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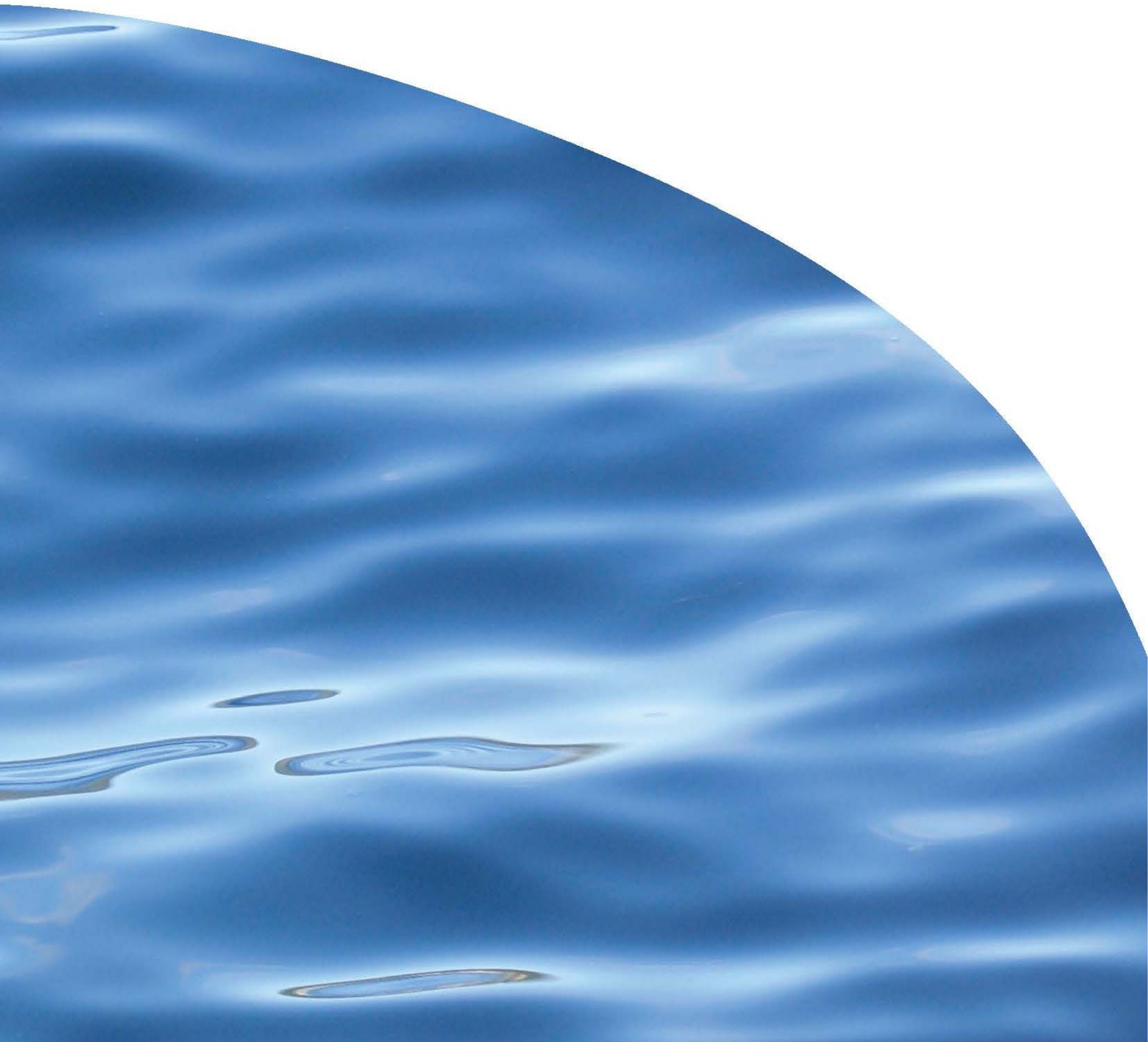
AQUATIC ECOLOGY: MITIGATION AND MANAGEMENT OPTIONS ASSOCIATED WITH WATER STORAGE IN THE PROPOSED LEE RESERVOIR: ADDENDUM



AQUATIC ECOLOGY: MITIGATION AND MANAGEMENT OPTIONS ASSOCIATED WITH WATER STORAGE IN THE PROPOSED LEE RESERVOIR: ADDENDUM

ROGER YOUNG, KATI DOEHRING

Prepared for Tonkin & Taylor Ltd on behalf of the Waimea Water Augmentation Committee

CAWTHRON INSTITUTE
98 Halifax Street East, Nelson 7010 | Private Bag 2, Nelson 7042 | New Zealand
Ph. +64 3 548 2319 | Fax. +64 3 546 9464
www.cawthron.org.nz

REVIEWED BY:
Joe Hay

APPROVED FOR RELEASE BY:
Rowan Strickland

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1. BACKGROUND

As part of pre-feasibility and feasibility studies for the development of a water augmentation scheme for the Waimea Basin, several reports relating to aquatic ecology were prepared. This included:

- a review of biological data relating to the Waimea River catchment (Hay & Young 2005a)
- an in-stream habitat analysis to provide guidance on appropriate minimum flows in the Waimea River (Hay & Young 2005b)
- a pre-feasibility assessment of issues and mitigation options (Hay *et al*. 2006)
- a feasibility level assessment of mitigation and management options associated with water storage (Hay *et al*. 2009).

