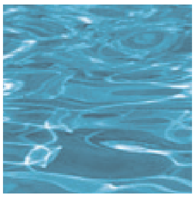
Appendix C

# NIWA Report



# Technical memo summarising the effects to aquatic ecology of proposed water supply options for the Kapiti Coast

**NIWA Client Report: CHC2010-064**
**May 2010**

**NIWA Project: BEC10501**

# Technical memo summarising the effects to aquatic ecology of proposed water supply options for the Kapiti Coast

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# 1. Methods

## 1.1. Water quality measurements

Greenspan data sondes were deployed at two sites: one above the water treatment plant, and one approximately 20m below the discharge of bore water, 2 m from the true right bank. Data sondes were configured to record water temperature, pH, dissolved oxygen and conductivity every 15 minutes. Data was downloaded at regular intervals. Water samples were also collected during the bore water discharge tests from the river upstream of the bore, and at the lower data sonde. Water was also collected from the outflow of the bore, prior to mixing. All samples were sent to RJ Hill Laboratories for analysis of heavy metals, anions and cations.

A dye test was also conducted to document the flow and dilution dynamics of the proposed bore water discharge into the Waikanae River (Option 29). Rhodamine (WT) dye was used to identify the typical dispersion patterns of bore water as it mixed with the river downstream from the discharge. The bore on the day of the dye test was discharging at approximately 35 L $s^{-1}$ into the Waikanae River with the discharge of approximately 1090 L $s^{-1}$ (Wellington Regional Council flow record). A total of 1 L of concentrate rhodamine (WT) dye was mixed with 4 L of river water in a "Marriot" constant head vessel. This was placed at an access manhole approximately 30 m from the end of the bore water discharge pipe. The vessel was set to a discharge rate of 0.1 L $min^{-1.}$ The dye was discharged into the bore water via a long length of PVC tube placed with its end just above the water.

At predetermined distances downstream from the bore water discharge, fluorescent paint was used to mark transect positions on the true right of the river. These marked at increasing distances up to 600 m downstream. Painted stones were placed across the river at each transect at 20, 40, 60, and 80% of river width. Water samples were collected at each points along each transect commencing at the upstream transect 20 minutes following the start of dye injection, by which time the dye plume was assumed to have reached a steady state. Samples (250 ml polycarbonate bottles) were collected just beneath the water surface at each location. Triplicate samples of the bore water (and dye) were collected at the outflow of the pipe and used as a start concentration for subsequent dilution calculations. Three replicates of river water upstream of the bore water discharge were also collected to establish a background level of dilution values. Samples were kept in the dark and analysed by an in-house spectrofluorometric method whereby absorbance at 555 nm was measured.

## 1.2. Biological surveys – field methods

Fish and invertebrates were sampled from three waterways in the area in the week of April 19th – 23rd 2010 (Figure 1). Samples were collected from two rivers where the proposed dams were to be built – the Kapakapanui Dam stream[1] and the Mangakotukutuku. At each of these rivers, freshwater invertebrates were collected at two sites above the proposed dam, and at two sites below. Care was taken to ensure that sites were selected so that one of the upstream sites would be inundated by the reservoir immediately above the dam, and one of the downstream sites was just below the dam. These locations are expected to be the most affected by dam construction and reservoir filling. Invertebrate samples were also collected from the Waikanae River at sites below the confluence with the Kapakapanui Dam stream, and the Mangakotukutuku, as well as below the water treatment plant. At each site, three semi-quantitative "kick" samples were collected using a 0.3 mm mesh net, following Ministry for the Environment standard protocols for semi-quantitative sampling in stony -bottomed streams (Protocol C1: Hard-bottomed, semi-quantitative: Stark et al. 2001). Water pH, temperature and conductivity were measured at each site.

Fish at all sites were surveyed using a battery-powered KAINGA EFM300 portable electrofishing machine. These machines are routinely used throughout New Zealand for electric fishing survey and sampling work. Approximately 30 m of stream length were surveyed, chosen to encompass at least ½ a riffle and ½ a run. All fishing was done methodically upstream in this area, covering 2-3 $m^2$ each time, until the end of the 30 m reach was reached. In larger rivers, only from the middle of the stream to one bank was fished. The area fished thus depended on stream width, and varied from 60 to 175 $m^2$. A stop net was deployed below the area being fished to capture stunned animals drifting downstream. Electric fishing was done mainly to confirm the presence of fish in the streams, although the resultant single-pass abundance data was used to calculate a first approximation of the relative density of fish per $m^2$ of streambed. Fish caught were retained, anaesthetised, identified, and their length measured to the nearest millimetre. Fish were allowed to recover before being released. The New Zealand Freshwater Fish Database (NZFFDB) was also accessed for records of fish occurrence in the region.

[1] The name Kapakapanui Dam stream in fact does not refer to the "proper" Kapakapanui stream, but rather an un-named tributary into the Waikanae River, to the east of the Kapakapanui. For convenience, this un-named tributary has been called the Kapakapanui Dam stream.

