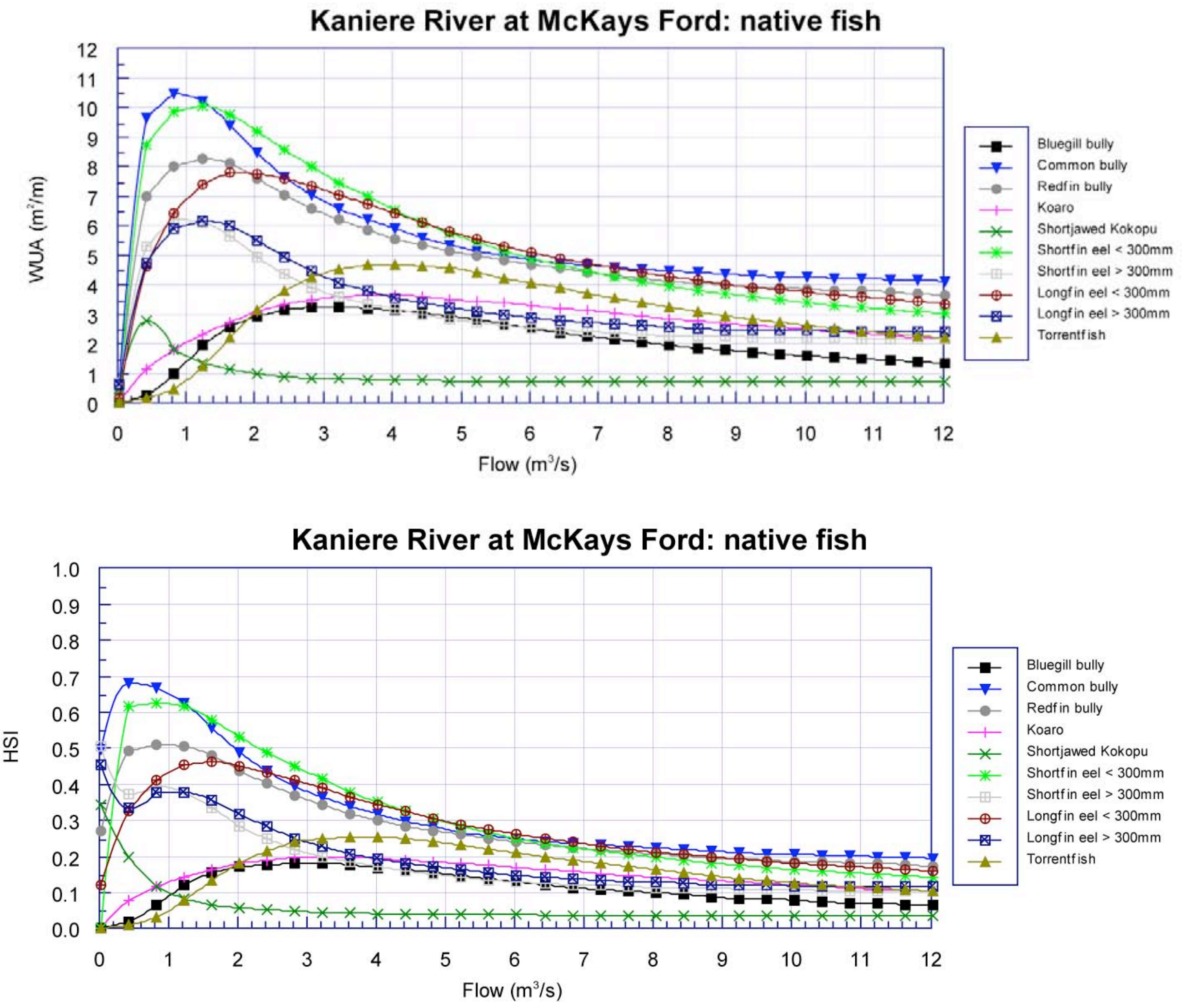


Figure 6.19 *Variation of WUA (m^2/m) and HSI with flow for bluegill bully, common bully, redfin bully, koaro, shortjawed kokopu, longfin and shortfin eels (<300mm and >300mm) and torrentfish in the Kaniere River at McKays Ford.*

Brown trout

Habitat for adult brown trout and food producing is maximised at flows of 2.5 and 3.7 cumecs respectively at the Wards Road IFIM reach (Figure 6.20). Smaller trout (<100mm) have lower flow requirements with habitat maximised at flows of 2.3 cumecs (Figure 6.20).