An assessment of risks associated with increased irrigation on water quality in the river and estuary has also been completed (Fenemor *et al.* 2013).

Subsequent to the Hay *et al*. (2009) report, detailed design work has been conducted by Tonkin & Taylor, including some minor changes to the proposed hydro-power scheme that could be linked with the water storage scheme. This addendum to the 2009 report addresses the changes in the flow regime associated with the proposed changes to the hydro-power scheme. It also comments on the proposed design of the fish pass and water intake structure within the reservoir, which aims to address the potential effects of reservoir stratification. Comments are also provided on the likely need for flushing flows in the Lee River, potential conditions relating to flushing flows, the potential need for mitigation and off-setting relating to effects on redfin bullies and longfin eels, potential effects of construction, and monitoring conditions and appropriate receiving water standards for construction-related discharges.

2. CHANGES TO THE HYDRO-POWER SCHEME

Our assessment of the hydro scenario information provided by Tonkin & Taylor (David Leong, 18 November 2013) indicates very minor effects on key ecologically relevant flow statistics. For example, the median flows in the Lee River downstream of the dam, based on analysis of the scenarios from November 1957 to November 2007, are predicted to be 1.75 m^3/s ‘with hydro’ and 1.68 m^3/s ‘without hydro’ (compared to 1.61 m^3/s without the dam). Median flows over the same period at the Wairoa at Irvines site are predicted to be 7.30 m^3/s ‘with hydro’ and 7.20 m^3/s ‘without hydro’ (compared to 7.25 m^3/s without the dam). Such small differences are predicted to have a negligible effect on habitat availability. A similar conclusion is reached after examination of changes in monthly median flows over the 1957 to 2007 period, where the differences between ‘with hydro’ and ‘without hydro’ scenarios are relatively minor in most months (Figure 1). However, median flows in June, July and November in the Lee River downstream of the dam are predicted to be 200–300 L/s higher for the ‘with hydro’ scenario than for the ‘without hydro’ scenario, but again this effect is relatively small and will attenuated further downstream at the Wairoa at Irvines site (Figure 1). The increase in median flows in some months is expected to have a minimal or minor positive effect on habitat availability for macroinvertebrates.

The inclusion of the ‘with hydro’ option has an impact on the frequency of flushing flows in the Lee River (see Section 4 below for further details).

As also mentioned in Hay *et al*. (2009), the above analysis of the potential effects of hydro-power generation do not include any analysis of the potential effects of regular flow fluctuations associated with the operation of the hydro-power system on habitat availability downstream. If future optimisation of the hydro-power addition to the scheme is likely to result in regular fluctuations in flow downstream, then the specific effects on habitat need to be assessed. Consent conditions outlining the degree of flow fluctuation that will be allowed during the operation of the scheme could be developed to avoid or limit effects. For example, these conditions could set out a maximum increase or decrease in flow of 1.2 m^3/s that can occur as a result of discharge through the turbines from the dam within a 24-hour period. This condition would be met for 99.9% of the time over the November 1957 to November 2007 period for the ‘no hydro’ scenario and 96.4% of the time for the ‘with hydro’ scenario. An effective condition might be that if flows at the dam are less than median (1.7 m^3/s), the 95th percentile of flow changes over a 24-hour period shall be less than 1.2 m^3/s.

The 1.2 m^3/s value was not determined directly on the basis of probable ecological effects, but rather based on the level of flow variability predicted in the flow scenarios. We have assumed that flow variability of less than 1.2 m^3/s is likely to cause minimal ecological effects, whereas larger levels of flow variability that may result from a more aggressive dam operating regime are likely to cause detrimental ecological effects. It is difficult to determine the validity of these assumptions without further work on the ecological effects of different fluctuating flow levels. Regular variations in flow of 1.2 m^3/s in the Lee River are quite large given the median flow in the reach is only 1.75 m^3/s. Further downstream, variations of 1.2 m^3/s will be more minor since median flows are considerably larger downstream (*e.g*. 7.3 m^3/s at Wairoa at Irvines). There will also be some attenuation of peaks in flow variability as the water flows downstream.