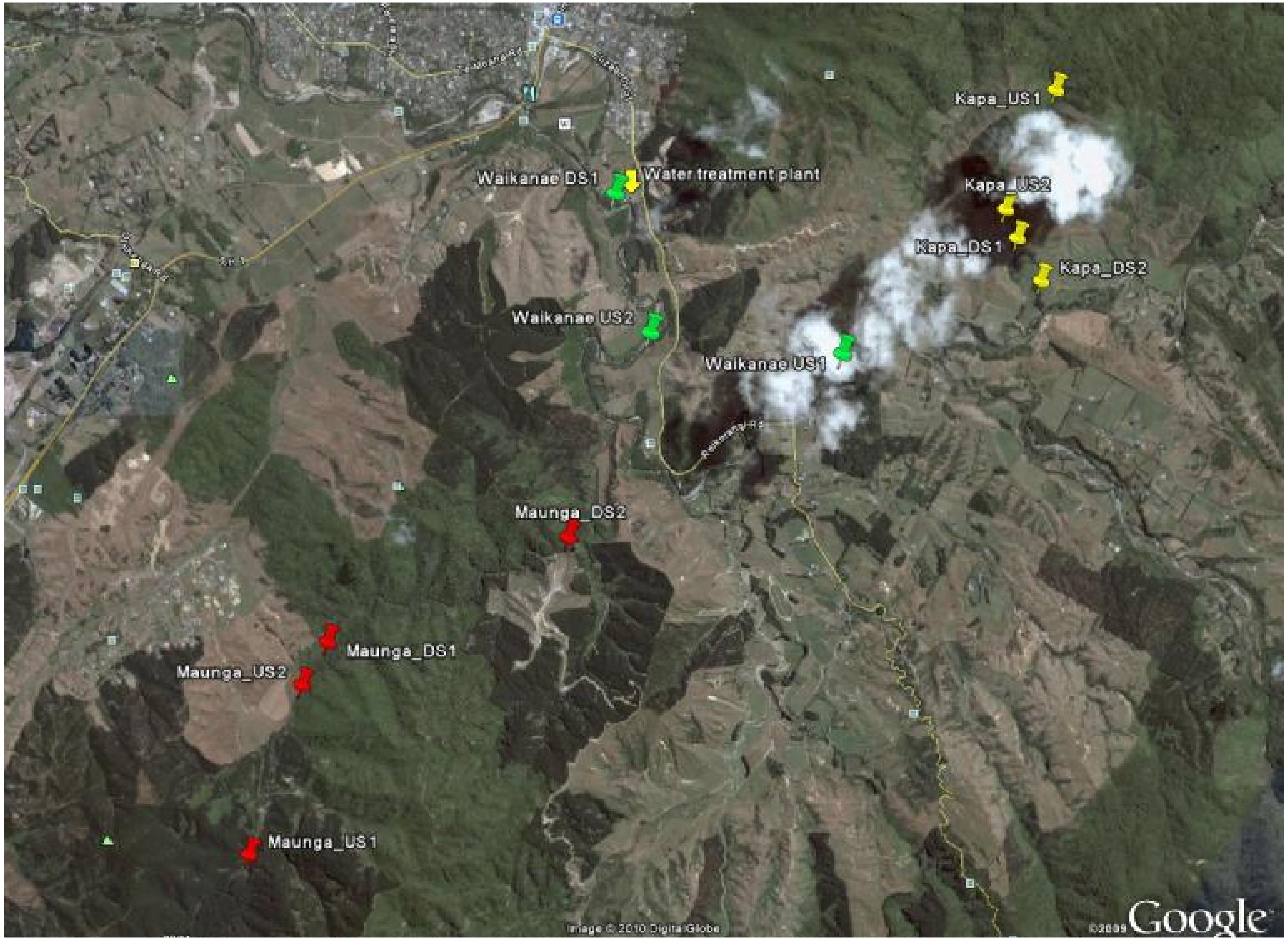


**Figure 1: Location of the different sampling sites where biological surveys were conducted: Maunga = Maungakotukutuku; Kapa = Kapakapanui Dam stream**

## 1.3. Laboratory methods and analysis

All invertebrate samples were processed using a modification of Protocol P2: 200 fixed count + scan for rare taxa (Stark et al. 2001), where all material trapped on a small sieve (0.5 mm mesh size) was examined for invertebrates under a dissecting microscope, instead of removing invertebrates by eye from a sub-sample. Invertebrates were identified to as low a taxonomic resolution as possible; usually to Family, Order, or Genera, and counted. Some of the larger insects (e.g., Trichoptera) could be identified to species, while other insects were either too small to identify to species, or could not be identified due to lack of suitable identification keys.