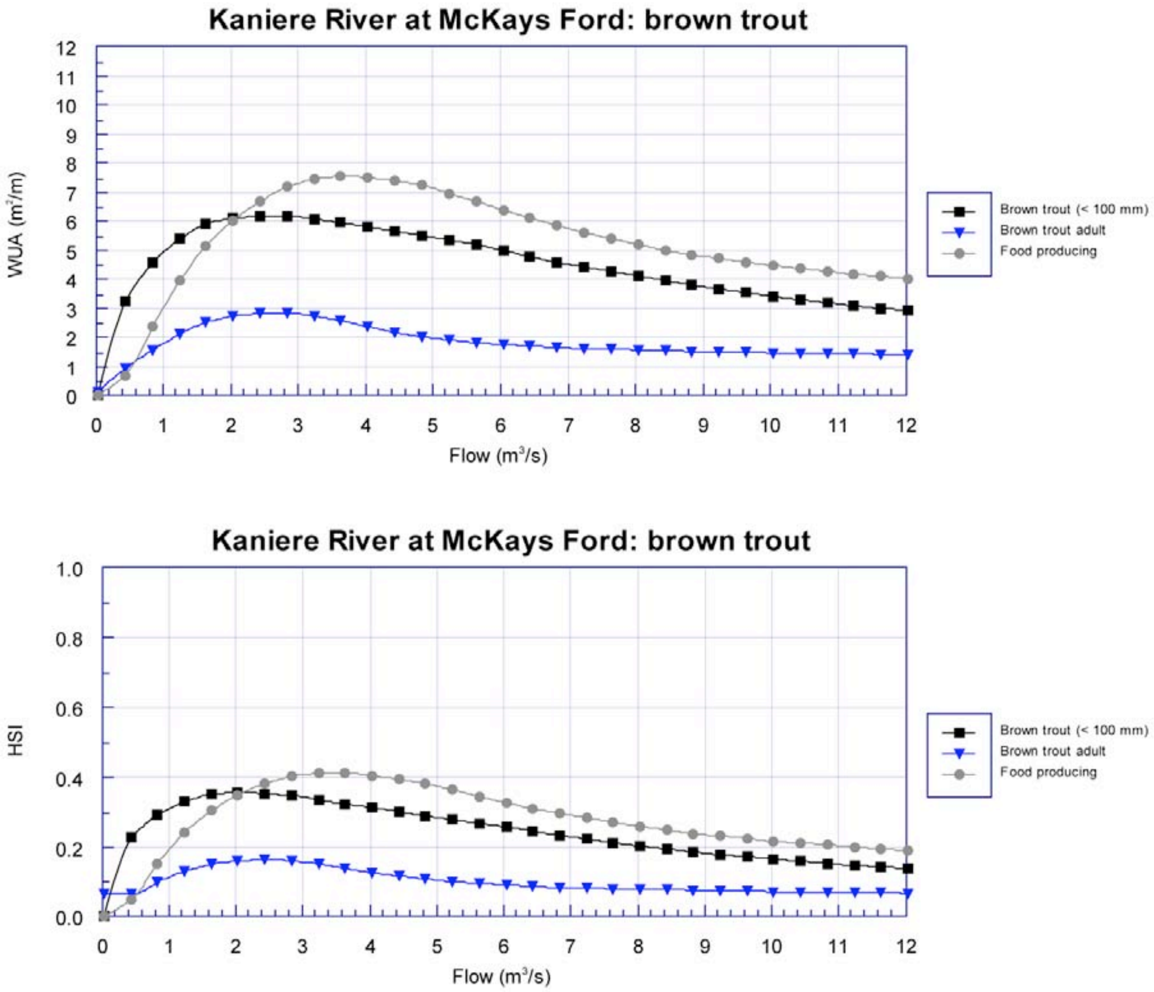


Figure 6.20 *Variation of WUA (m²/m) and HSI with flow for brown trout and food producing habitat in the Kaniere River at McKays Ford.*

Benthic macroinvertebrates

Available habitat for the five macroinvertebrate taxa modelled show differing responses to decreasing flow (Figure 6.21). Both the quantity (WUA) and quality (HSI) of habitat increases for Elmidae (beetles) and *Potamopyrgus* (snail) as flows decrease; however, for *Aoteapsyche* (net spinning caddisfly) habitat improves as flows increases (Figure 6.21). Habitat for *Deleatidium* mayflies is maximised at 5 cumecs (Figure 6.21).