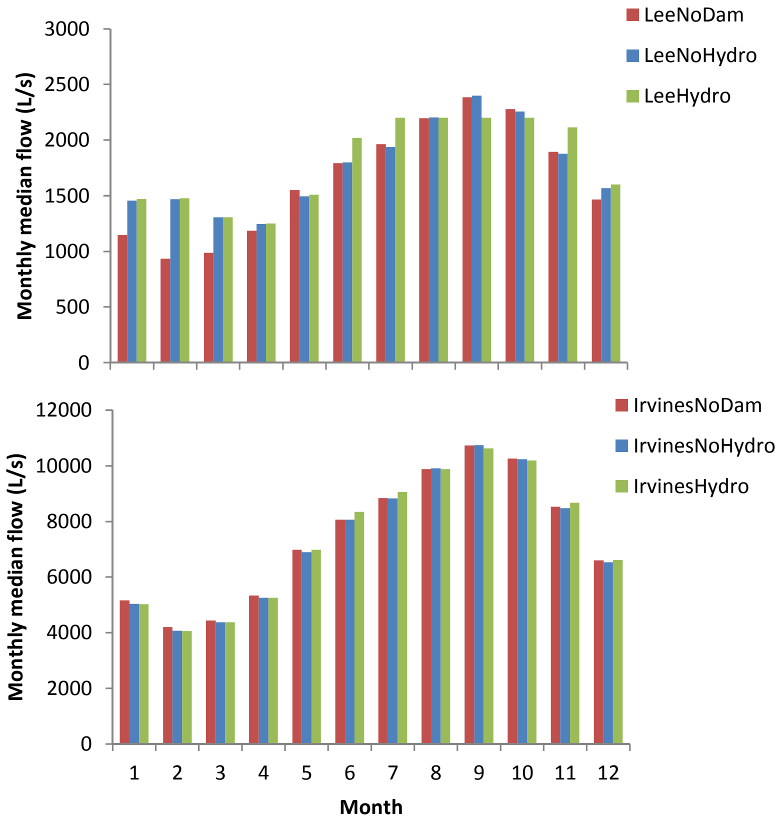

Figure 1. Changes in monthly median flows in the Lee River (top) and Wairoa River at Irvines (bottom) as a result of the proposed scheme, with and without a hydro-power option.

3. FISH PASS AND INTAKE DESIGN

Design drawings of the fish pass and intake were provided by Tonkin & Taylor (Emily Grace, 31 October 2013). They appear to reflect the requirements for these structures as outlined in Hay *et al*. (2009). In a meeting between Tonkin & Taylor, Cawthron Institute, Department of Conservation and Fish & Game NZ, the specific requirements for the fish pass were discussed.

Some further consideration is needed for how to induce fish to move down the back face of the dam. Some form of flushing mechanism is required to ensure that fish that have ascended the front face of the dam make their way into the reservoir. We understand that the final design will provide for this.

Screening of the outlet to protect downstream migrating eels will also have to be considered if a hydro-power option is included within the scheme. However, it is acknowledged that outlet screening is somewhat experimental (*e.g.* the efficacy of screen maintenance and cleaning programmes is not well proven) and other options promoting safe downstream movement of eels could also be considered. We note that the design includes a screen with a mesh size of 20 mm and an approach velocity of around 0.3 m/s, as recommended in Hay *et al*. (2009).

The variable level outlet was recommended as an appropriate way to manage stratification and any water quality issues within the proposed reservoir (Hay *et al*. 2009). While maintaining the flexibility to release water from multiple levels within the reservoir remains an important requirement, the addition of an aeration system just upstream of the dam face would provide a further mechanism to manage stratification and water quality. An aeration system was retrofitted to the Opuha Dam in Canterbury to help address water quality concerns there, and an aeration system has been included in the design of the proposed Ruataniwha Reservoir in the Hawkes Bay. The aeration system in the Opuha Dam has been very effective at mixing surface and bottom waters within the reservoir and thus reducing the risk of water quality issues associated with stratification and deoxygenated bottom waters (pers. comms. Adrian Meredith, Environment Canterbury). Installation of an aeration bar and associated structures (or just the fittings required to attach an aeration bar) prior to reservoir filling will presumably be much easier and cheaper than subsequent retrofitting.

4. FLUSHING FLOWS

Hay *et al*. (2006) and Hay *et al*. (2009) discussed the potential for 'flat lining' of flows occurring in the Lee River downstream of the reservoir in situations where the reservoir is refilling after a prolonged period of flow augmentation. A flushing flow of 5 m^3/s was recommended as a potential mitigation option to address any accumulations of periphyton that occur below the dam during these long low flow periods (Hay *et al*. 2009). We understand that the dam has been designed with this capacity in mind.

An analysis of the updated flow regime for 'with hydro' and 'without hydro' scenarios, as provided by Tonkin & Taylor (David Leong, 18 November 2013), indicates that a small reduction in the frequency of potential flushing flows (defined as flows greater than three times the median) is predicted immediately downstream of the dam as a result of the scheme. This reduction is exacerbated for the 'with hydro' scenario (Figure 2) when on average there will be a loss of 1–2 flushing flows per year (*i.e.* from 18 down to 16 per year). Although the reductions may occur in late summer and autumn, when low river flows and warm water temperatures increase the risk of periphyton accumulations. Further downstream at the Wairoa at Irvines site, the reduction in the frequency of potential flushing flows is minor with an average reduction of less than one flushing flow per year predicted over the 1957 to 2007 period (Figure 2). This is not surprising since flow variability at this site will be maintained to a large extent by flows from the Roding and upper Wairoa rivers.