Invertebrate data from streams in the area was also obtained from the Wellington Regional Council so that we could compare the community in the waterways we surveyed to those of other streams in the region. In this way we could properly assess the value and uniqueness of the invertebrate communities. As part of this comparison, all streams were allocated to their appropriate River Environment Classification (REC) class (see Snelder et al. 2004). All streams had the same climate (warm, wet) and source-of-flow (lowland) but different in their geology (being either soft sedimentary or hard sedimentary) and landcover (either pasture or exotic forest).

The following biological indices were calculated from the invertebrate data: total density; taxonomic richness; the hard-bottomed macroinvertebrate community index (MCI); its quantitative variant, the QMCI; the number of Ephemeroptera, Plecoptera, and Trichoptera taxa (i.e., EPT); and % EPT. The MCI represents a useful index describing overall invertebrate community "health", with high scores (e.g., MCI > 120) indicate pristine waters, while scores < 80 indicate "probable organic enrichment", and streams in poor condition. The number and % of EPT taxa also conveys information about overall invertebrate community composition and condition. As sediment loads, or algal biomass, increase, the number or % of EPT taxa often declines. These different indices are useful for assessing both the current condition of the invertebrate community, as well as for monitoring changes to the community over time as a result of any activities in the catchment.

Differences in the invertebrate communities in the three waterways (the Waikanae River, Kapakapanui Dam stream, and Mangakotukutuku) to other waterways in the region were also examined by ordination (Decorana: DCA). This statistical technique graphically represents the location of samples based on their invertebrate communities, so that samples with similar communities are found close together on a graph, while samples with very different communities are far apart from each other. Samples are plotted in two dimensions with arbitrary sample scores (i.e., low or high scores tell nothing about the "condition" of the invertebrate communities, but merely reflect the overall species composition).

Analysis of Variance (ANOVA) was used to determine whether the calculated metrics and DCA samples scores differed between the waterways sampled in the area, and throughout the greater Wellington region.

## 1.4. Hydrological analyses

A river's flow regime is considered one of the most important environmental factors influencing ecological communities. For example, large floods reduce invertebrate densities by washing animals from the streambed. However, numbers can quickly recover because there will always be a source of colonists in sheltered areas at the stream edge, or in smaller side-streams. Moreover, flood events are beneficial to stream ecosystems as they remove excess algal growth and fine sediments that may have deposited in slower flowing areas. Floods also transport recently hatched fish fry from a stream's upper reaches to the ocean. Floods affect stream life in terms of both their magnitude, and their frequency. A useful statistic that combines these parameters is the FRE3 - the number of floods greater than three times the long-term median. This has been shown to influence both algal and invertebrate communities (Clausen and Biggs 1997).

Periods of extended low flow can also influence stream ecosystems, with implications to water chemistry (for example nutrient and oxygen concentrations), stream temperature, and instream plant growth. In some instances, extended periods of low flow can result in excessive aquatic plant growth which can alter instream habitat conditions to the detriment of fish and invertebrate communities (Suren et al. 2003; Suren and Riis 2010). Potential detrimental effects of extended periods of low flow are ameliorated by "flushing flows" that remove excessive plant growth from streams, and rearrange some of the streambed. These are commonly used below impoundments to ensure the maintenance of healthy ecological conditions.

The different options proposed can be divided into activities having the following hydrological effects. For dam construction (Option 12 and 18), there will be a potential reduction in residual flows below the dam, as well as a potential reduction in flood frequency and / or magnitude. Two other options (number 27 and number 38) involve extracting water from the Waikanae River, which may result in a reduction of some flow related parameters such as frequency or magnitude of flows. Option 29 will, in theory, not change the flow regime of the Waikanae River, as bore water will be used to replenish any additional abstraction of river water

The basis of the hydrological analysis was the flow record from the Waikanae at Water Treatment hydrological station (TIDEDAnumber 31504) for 3 March 1975 to 13 April 2010. The recorder is located ~200 m upstream of the water treatment take. The record was used as supplied as it was assumed that it had undergone appropriate quality checks. Water demand data was supplied by BECA for July 2002 to June 2006. This was a time of high water demand and low river flow. All flow frequency analyses were started at 1 January 1976 to obtain statistics for calendar years.

To generate current demand data for our analysis, the maximum daily demand for this 4 year period was extracted. This time series was used to calculate for each month the mean daily maximum demand. Little difference was found between the mean monthly demand and the maximum mean monthly demand calculated as above. Thus, the maximum mean monthly demand data was used to obtain a "worst case" estimate of the hydrological effects of the various options to the Waikanae River, and its tributaries.

The hydrological effects of the various take and supplementation options of the residual flows are compared with hydrological statistics for the Water Treatment site. The analyses used were standard outputs from the TIDEDA time series archiving and analysis software except for the addition of the FRE3 analysis. This analysis measures the frequency of floods and freshes more than three times the median flow. The FRE3 analysis was carried out on mean daily flows, and treated floods occurring within 7 days of one another as a single flood.

Hydrological simulations were carried out on the entire record using demand data as detailed above to simulate the residual flows downstream of the treatment plant or the bore water discharge location for the bore water option. The simulations required a number of assumptions to be made, which are detailed below.