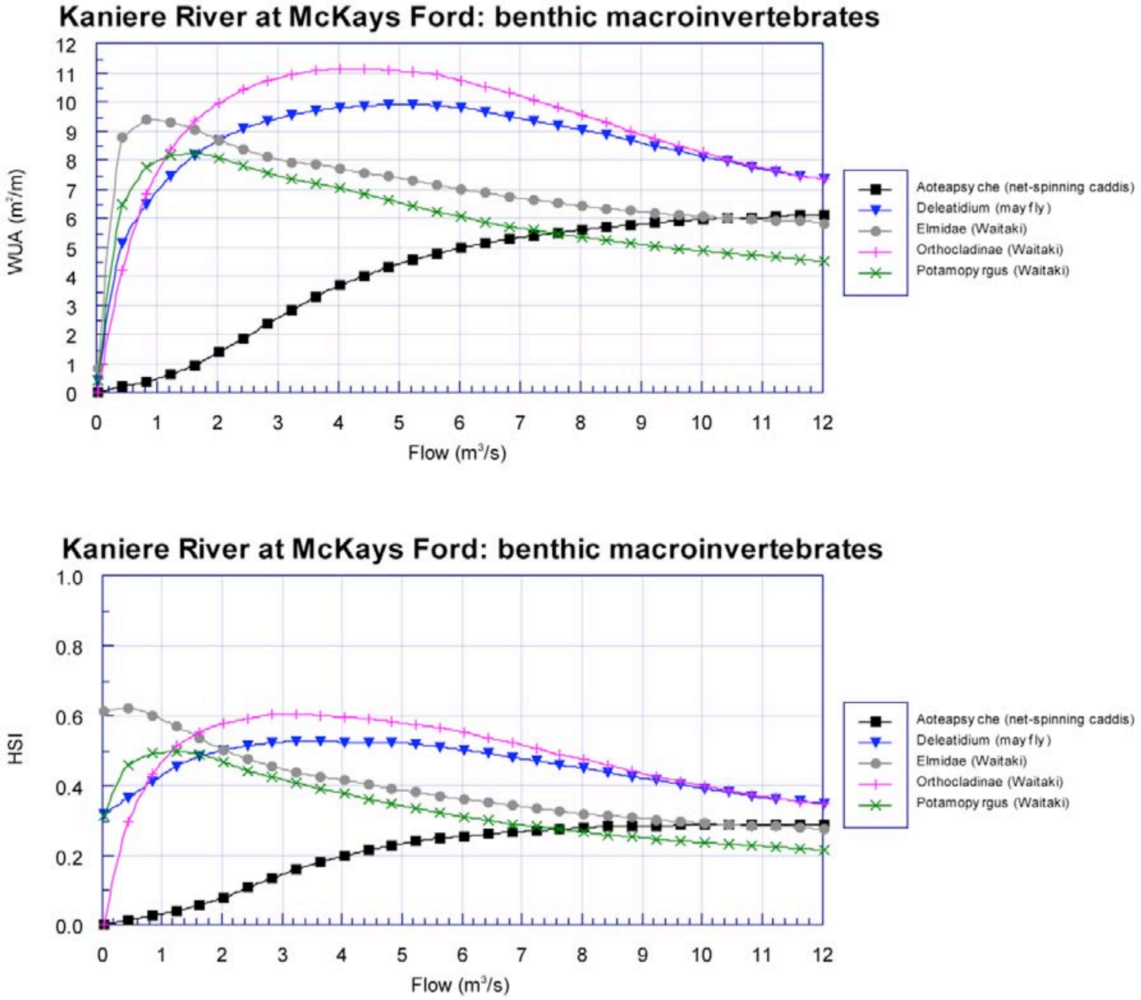


Figure 6.21 Variation of WUA (m²/m) and HSI with flow for five benthic macroinvertebrate taxa in the Kaniere River at McKays Ford.

Periphyton

The growth of long filamentous algae in a river can result in changes to invertebrate communities and in the availability of invertebrates as food for fish. As flows decrease in the river, the amount of potential habitat for both short and long filamentous algae increases (Figure 6.22). The quantity (WUA) and quality (HSI) of habitat for long filamentous algae is high at flows around 0.7 cumecs (Figure 6.22). In contrast, as flows decrease the habitat becomes less suitable for diatoms (Figure 6.22).