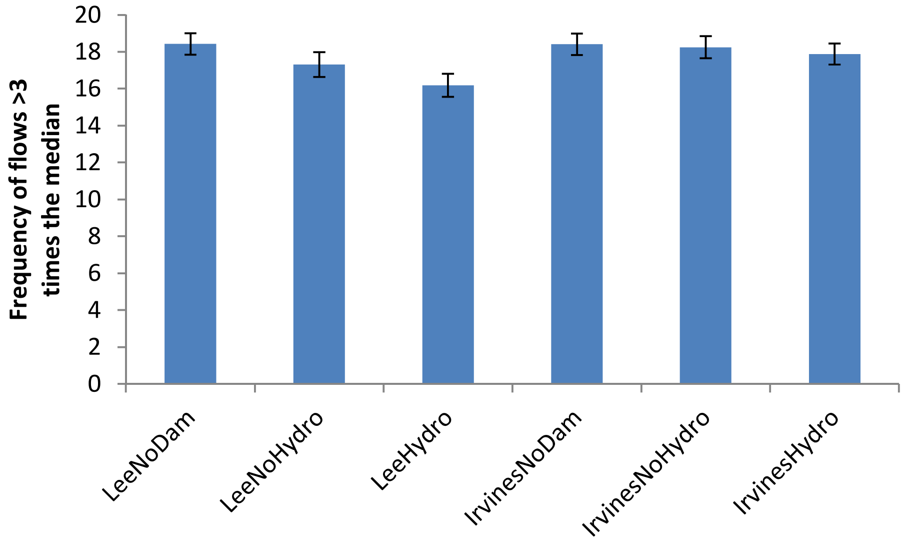

Figure 2. Changes in frequency of flows greater than three times the median in the Lee River and Wairoa River at Irvines as a result of the proposed scheme with and without a hydro-power option.

We consider that it is appropriate for the scheme to provide flushing flows to mitigate any ecological effects that are associated with this reduction in flushing flow frequency in the Lee River. We recommend that flushing flows of 5 m^3/s for at least three hours are provided as part of the scheme. These flushing flows may also have minor positive effects further downstream, such as removal of detached algae and cyanobacteria that have accumulated along the river margins. However, we see no justification for targeting the flushing flows specifically at periphyton and cyanobacterial removal from the lower reaches of the Waimea River because the effects of the scheme on flushing flow frequency are predicted to be negligible or minor in that part of the river.

A consent condition detailing the triggers for when a flushing flow should be released from the dam is required. Ideally, flushing flow releases should be triggered to interrupt any prolonged periods of low flow that occur in the Lee River as a result of the dam. According to the updated flow regime from 1957 to 2007 provided by Tonkin & Taylor (David Leong, 18 November 2013), 2–9 flushing flows (average 4.7) would be required per year to interrupt periods when flows were below 5 m^3/s for more than 30 days. To interrupt periods of more than 40 days of low flow, 0–6 flushing flows would be required per year (average 2.8).

It is not appropriate for the scheme to be required to interrupt all prolonged periods of low flow, since many of these prolonged low flow periods occur naturally. As mentioned above, the scheme results in an average reduction of 1-2 flushing flows per year.

Given this, we recommend that up to three flushing flows of 5 m^3/s for at least three hours are provided over the period from 1 November to 30 April and aim to interrupt any periods of low flows (*i.e.* <5 m^3/s) of more than 40 days. This condition would result in flushes being provided during the warmer months of the year when proliferations of periphyton are more likely and when recreational use of the river is high.

Monitoring of the effectiveness of the flushing flows in the Lee River should be included in the consent conditions and could be used to adaptively manage the size, frequency and duration of flushing flows so they are most effective.

5. MITIGATION/OFFSETTING FOR EFFECTS OF THE SCHEME ON REDFIN BULLY AND LONGFIN EEL

Hay *et al*. (2009) identified that redfin bully (*Gobiomorphus huttoni*), which tend to prefer slow, shallow water, will not necessarily benefit from enhanced minimum flows. They are also unlikely to negotiate the fish pass, so will no longer occupy any habitat above the proposed dam. They also identified that downstream passage of adult longfin eels (*Anguilla dieffenbachii*) will be challenging. Manual trapping of migrants and transferring them downstream over the dam wall may be required. Therefore, we were asked to comment on the potential need for mitigation / off-setting relating to the potential effects of the scheme on these species. Background information on the distribution and abundance of each species is reported below.

5.1. Redfin bully

The probability of species presence can be assessed with a fish distribution model (Leathwick *et al*. 2008). For redfin bully (*Gobiomorphus huttoni*), the highest probability of occurrence predicted by the model was between 61%–80% in the lower reaches of the Waimea catchment (Figure 3). The total reach length with a predicted probability of occurrence higher than 60% for the Waimea catchment was 2.9 km.