### 1.4.1. The current situation

If the unmodified flows in the Waikanae River were less than 750 L $s^{-1}$, it was assumed no water would be taken. When unmodified flows were between 750 L $s^{-1}$ and 750 L $s^{-1}$ + the monthly demand, a residual flow of 750 L $s^{-1}$ was assumed. At higher flows the residual flow was calculated as the unmodified flow less demand. These higher flows varied by month from 984 L $s^{-1}$ in August to 1045 L $s^{-1}$ in February.

### 1.4.2. The bore water option

When flow in the Waikanae River is low and the amount of water that can be taken is limited due to the residual flow requirement, every additional litre abstracted from the river is assumed to be offset by a litre of groundwater discharged downstream of the water treatment plant intake. At higher flows, as defined above, the residual flow was set at the unmodified flow less demand.

### 1.4.3. Off site storage option

It was assumed that when river flow was greater than the minimum flow plus the monthly demand, the difference between monthly demand and 301 L $s^{-1}$ is taken to storage via the treatment plant. However, no water is taken to storage when natural flow upstream of the take is more than 4.79 $m^3$ $s^{-1}$ (the unmodified mean flow) as turbidity tends to exceed 5 NTU at greater flows and the water becomes too turbid to store. It was also assumed that the flow downstream of the treatment plant will not fall below 750 L $s^{-1}$ unless the flow upstream naturally fell below 750 L $s^{-1}$.

### 1.4.4. Dam options

From the demand data for 2002-2006, it appears in most cases that the dams would be refilled within a short period, so our hydrological simulations concentrated on the low flow behaviour. The residual flow down stream of the take would normally be the same as the bore water option. However, when the dam is being filled the residual flow from the dam will be restricted and this will reduce the flow in the main stem and could increase the time when the residual flow is 750 L $s^{-1}$, but this aspect was not modelled because of lack of data.

# 2. Results

## 2.1. Option # 12 Kapakapanui Dam stream

### 2.1.1. Habitat conditions

The four sites samples in the Kapakapanui Dam stream river differed considerably from each other, with the mid sites closest to the proposed dams (Kapakapanui Dam stream US2 and DS1) being in open farmland, and the upper and lowermost sites (Kapakapanui Dam stream US1 and DS2 respectively) being in shaded native forest (Figures 2-5). The streambed at all sites was dominated by boulders, cobbles and coarse gravels. The stream was wider at the upper locations (average width – 3.5 m) than the downstream locations (average width 1.75 m).

### 2.1.2. Biological communities

Four fish species were found in the Kapakapanui Dam stream River (Table 1), the most common of which were longfin eels and redfin bullies. Highest approximate densities were found in the two middle sites, most likely reflecting the more open nature of these sites, and subsequent higher algal and invertebrate biomass.

**Figure 2: Photograph of the Kapakapanui Dam stream upstream site 1**

**Figure 3: Photograph of the Kapakapanui Dam stream upstream site 2**

**Figure 4: Photograph of the Kapakapanui Dam stream downstream site 1**

**Figure 5: Photograph of the Kapakapanui Dam stream downstream site 2**

**Table 1: List of the fish species encountered in the Kapakapanui Dam stream River, as well as the area fished, and estimated fish density (based on a single pass).**

| Location | Site | Giant Kokopu | Koaro | Longfin eel | Redfin bully | Area fished | Number of fish | Approximate Density |
|---|---|---|---|---|---|---|---|---|
| Upstream | 1 | | 5 | 3 | 2 | 80 | 10 | 0.125 |
| Upstream | 2 | 1 | | 32 | 4 | 90 | 37 | 0.411 |
| Downstream | 1 | | | 11 | 9 | 50 | 20 | 0.4 |
| Downstream | 2 | | 1 | 4 | 6 | 60 | 11 | 0.183 |

There are no records of fish surveys in the Kapakapanui Dam stream River in the New Zealand freshwater fisheries database. However, the fish fauna found there appears typical to that of other rivers within the Waikanae catchment.

The invertebrate communities in the Kapakapanui Dam stream were dominated by four species of caddisfly (*Helicopsyche*, *Olinga*, *Beraeoptera* and *Pycnocentrodes*), the mayfly *Deleatidium*, elmid rifle beetles and the snail *Potamopyrgus*. Many of these taxa (e.g., *Helicopsyche*, *Olinga*, *Beraeoptera* and *Deleatidium*) are indicative of streams in good conditions, with low-nutrient water. Despite the considerable differences in habitat conditions between the shaded and forested locations sampled on this river, the DCA analysis showed that invertebrate community composition changed little along the continua.