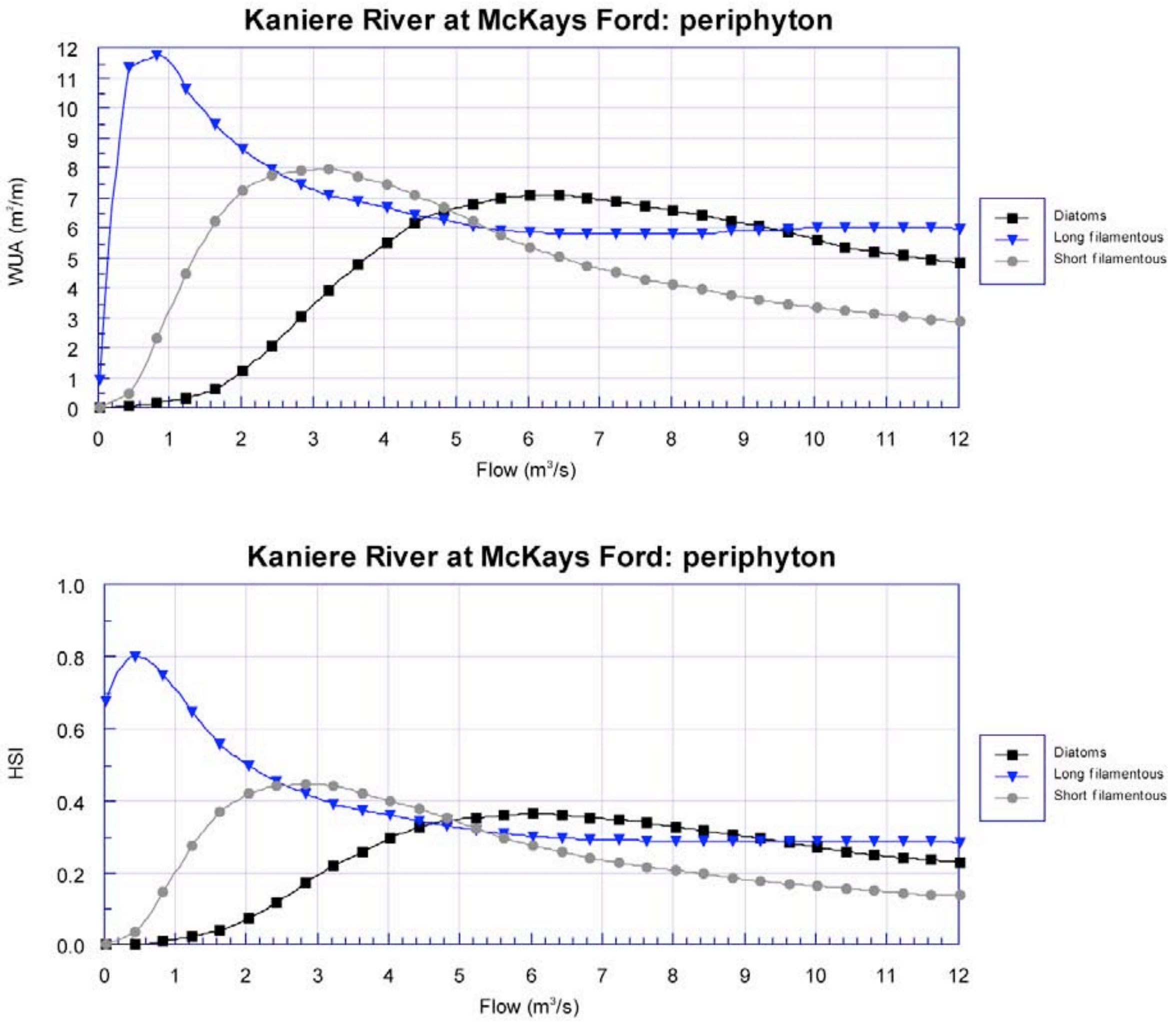


Figure 6.22 *Variation of WUA (m²/m) and HSI with flow for periphyton (diatoms, short and long filamentous algae) in the Kaniere River at McKays Ford.*

3. Instream habitat quantity summary

The amount of available instream habitat (WUA) for aquatic species under the existing situation and enhanced scheme is shown for each of the five locations in the river in Tables 6.11-6.15. The approximate length of river relating to each location is as follows:

- Lake outlet – 3.1km;
- Wards Road – 4.1km;
- Downstream of McKays weir – 1.8km;
- Downstream of Kaniere Forks Station – 2.0km; and
- Downstream of McKays Creek Station – 5.6km.

The amount of habitat available for a species depends on its habitat requirements, for some species the amount of habitat increases as flows increase (e.g. koaro and torrentfish) and for other species it decreases (e.g. common bully and redfin bully). Habitat requirements depend on the management objectives of the river, and it is fair to say that to date the Kaniere River has been managed primarily for hydro generation. However, the river also provides habitat for native fish species and consideration is required to provide sufficient flow to sustain their populations as well as providing some habitat for other aquatic taxa (e.g., brown trout and benthic invertebrates) and minimising nuisance algae growths. The amount of habitat for aquatic taxa under the enhanced scheme relative to the existing situation at minimum and median flows is discussed below (progressing from upstream to downstream).