Redfin bullies are highly territorial and generally prefer living in smaller streams with modest flows and water depths. Examples of such suitable habitats in the region include; Poorman's Valley Stream and other small coastal waterways along Tasman

Bay (in particular in the Abel Tasman National Park) and streams in the Marlborough Sounds (pers. comm. Neil Deans, Fish & Game NZ; Tasman District Council 2011).

Predicted probability of the occurrence of redfin bully in the area upstream of the proposed dam (Leathwick *et al.* 2008) were generally low (0–20%) or low-medium (*i.e*. 23% in a single 1.1 km reach). To some extent these predictions are contrary to observations recorded in the New Zealand Freshwater Fish Database (NZFFD), since redfin bully have been found in areas with a low predicted probability of occurrence (Figure 3). This includes three locations near the proposed dam; the Lee River main stem, a Lee River tributary and in Waterfall Creek.

No additional redfin bully records for the Waimea catchment have been added to the NZFFD since 2005, when fish distribution in the catchment was summarised by Hay & Young (2005a). Of the 90 sites in the Waimea catchment that have been sampled for fish communities (and the data entered into the NZFFD), redfin bully were found at only 10 sites. Redfin bully were regarded as being common at only one site, in the lower Waimea River. This record is likely to have been a spawning aggregation, as such high numbers in that location are regarded as unusual (pers. comm. Neil Deans, Fish & Game NZ). All other redfin bully records were of occasional fish, with numbers ranging from 1–5 per sample, where recorded. These are relatively low abundances for redfin bully.

In conclusion, we consider that mitigation of any losses to redfin bully habitat is not required because the effects of the scheme are expected to be no more than minor. This is because there is a limited amount of suitable habitat upstream of the proposed dam for them, and there have been only small numbers of individuals observed in the vicinity of the dam.