Calculated metrics describing the invertebrate community in this river showed that the average number of EPT taxa at this site was high (20), as was the average % of EPT (80%). Calculated MCI scores (average = 134) were indicative of streams in “pristine” condition, as were the average QMCI scores (7.9). Values of these metrics were compared to those from streams in the same REC class (Cool wet / Lowland / Hard Sedimentary / Indigenous forest) sampled by the Wellington Regional Council as part of their SOE monitoring. We found that % of EPT, and calculated MCI / QMCI scores were higher in the Kapakapanui Dam stream, suggesting that the invertebrate communities in this river were representative of streams in “excellent” condition. Examination of species composition showed some interesting differences, which in part would explain the higher metrics in this stream. For example, the caddisfly *Helicopsyche* dominated the invertebrate community in the Kapakapanui Dam stream (contributing up to 21% of total density), whereas this animal in comparable streams sampled by the WRC composed only 0.16%.

### 2.1.3. Hydrological analysis

Table 2 shows hydrological statistics for the unmodified flows at the Water Treatment hydrological site and for the effect of the Kakakapanui dam option.

**Table 2:** **Hydrological statistics showing the unmodified flows at the Water Treatment hydrological site and the effect of the Kapakapanui Dam stream dam option on these flows downstream of the take.**

| Waikanae at Water treatment | | 1976-2009 | Current take | With flow from dam |
|---|---|---|---|---|
| Maximum flood | $m^3 s^{-1}$ | 381 | 381 | 381 |
| Mean annual flood | $m^3 s^{-1}$ | 155 | 155 | 155 |
| 5% exceedance | $m^3 s^{-1}$ | 13.6 | 13.4 | 13.4 |
| 25% exceedance | $m^3 s^{-1}$ | 5.12 | 4.86 | 4.86 |
| Mean flow | $m^3 s^{-1}$ | 4.79 | 4.53 | 4.53 |
| Median flow | $m^3 s^{-1}$ | 2.97 | 2.71 | 2.71 |
| 75 % exceedance | $m^3 s^{-1}$ | 1.79 | 1.52 | 1.52 |
| 95% exceedance | $m^3 s^{-1}$ | 1.02 | 0.754 | 0.754 |
| 7 day MALF | $m^3 s^{-1}$ | 0.923 | 0.785 | 0.750 |
| MALF | $m^3 s^{-1}$ | 0.928 | 0.792 | 0.792 |
| Minimum flow | $m^3 s^{-1}$ | 0.539 | 0.539 | 0.539 |
| FRE3 | Exceed $y^{-1}$ | 11.3 | 11.8 | 11.8 |
| (mean daily flow, 7 days between floods) | | | | |

Examination of Table 2 shows that there is very little difference in the hydrological statistics of the residual flows downstream of the take when low flows are augmented with release from the proposed dam. The small difference in FRE3 between the unmodified flow and the dam-modified flow would not be ecologically significant. The flow distribution curve (Figure 6) shows that the flow duration curve of the Waikanae River above the treatment plant, and below after the dam recharge option are so similar that they overlap on this plot. The flow duration curve shows that the flows for the options are flat lined for 5% of the time at ~750 L s-1. Flat lining for this duration does not represent any ecological concerns.

The dam option on the Kapakapanui Dam stream has hydrological and ecological advantages and disadvantages: The major disadvantage is that fish passage is blocked by the dam. In addition, downstream flows in the Kapakapanui Dam stream below the dam would only be 29 L $s^{-1}$. However this limited flow should be sufficient to preserve the life supporting capacity of the tributary. For the long 2003 drought that we modelled, the limited flow period could last for up to ~108 days. This 3½ month period of low flow may have the potential to adversely affect benthic communities in this river, especially if algal biomass accumulates in the open sites below the dam. However, the section of river involved is relatively small, and so any adverse effects are likely to be relatively minor. Thus, this dam option will disrupt natural flows in the Kapakapanui Dam stream by increasing the time the river is at low flow.

However, the dam option has the advantage of supplementing natural low flows when those in the Waikanae can not meet the demand and minimum flow requirements. This situation would usually occur when the river is already experiencing low flows, and so the extra flow from the Kapakapanui Dam stream into its lower reaches and the Waikanae mainstem would help sustain instream life. Provided that per capita use is capped at ~ 500 l/d/person, the dam will not be called on to provide water very often and so the dam will usually be full and inflows will equal outflows - albeit with some lag. From the data provided, it appears that after the dam water has been released, the dam will fill quite quickly with the capture of just a few floods, so that the number of flushing flow events provided by the dammed tributary will usually be sufficient to maintain stream health. Most dam filling will take place in winter when water temperatures are lower and there is less risk of algal proliferations.