Under the enhanced scheme, *minimum* flows in the two upstream locations (i.e. at 'lake outlet' and 'Wards Road') will be reduced by approximately 57-67% relative to the existing situation and as a result habitat for most native fish (except common bully, redfin bully, shortjaw kokopu and short fin eel (<300mm)), brown trout, food producing habitat and invertebrates in the river is generally predicted to decrease (Tables 6.11 and 6.12). In contrast, although the *median* flow would be reduced at the lake outlet by approximately 94% relative to the existing situation, due to the physical characteristics of the river here, a *median* flow reduction is actually predicted to increase habitat for most native fish species (Table 6.10). Habitat for native fish species with higher velocity preferences (bluegill bully, koaro, and torrentfish), adult brown trout, food producing habitat and most invertebrates is, however, predicted to reduce (Table 6.11).

At Wards Road the proposed *median* flow is approximately 2 cumecs higher than the existing median flow (Table 6.12). Due to the physical characteristics of the river this will result in a reduction in habitat for all fish species, food producing habitat, and most invertebrate species (Table 6.12).

In the reach downstream of McKays weir, the *minimum* flow of 0.3 cumecs is slightly higher than the existing situation (Table 6.13). This will result in similar or increased habitat for all fish species, food producing habitat, and invertebrate species relative to the existing situation (Table 6.13). However, the *median* flow is also approximately 0.3 cumecs, which is approximately 1.1 cumecs lower than the existing median flow, resulting in predicted habitat reductions for most species (Table 6.13).

Minimum flows in the vicinity of 'downstream of Kaniere Forks' are approximately 0.12 cumecs higher than the existing situation, resulting in slightly increased habitat, however, *median* flows are lower (Table 6.14). Decreased *median* flows will increase habitat for some native fish species, although habitat for native fish species with higher velocity preferences, adult brown trout, food producing habitat and most invertebrates will reduce (Table 6.14).

At the most downstream location, *minimum* flows are reduced by approximately 0.1 cumecs relative to the existing situation with habitat for most native fish, trout, food producing habitat and invertebrates predicted to be similar or slightly reduced as a result (Table 6.15). *Median* flows are increased by approximately 1.5 cumecs with habitat for most native fish, trout, food producing habitat and invertebrates predicted to be similar or slightly reduced as a result (Table 6.15).

In conclusion, relative to the existing situation upstream of McKays weir (reach length approximately 7.2km), the proposed decreased *minimum* flows are predicted to decrease habitat for native fish, brown trout, food producing habitat and invertebrates. Reduced *median* flows at the lake outlet would increase habitat for native fish species with low velocity preferences, however, increased *median* flows at Wards Road would decrease habitat.

In the reach downstream of McKays weir (length approximately 1.8km) the proposed *minimum* flow is the slightly higher than the existing situation resulting in similar or slightly increased habitat. However, the proposed decreased *median* flow is predicted to decrease habitat for most species.

In the reach downstream of Kaniere Forks station (length approximately 2km) proposed *minimum* flows are predicted to slightly increase habitat for native fish, trout, food producing habitat and invertebrates relative to the existing situation. However, proposed decreased *median* flows are predicted to decrease habitat for all species except those with lower velocity preferences.

In the reach downstream of McKays Creek station (length approximately 5.6km) proposed decreased *minimum* and increased *median* flows are predicted to increase habitat for native fish species with low velocity preferences, relative to the existing situation.

In most reaches habitat for nuisance long filamentous algae growths are predicted to be similar or increased under the enhanced scheme relative to the existing situation.

Table 6.11 Physical habitat expressed as WUA (m^2/m) for a range of species at the minimum and median flows (cumecs) in the Kaniere River at the lake outlet under the existing situation and the enhanced scheme. Predicted using the Wards Road IFIM model.

Operating regime	**Existing**	**Enhanced**	**Existing**	**Enhanced**
	Minimum flow (cumecs)		***Median flow (cumecs)***	
	0.92	**0.3**	**5.5**	**0.33**
Native fish				
Bluegill bully	2.3	0.4	1.4	0.4
Common bully	7.5	7.8	0.9	7.8
Redfin bully	7.0	6.8	1.3	6.8
Koaro	2.7	1.5	1.9	1.5
Shortjaw kokopu	0.4	1.4	0.0	1.4
Longfin eel (<300mm)	6.8	5.0	3.0	5.0
Longfin eel (>300mm)	4.0	1.8	0.3	1.8
Shortfin eel (<300mm)	8.5	7.9	1.9	7.9
Shortfin eel (>300mm)	4.3	2.8	0.2	2.8
Torrentfish	1.3	0.0	3.4	0.0
Trout				
Brown trout, <100mm	5.3	3.9	2.7	3.9
Brown trout, adult	1.2	0.2	1.1	0.2
Food producing habitat	4.2	1.1	7.2	1.1
Macroinvertebrates				
Aoteapsyche species	0.4	0.2	5.1	0.2
Deleatidium species	5.9	4.0	6.5	4.0
Elmidae	5.0	5.2	2.9	5.2
Orthocladiinae	7.2	4.3	9.3	4.3
Potamopyrgus species	4.8	4.1	2.6	4.1
Periphyton				
Diatoms	0.0	0.0	9.4	0.0
Long filamentous	6.7	8.9	0.6	8.9
Short filamentous	5.1	0.6	4.6	0.6