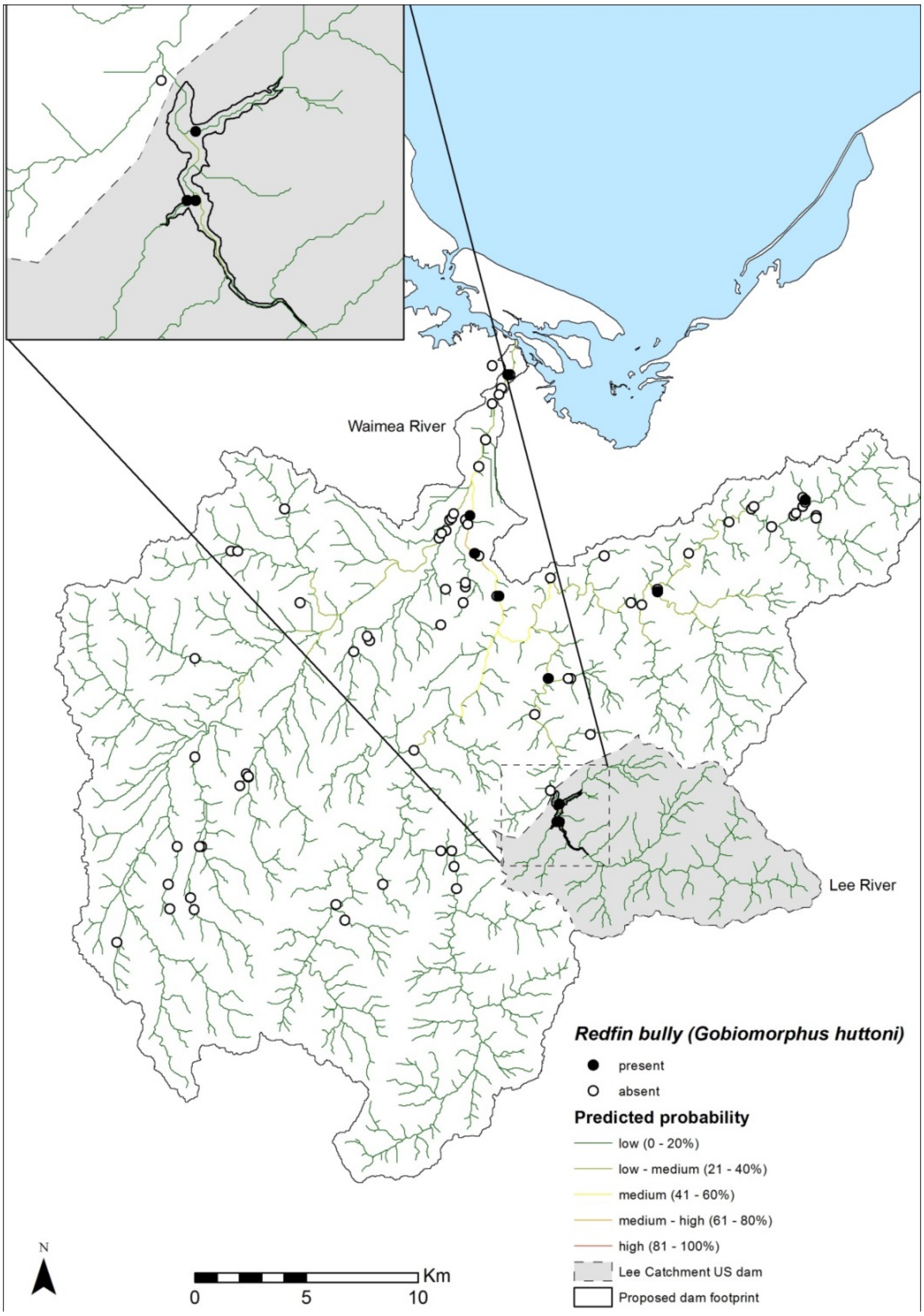

Figure 3. Predicted probability and presence / absence of redfin bully in the Waimea catchment.

5.2. Longfin eel

Longfin eel are more widely distributed in the Waimea catchment than redfin bully. Predicted probability of occurrence is high (81–100%) in the lower and middle reaches of the catchment. The highest probable occurrence upstream of the proposed dam is 68%, with the majority of this habitat adjacent to the proposed dam (Figure 4). The lowest probable occurrence is 1% in the headwaters of the Lee catchment.

There are 18.6 km of stream length with a medium to high probability of occurrence (*i.e.* >60%) of longfin eel upstream of the dam, compared to 700 km for the entire Waimea catchment. Therefore, the potential area of habitat upstream of the dam for this species is relatively small (2.6%) compared to the amount of habitat available elsewhere throughout the catchment.

There were 62 observations recorded for longfin eel in the NZFFD for the Waimea catchment, two of those at the proposed dam site and one just downstream in Anslow Creek recorded with a 'common' abundance (Figure 4). Predictions and observations of longfin eel presence generally concurred, with the majority of longfin eel recorded in reaches that have medium to high (61–80%) and high (>81%) predicted probability of occurrence (Figure 4).

Longfin eel habitat is expected to be better within the proposed reservoir compared to the current habitat in the upper Lee River. This species, together with koaro, are being specifically provided with fish passage to facilitate access to this upstream habitat. They will also have improved habitat downstream in the lower river with higher minimum flows; this improvement is expected to be particularly relevant for juvenile eels which are often found in shallow riffles. As mentioned in Hay *et al*. (2009), the major concern is that downstream migrating adult eels will find it difficult to get past the dam wall.

In summary, the dam is likely to provide better habitat for longfin eel than is there currently and eels will continue to access this habitat via the fish pass. Downstream movement of longfin eels is an issue, and some form of downstream trap and transfer would be useful to enable mature eels to migrate to sea to complete their life cycle. No further consideration for longfin eels is required in the biodiversity offsets package.