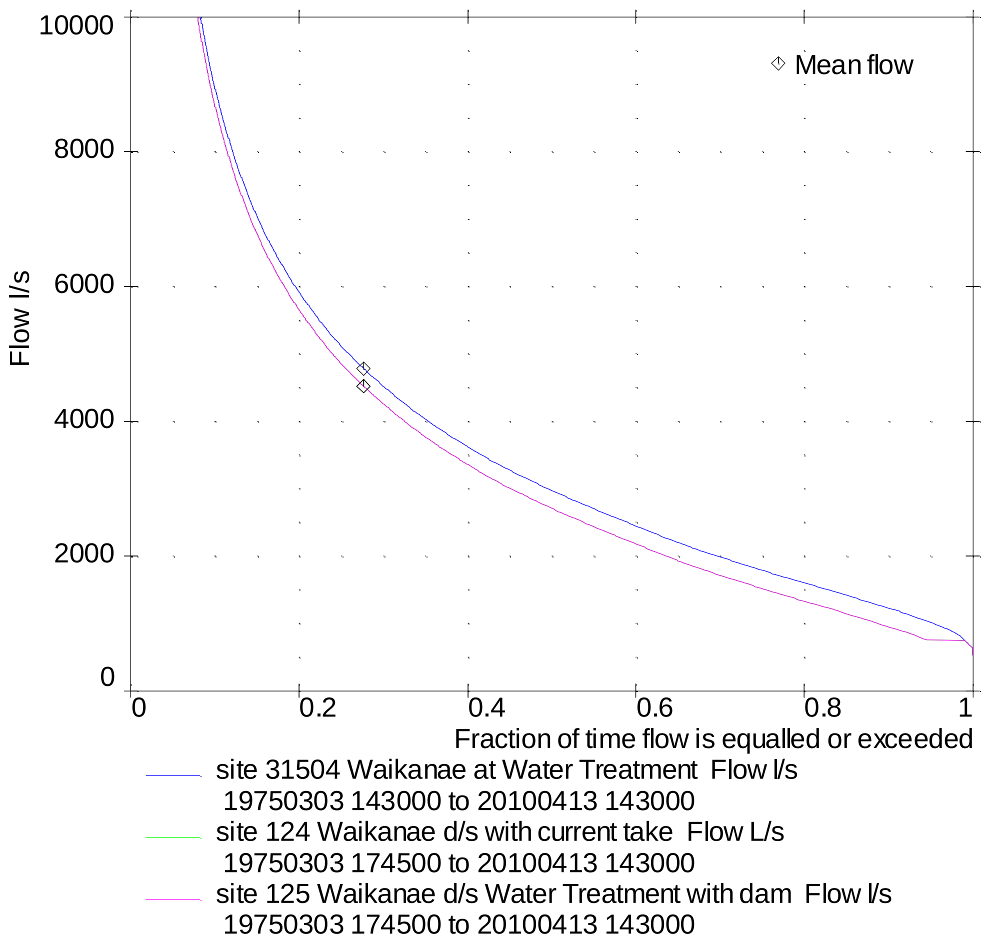


**Figure 6:** **Flow distribution curves for the unmodified flow in the Waikanae River, and the flows downstream of the take with the Kapakapanui Dam stream dam option. Note the over plotting of the flows from the Waikanae River downstream of the current take and those from the proposed dam option.**

### 2.1.4. Issues with dam construction

#### (i) Ensuring fish migration

The four native fish found in this river (redfin bullies, longfin eels, giant kokopu, and koaro) require access to the sea to complete their life cycles. For example, larvae of kokopu and koaro hatch from eggs and are washed out to sea during high flows, where the larvae grow and develop before returning as whitebait. Giant kokopu can be landlocked, so access to the sea is not as essential for the species, but it is essential for the others such as koaro. Long-fin eels also need access to and from the sea, as juveniles returning from the ocean need to swim inland, while the older, mature migrant adults (+ 90y) need to swim back to the ocean to breed. These large eels often remain in the headwaters until ready to move, usually when a flood or fresh in the autumn/early winter 'triggers" their migration. Construction of a dam in this catchment would thus disrupt the downstream movement of adult eels to the sea. There is a high risk that any migrant eels will encounter a dam when they move with the flood, and proceed down/over a spillway. If the dams are constructed by RCC methods, the dam/spillway design may include ~1m steps (Nigel Connell, Damwatch, pers comm.), and at moderate flood flows there won't be much water covering these steps. An obvious issue will then be survival of, or damage to eels bouncing down these steps. One possible way to avoid this problem is by constructing a bypass pipe/channel such that when water gets close to crest/spill levels, an open pipe through the dam and down to the riverbed provides safe eel passage.

No trout were found in this stream, possibly reflecting presence of a large waterfall in the lower part of the river and the inability of these fish to negotiate this natural barrier.

#### (ii) Potential changes to water quality, especially as flooded vegetation decays

Water quality in the reservoir may be affected as flooded vegetation at the proposed site decomposes. However, much of the area upstream of the proposed dam is grazing land, with a relatively low biomass of vegetation. Thus, potential issues with changes in water quality should not be particularly large from plant material decomposition, given the low biomass involved.

The effect of the dam on downstream water quality needs to be considered, particularly when designing the outlet structure. If a surface take is proposed, then the lake could undergo stratification. However, a deep-water off-take may minimise the likelihood of stratification, but could have potentially adverse effects to water chemistry below the outfall. Release of anoxic bottom waters into rivers may have significant detrimental effects to benthic stream life, as initially occurred with the

Opuha dam in South Canterbury. Thus it is strongly recommended that a multi-level outlet structure be included in the dam design to allow the release of both surface oxygenated water, and some deeper water to avoid any adverse effects.