Table 6.12 *WUA (m^2/m) for a range of species at the minimum and median flows (cumecs) in the Kaniere River at Wards Road under the existing situation and the enhanced scheme. Predicted using the Wards Road IFIM model.*

Operating regime	**Existing**	**Enhanced**	**Existing**	**Enhanced**
	Minimum flow (cumecs)		***Median flow (cumecs)***	
	0.95	**0.4**	**5.8**	**7.9**
Native fish				
Bluegill bully	2.5	0.7	1.4	0.9
Common bully	7.1	8.2	0.9	0.6
Redfin bully	6.7	7.2	1.2	0.7
Koaro	2.8	1.8	1.8	1.3
Shortjaw kokopu	0.3	1.2	0.0	0.0
Longfin eel (<300mm)	6.8	5.7	2.8	1.9
Longfin eel (>300mm)	4.1	2.3	0.3	0.1
Shortfin eel (<300mm)	8.4	8.3	1.7	1.2
Shortfin eel (>300mm)	4.3	3.4	0.2	0.1
Torrentfish	1.6	0.1	3.2	2.0
Trout				
Brown trout, <100mm	5.3	4.5	2.6	2.0
Brown trout, adult	1.3	0.4	0.9	0.3
Food producing habitat	4.6	1.7	7.0	4.8
Macroinvertebrates				
Aoteapsyche species	0.5	0.2	5.2	5.3
Deleatidium species	6.1	4.4	6.4	5.5
Elmidae	4.9	5.2	2.8	2.3
Orthocladiinae	7.5	5.1	9.3	8.5
Potamopyrgus species	4.7	4.4	2.5	1.9
Periphyton				
Diatoms	0.0	0.0	9.4	9.4
Long filamentous	6.2	8.9	0.6	0.3
Short filamentous	5.8	1.4	4.2	2.1

Table 6.13 *WUA (m^2/m) for a range of species at the minimum and median flows (cumecs) in the Kaniere River downstream of McKays weir under the existing situation and the enhanced scheme. Predicted using the McKays Ford IFIM model.*

Operating regime	**Existing**	**Enhanced**	**Existing**	**Enhanced**
	Minimum flow (cumecs)		***Median flow (cumecs)***	
	0.20	**0.30**	**1.4**	**0.31**
Native fish				
Bluegill bully	0.1	0.2	2.3	0.2
Common bully	7.9	8.9	9.8	8.9
Redfin bully	5.7	6.5	8.2	6.5
Koaro	0.7	0.9	2.5	0.9
Shortjaw kokopu	3.2	3.1	1.2	3.1
Longfin eel (<300mm)	3.4	4.0	7.6	4.0
Longfin eel (>300mm)	3.5	4.2	6.1	4.2
Shortfin eel (<300mm)	7.4	8.2	9.9	8.2
Shortfin eel (>300mm)	4.2	4.8	5.9	4.8
Torrentfish	0.1	0.1	1.7	0.1
Trout				
Brown trout, <100mm	2.1	2.8	5.7	2.8
Brown trout, adult	0.6	0.8	2.3	0.8
Food producing habitat	0.2	0.4	4.6	0.4
Macroinvertebrates				
Aoteapsyche species	0.1	0.1	0.8	0.1
Deleatidium species	4.3	4.8	7.8	4.8
Elmidae	8.1	8.4	9.2	8.4
Orthocladiinae	2.5	3.4	8.9	3.4
Potamopyrgus species	5.4	5.9	8.2	5.9
Periphyton				
Diatoms	0.0	0.0	0.5	0.0
Long filamentous	10.7	11.0	10.0	11.0
Short filamentous	0.2	0.3	5.4	0.3

Table 6.14 *WUA (m^2/m) for a range of species at the minimum and median flows (cumecs) in the Kaniere River downstream of Kaniere Forks station under the existing situation and the enhanced scheme. Predicted using the McKays Ford IFIM model.*