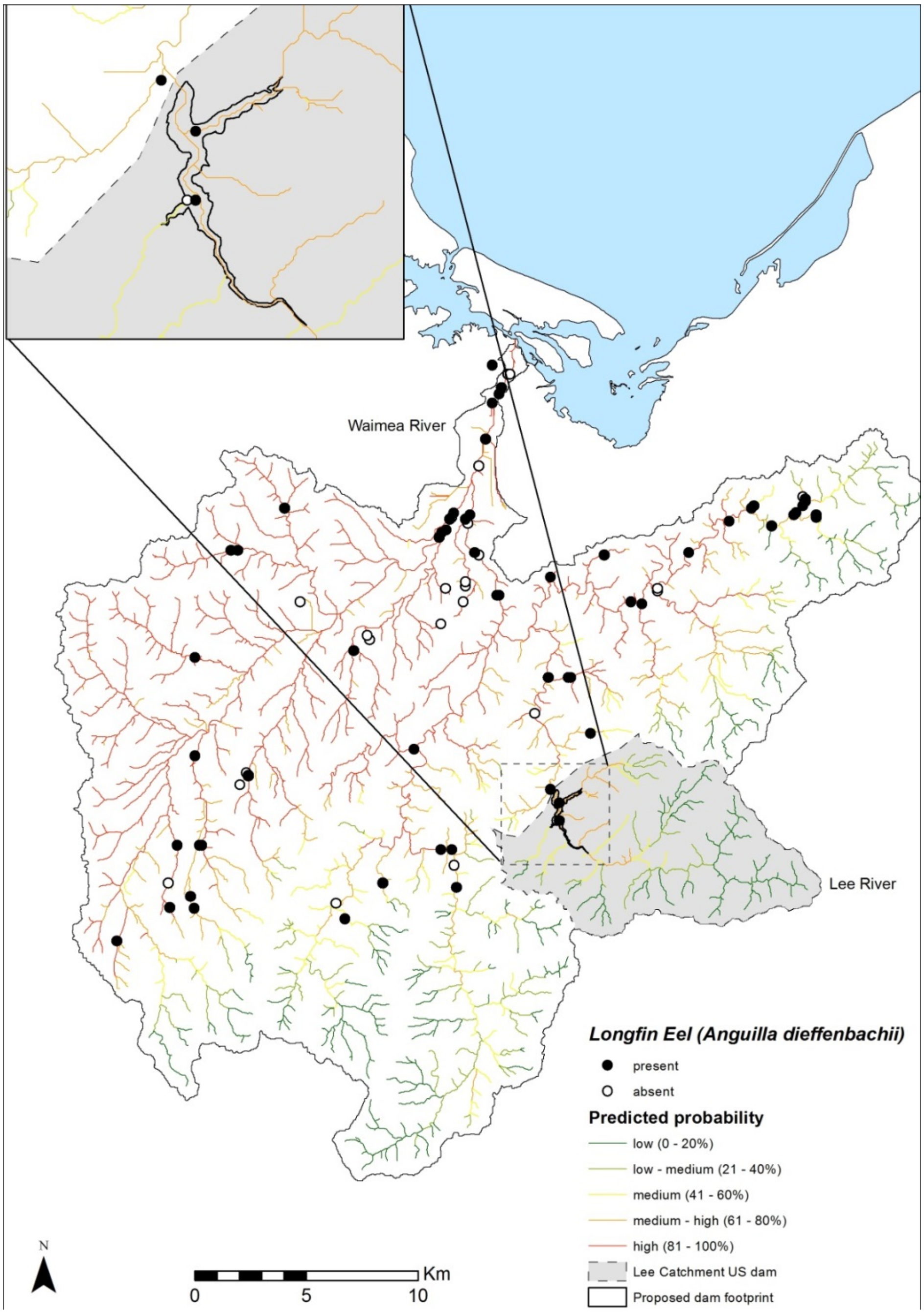

Figure 4. Predicted probability and presence / absence of longfin eel in the Waimea catchment.

6. CONSTRUCTION EFFECTS

Dam construction procedures include two main physical areas that will require different management practices during construction: 1) within the river or its tributaries and 2) on the river banks. Activities in both of these areas will potentially have effects on the downstream aquatic environment; however, activities within the river are expected to have the greatest direct ecological impacts. The most significant ecological effects are those resulting from mobilisation of sediment, with both increased suspended sediments and sedimentation due to river bed disturbance.

Specific activities within the river as outlined in Tonkin & Taylor (2012) include:

- the construction of coffer dams and diversion of the river through a culvert
- abutment excavation
- construction of the main dam embankment
- grouting of the foundation under the main dam embankment, spillway and intake works.

Apart from these major, short-term disturbances in the river bed, smaller disturbances such as consistent vehicle stream crossings will mobilise sediment (Tonkin & Taylor 2012). A small water take from the Lee River (maximum instantaneous take of 28 L/s) will be required during construction.

6.1. Effects on the physical environment

While there are not likely to be major changes to the overall river morphology caused during the construction phase, movement of excavated material will potentially cause changes in the physical environment of the Lee River immediately downstream of the construction site.

Along with a minor reduction in flow (6% of MALF) during construction, these changes include the deposition of generally coarser sediment (*e.g*. gravel) at the immediate downstream site, and the deposition of fine sediments further downstream. The terms fine sediment and sedimentation describe sediments less than 2 mm in size, thus encompassing sand (< 2,000 to > 62 µm), silt (< 62 to > 4 µm) and clay (< 4 µm). In low energy environments such as reservoirs or backwaters, sedimentation can create fine sediment banks along the river bank and changing river morphology in the downstream reaches. Sedimentation also alters physical habitat quality, particularly by smothering larger substrate or clogging interstitial spaces. Fine sediment deposition on the river bed will cause short-term loss of interstitial space, changing the river bed's porosity and composition. However, fine suspendable material will be moved through the reach with the next flood or will be widely dispersed, so that changes are unlikely to be detectable downstream of the dam following flooding (Doeg & Koehn 1994; Collier 2002). In contrast, gravel can become wedged in the interstices of larger substrate elements, and levels can remain high for an extended period after flushing at more flow protected sites (Collier 2002).

If the working site is adequately stabilised at completion of the diversion channel, reaches downstream of the dam site will no longer receive large amounts of bed load from areas upstream.

In the event of failure of the upstream coffer dam, deposited sediment may temporarily alter the morphology of the Lee River below the dam until the material is dispersed further downstream by successive bed-defining floods (*i.e.* those with about an annual return period).

Overall, the effects of construction on the physical environment are expected to be relatively localised to the area at, and immediately downstream of, the construction site. Fine sediment deposited within the substrate further downstream will be resuspended by floods sourced from the Roding and Wairoa rivers and are not expected to have effects lasting more than a year after construction, while fine sediment deposited on the riverbed immediately downstream of the dam may persist for a couple of years depending on the timing and size of floods that pass over the spillway.

6.2. Changes to water quality

Mobilisation of sediment is expected to be the main factor affecting water quality in the Lee River downstream of the construction site. Increased concentrations of fine sediment in suspension will affect water clarity and the visual appearance of the river. This is particularly likely during low-moderate flows, when water clarity would be expected to be high. Any observed changes will be less obvious during periods of high flow (under status quo conditions) when water clarity is typically reduced and concentrations of suspended sediment reduction elevated. The effects on water clarity will subsequently affect the biological environment (*i.e*. invertebrates, fish and primary producers such as algae).