**(iii) Loss of habitat as running water is replaced by deep, standing water**

Most of the invertebrates currently present in the stream (for example filter feeding mayflies, stoneflies and caddisflies) require shallow, fast flowing water, and will not tolerate conditions typical of standing water behind the dam. There will be a total loss of the riverine invertebrate community and a replacement to one more typical of standing (lentic) water. This lentic fauna is likely to be dominated by snails, midges, and zooplankton. The ordination analysis showed that the fauna of the Kapakapanui Dam stream was similar along its length, so loss of a section of river as a result of creation of the dam will not necessarily lead to a reduction to the invertebrate biodiversity values of this river. Moreover, we showed that it contained a fauna similar to other streams in the region (although it was more representative of a system with less human disturbance), and so on a regional scale, the loss of the riverine invertebrate community within the proposed reservoir area will not be an important loss.

Fish species such as redfin bullies, torrent fish and koaro require relatively fast flowing shallow water. The reservoir created behind the dam will not provide suitable habitats for these species. Koaro were found in the bush area above the proposed dam site, so construction of a dam would prevent migration of this animal to and from the headquarters. We found more koaro (5) in the upper forested site then in the lower forested site (one individual), highlighting the importance of the upper reaches of rivers as habitat to these native fish.

The river upstream of the proposed dam (Kapakapanui Dam stream US2) receives full sunlight, and supports a high biomass of algae, which in turn supports high invertebrate densities (although our results showed that the community composition was similar to that of the shaded parts of the river). Although we did not undertake a quantitative electric fishing survey, this open site supported the greatest number of longfin eels. Flooding of this area would result in the loss of this productive eel habitat.

**(iv) Necessity to maintain residual flow below the dam**

Once a dam is constructed, it will be necessary to maintain a residual flow below the dam to ensure the protection of habitat in this area. This may be particularly important as there is a relatively large waterfall before the Kapakapanui Dam stream enters the

Waikanae. Our analysis showed that residual flows below the dam would only be 29 L $s^{-1}$, and that this low flow could last for up to 103 days. This may have the potential to adversely affect benthic communities in the river, especially if algal biomass accumulates. After the dam has filled, it is expected that inflows will match outflows, and thus mirror that which naturally occurs. During times when flows at the water treatment plant cannot keep up with demand, excess water from the dams will be released to top of flows in the Waikanae River. This would result in an enhancement of flows in the river below the dam, which may have beneficial ecological effects.

**(v) Potential effects of construction**

Most of the effects associated with construction would stem from sedimentation, and this can best be ameliorated by use of best practice techniques. Moreover, many native fish appear to be highly tolerant of suspended sediments in water, as are invertebrates. However, many invertebrates may actively drift downstream from areas exposed to sedimentation, with a potential reduction in food supply for fish populations.

### 2.1.5. Summary of effects of Option # 12: Kapakapanui Dam stream

#### Overview of evaluations

The biological communities of the Kapakapanui Dam stream were investigated. Four fish species were found, of which longfin eels and redfin bullies were most numerous. The fish fauna appears typical to that of other rivers within the Waikanae catchment. The invertebrate communities were dominated by four species indicative of streams in good – excellent condition, and typical of streams with low-nutrient water. The community composition changed little along the stream. Although many of the taxa found here are found in other streams in the region, this stream supports higher relative abundances of some taxa, such as those indicative of streams in excellent condition. Hydrological analysis of data from the Waikanae River shows that there would be very little difference in flow statistics of the residual flows downstream of the take when low flows are augmented with release from the proposed dam.

#### Key Issues encountered

1. Dam construction would potentially disrupt movement of native fish to and from the sea. In particular, there is a high risk that eels will encounter the dam when migrating downstream. Survival of, or damage to eels moving past the dam will be an issue.

2. Water quality in the reservoir may be affected as flooded vegetation at the proposed site decomposes. However, much of the area upstream of the proposed dam is grazing land, so this may not be a particularly large issue

3. There will be a total loss of river habitat, displacing both fish and invertebrates from the flooded river. In particular, flooding the upstream site would result in the loss of this productive eel habitat.

**Mitigation**

1. Fish passage can be assisted by constructing a bypass pipe/channel such that when water gets close to crest/spill levels, an open pipe through the dam provides safe passage down to the riverbed.

2. A multi-level outlet structure could be included in the dam design to allow the release of both surface oxygenated water, and deeper water to minimise against release of poor quality water.