Operating regime	**Existing**	**Enhanced**	**Existing**	**Enhanced**
	Minimum flow (cumecs)		***Median flow (cumecs)***	
	0.26	**0.38**	**2.9**	**0.68**
Native fish				
Bluegill bully	0.2	0.3	3.2	0.7
Common bully	8.9	9.6	6.9	10.4
Redfin bully	6.5	7.0	6.5	7.9
Koaro	0.9	1.1	3.5	1.6
Shortjaw kokopu	3.1	2.8	0.8	2.0
Longfin eel (<300mm)	4.0	4.6	7.3	6.0
Longfin eel (>300mm)	4.2	4.7	4.3	5.7
Shortfin eel (<300mm)	8.2	8.7	7.9	9.4
Shortfin eel (>300mm)	4.8	5.3	3.8	6.1
Torrentfish	0.1	0.1	4.3	0.3
Trout				
Brown trout, <100mm	2.8	3.2	6.1	4.3
Brown trout, adult	0.8	0.9	2.8	1.4
Food producing habitat	0.4	0.7	7.2	1.9
Macroinvertebrates				
Aoteapsyche species	0.1	0.2	2.5	0.3
Deleatidium species	4.8	5.1	9.4	6.1
Elmidae	8.4	8.8	8.0	9.4
Orthocladiinae	3.4	4.2	10.8	6.3
Potamopyrgus species	6.0	6.5	7.5	7.6
Periphyton				
Diatoms	0.0	0.0	3.2	0.1
Long filamentous	11.0	11.3	7.3	11.9
Short filamentous	0.3	0.5	7.9	1.7

Table 6.15 *WUA (m^2/m) for a range of species at the minimum and median flows (cumecs) in the Kaniere River downstream of McKays Creek station under the existing situation and the enhanced scheme. Predicted using the McKays Ford IFIM model.*

Operating regime	**Existing**	**Enhanced**	**Existing**	**Enhanced**
	Minimum flow (cumecs)		***Median flow (cumecs)***	
	0.82	**0.74**	**7.5**	**9.0**
Native fish				
Bluegill bully	1.0	0.7	2.1	1.8
Common bully	10.5	10.4	4.5	4.3
Redfin bully	8.0	7.9	4.2	4.0
Koaro	1.8	1.6	2.9	2.7
Shortjaw kokopu	1.8	2.0	0.7	0.7
Longfin eel (<300mm)	6.4	6.0	4.4	4.0
Longfin eel (>300mm)	5.9	5.7	2.8	2.5
Shortfin eel (<300mm)	9.8	9.4	4.1	3.7
Shortfin eel (>300mm)	6.2	6.1	2.3	2.2
Torrentfish	0.4	0.3	3.4	2.9
Trout				
Brown trout, <100mm	4.6	4.3	4.3	3.7
Brown trout, adult	1.5	1.4	1.6	1.5
Food producing habitat	2.4	1.9	5.4	4.8
Macroinvertebrates				
Aoteapsyche species	0.4	0.3	5.5	5.8
Deleatidium species	6.4	6.1	9.2	8.6
Elmidae	9.4	9.4	6.5	6.2
Orthocladiinae	6.8	6.3	9.9	8.9
Potamopyrgus species	7.7	7.6	5.5	5.1
Periphyton				
Diatoms	0.1	0.1	6.8	6.2
Long filamentous	11.7	11.9	5.8	5.9
Short filamentous	2.3	1.7	4.3	3.7

6.4.3 Fluctuating water levels in Lake Kaniere

There will be no change to the consented operating range of Lake Kaniere, which is -0.2m to 1m, under the enhanced scheme, with no lake releases for power generation occurring at lake levels below -0.1m and a reduced flow range between -0.1m and 0.2m (Palmer 2010). However, the amount of time that the lake is at levels within this range will change (Table 6.16). Under the enhanced scheme median and mean lake levels will decrease by 0.54m and 0.43m respectively relative to the existing situation, with the percent of time that the lake is spilling decreasing to 8% (Table 6.16). Such changes may potentially adversely impact aquatic plant communities in the littoral zone of the lake; however, any effects are anticipated to be minor as most species are present at a range of depths, the changes are within the existing operating range, and variations in lake level will take place over periods of weeks rather than daily fluctuations (Table 2.2). A reduction in the percent of time that the lake is spilling may affect fish passage (refer to earlier discussion in Section 6.2.4), but this could be mitigated through the provision of release flows, within the limits of control gate operation, timed to coincide with peak migration periods for key species (e.g., eels).

Table 6.16 Lake Kaniere water levels under the existing situation and enhanced scheme (data from Table 6.2.1 Palmer 2010).