Along with other water quality concerns, concrete pouring (and potential for spillage) during construction activities could increase the pH of the river. A pH below 9 should be maintained, and this is at risk of being elevated during the placement of submerged concrete structures. Increases in pH can be managed by the use of grout bags, turbidity curtains (designed to isolate the concrete placement site from stream flow) and application of anti-washout admixtures (designed to decrease the loss of fines and cement paste during concrete setting). Ideally, concrete pours should be done in dewatered areas with the concrete well cured prior to exposure to stream water.

6.3. Effects on the biological environment

Increased mobilisation of suspended solids during construction are likely to affect fish and invertebrate communities due to increased turbidity of the stream water and increased siltation of stream beds. The scale of increased mobilisation of suspended solids is hard to predict.

Suspended sediment can affect in-stream biota either directly (*e.g*. behaviour, abundance, survival) or indirectly (*e.g*. reduction of food sources, alteration of habitat). Direct effects on aquatic biota will generally be limited to the time of construction; however, sediment deposited downstream in low energy areas (*i.e*. backwaters, pools) can cause prolonged effects on the biological environment.

Fine sediment suspension in the water column and deposition on the river bed affects periphyton in these four main ways:

1. Reducing the penetration of light and, as a result, reducing photosynthesis and primary productivity within the stream, with resultant impacts on the rest of the food chain (Davies-Colley *et al*. 1992)
2. Reducing the organic content of periphyton cells (Cline *et al*. 1982; Graham 1990)
3. Preventing attachment to the substrate of algal cells
4. Smothering and eliminating periphyton and aquatic macrophytes in extreme instances (Brookes 1986).

Some habitat will be lost, for example, as fine sediments settle into interstitial spaces on the river bed, clogging up and / or burying the loose gravel top layers (*i.e*. hyporheic zone). This zone provides valuable habitat and refuge for many (sub-) surface riverine species, such as macroinvertebrates and some native fish species (redfin bully; McEwan 2009).

Fine sediment suspension and deposition affect macroinvertebrates by altering substrate composition and changing the suitability of the substrate for some taxa. These effects include:

- increasing drift due to sediment deposition or substrate instability
- affecting respiration due to the deposition of silt on respiratory organs
- affecting feeding activities by impeding filter feeding
- reducing the food value of periphyton and prey density (Wood & Armitage 1997).

For sediment sensitive fish species (*e.g*. salmonids, upland bullies, koaro), high turbidity levels can directly affect fish by inhibiting feeding, reduced growth, reduced resistance to diseases, preventing successful egg and larval development and affecting migratory behaviour. Indirect effects include reducing the abundance, size and availability of food sources (Bruton 1985; Rowe *et al*. 2000; Richardson & Jowett 2002).

Reduction of visual range also has considerable effects on human perception of recreational water bodies and their 'fishability'.

Sedimentation effects on biota during dam construction will be most evident immediately downstream of the proposed dam site in the Lee River. The magnitude of effects will be reduced downstream of the confluences of the Roding and Wairoa rivers as they receive a greater proportion of water from the wider catchments, diluting high sediment levels downstream.

The rate of recovery from any effects on the aquatic biota depends on several factors, such as the duration and severity of disturbance, the survival of organisms in refugia from which recolonisation can take place, and on the timing of construction relative to life-history requirements of, for example, fish species (*e.g*. spawning, migration). Recovery may be quick following short-duration disturbances (*i.e*. days). However, when an impact is extended over several months or years, as expected for this dam construction, the stream ecology may be more significantly altered over a longer period of time. This means recovery of the stream ecosystem may take many months or years and may require human intervention to restore the system to a natural state (Wood & Armitage 1997). Studies have shown that it can take between six weeks to a year after construction for macroinvertebrates to recover (Tsui & McCart 1981; Reid & Anderson 1999), and between one month and one year for fish (Schubert *et al*. 1987).

6.4. Summary

The main effects of construction will be associated with the disturbance of the river bed and mobilisation of sediment. Concrete pours will also have to be managed carefully and ideally only in dewatered areas. It is difficult to quantify the likely amount of sediment that will be mobilised during construction. Effects on water quality will reduce rapidly once the working site is adequately stabilised after completion of the diversion channel. However, deposition of mobilised sediment downstream of the proposed dam site may have longer term effects that take six months to one year for recovery. The effects will be most marked close to the proposed dam site and have less influence downstream of the Roding, Wairoa and Wai-iti river confluences.

Sediment control measures will be required to reduce mobilisation of sediment and we understand that these are being prepared as part of a Construction Environmental Management Plan. However, an increase in sediment mobilisation compared with the status quo will be inevitable. We recommend that the duration of river works within the channel should be minimised as much as possible. We also recommend that river works are avoided wherever possible during times of the year when fish spawning and migrations are likely.

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