Lake	Existing	Enhanced
Median lake level (m)	0.94	0.40
Mean lake level (m)	0.89	0.46
Percent of time spilling (above 1.0m)	42	8
Percent of time level below 0.2m	2	28

Daily fluctuations in the level of Lake Kaniere as a result of scheme operation are minor, with daily fluctuations greater than 2cm occurring less than 50% of the time (Figure 6.23). The maximum daily change in lake level that can be achieved as a result of scheme operation would be less than 5cm, under conditions where there is no inflow to the lake and the maximum outflow of 8 cumecs is maintained (Figure 6.24, Palmer 2010). Such minor variation would have a less than minimal effect on the lake's littoral communities including plant communities. The largest changes in lake level observed (10cm and greater) are due to natural increases associated with rainfall events (Figure 6.24, Palmer 2010).

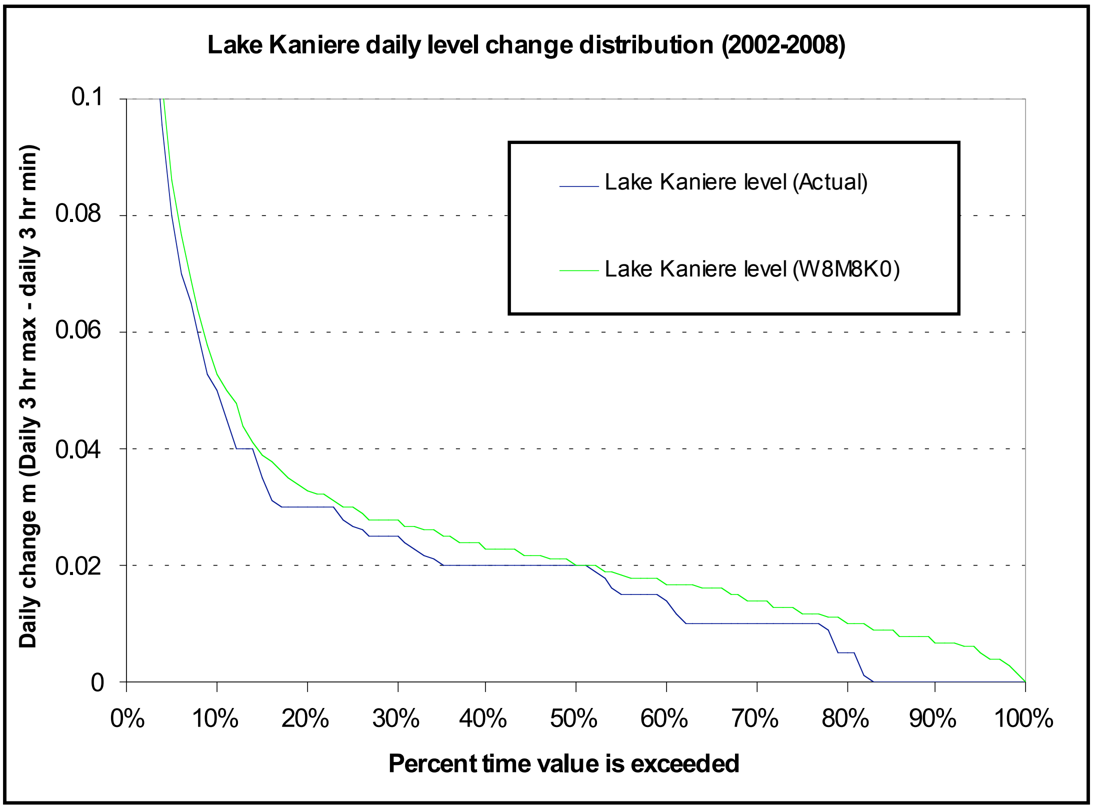


Table 6.23 *Lake Kaniere daily water level change (m) under the existing (Actual) and enhanced (W8 M8 K0) schemes (graph provided by Lennie Palmer, TPL).*

6.4.4 Fluctuating flows in the Kaniere River

Hydroelectric power schemes that operate in a daily peaking fashion typically cause flow fluctuations in rivers downstream of the power station discharge point. Daily flow fluctuations are not natural and typically provide a 'foreign' physical environment that river organisms are not necessarily adapted to. Rapid changes in flow fluctuations can cause significant changes in the physical environment. The low-flow end of the cycle may dewater the channel edge, affecting the suitability of this environment for species adapted to living in slow water, shallow environments, or species who simply are incapable of moving with the speed of the receding water level (i.e., stranding). The high-flow end of the cycle may result in mid-channel water depths and velocities exceeding the tolerance of species typically found in this environment.

The existing operation of the Kaniere Forks and McKays Creek schemes does not include peaking and therefore does not typically result in daily flow fluctuations in