## 2.2. Option #18 Maungakotukutuku dam

### 2.2.1. Habitat conditions

The four sampling sites in the Maungakotukutuku River were all fairly similar in that they were all relatively shaded, and had an immediate riparian margin dominated by native vegetation (Figures 7-10). The uppermost site was located in an area dominated by pine plantation, although the immediate riparian vegetation was natural. The other three sites were located in areas dominated by more native bush, although the site immediately above the proposed dam (Maungakotukutuku DS2) was located in an area with regenerating native bush on the true right and, and pasture on the true left. This river was deeply incised, and flowed through a deep gully for much of its length. The streambed at all sites was dominated by a mixture of small gravels, cobbles and boulders, with areas of bedrock. Stream width and average depth were similar at all sites (4-5 m wide, and 0.4 m deep).

### 2.2.2. Biological communities

Six fish species were found in the Maungakotukutuku River (Table 3), the most common of which were longfin eels and redfin bullies. Highest approximate densities were in the site immediately upstream of the proposed dam, and lowest approximate densities at the uppermost site. Presence of brown trout and inanga in this river most likely reflect the absence of downstream barriers to migration such as waterfalls that would prevent these generally weak swimmers from moving upstream.

**Figure 7: Photograph of the Maungakotukutuku upstream site 1**

**Figure 8: Photograph of the Maungakotukutuku upstream site 2**

**Figure 9: Photograph of the Maungakotukutuku downstream site 1**

**Figure 10: Photograph of the Maungakotukutuku down stream site 2**

**Table 3: List of the fish species encountered in the Maungakotukutuku River, as well as the area fished, and estimated fish density (based on a single pass).**

| Location | Site | Brown Trout | Giant Kokopu | Inanga | Longfin eel | Redfin bully | Torrent fish | Area | Total | Density |
|---|---|---|---|---|---|---|---|---|---|---|
| Upstream | 1 | | | | 9 | 8 | | 120 | 17 | **0.14** |
| Upstream | 2 | 2 | 1 | | 9 | 11 | | 60 | 23 | **0.38** |
| Downstream | 1 | | | 1 | 3 | 17 | | 75 | 21 | **0.28** |
| Downstream | 2 | 1 | | 1 | 19 | 12 | 2 | 135 | 35 | **0.26** |

Examination of the New Zealand freshwater fisheries database showed that three of these fish (longfin eels, redfin bully and torrent fish) had been found previously in the Maungakotukutuku River. However, our records of inanga, giant kokopu and brown trout are new for this river. Other fish found in Maungakotukutuku include banded kokopu, koaro and dwarf galaxias.

The five native fish found in this river (inanga, redfin bullies, longfin eels, giant kokopu, and torrent fish) require access to the sea to complete their life cycle. For example, larvae of inanga and kokopu hatch from eggs and are washed out to sea during high flows, where the larvae grow and develop before returning as whitebait. Giant kokopu can be landlocked, so access to the sea is not as essential for the species, but it is essential for the others such as koaro.

Long-fin eels also need access to and from the sea, as juveniles returning from the ocean need to swim inland, while the older, mature migrant adults (+ 90y) need to swim back to the ocean to breed. These large eels often remain in the headwaters until ready to move, usually when a flood or fresh in the autumn/early winter 'triggers" their migration. (Indeed, a large eel measuring 1010 mm was found in the Maungakotukutuku upstream 2 site). Construction of a dam in this catchment would thus disrupt the downstream movement of adult eels to the sea. There is a high risk that any migrant eels will encounter a dam when they move with the flood, and proceed down/over a spillway. If the dams are constructed by RCC methods, the dam/spillway design may include ~1m steps (Nigel Connell, Damwatch, pers comm.), and at moderate flood flows there won't be much water covering these steps. An obvious issue will then be survival of, or damage to eels bouncing down these steps. One possible way to avoid this problem is by constructing a bypass pipe/channel such that when water gets close to crest/spill levels, an open pipe through the dam and down to the riverbed provides safe eel passage.

The invertebrate communities in the Mangakotukutuku were dominated by five species of caddisfly (*Helicopsyche*, *Olinga*, *Pycnocentrodes*, *Aoteapsyche* and *Beraeoptera*), the mayfly *Deleatidium* and *Coloburiscus*, elmid rifle beetles and the snail *Potamopyrgus*. Many of these taxa (e.g., *Helicopsyche*, *Olinga*, *Beraeoptera* and

*Deleatidium*) are indicative of streams in good conditions, with low-nutrient water. The ordination analysis showed no changes in invertebrate community composition between the upper and lower sites along the river.

Calculated metrics describing the invertebrate community in this river showed that the average number of EPT taxa at this site was high (18), as was the average % of EPT (73%). Calculated MCI scores (average = 130) were indicative of streams in "pristine" condition, as were the average QMCI scores (7.6). Both the EPT and % EPT were similar to streams in the same REC class (Cool wet / Lowland / Hard Sedimentary / Indigenous forest) sampled by the Wellington Regional Council as part of their SOE monitoring, however the calculated MCI and QMCI scores were significantly higher (average =130 and 7.6 respectively) than in similar streams sampled by the WRC (average = 108 and 6, respectively). This means that the invertebrate communities in the Mangakotukutuku River represented streams in "excellent" condition, and better than other similar streams in the region. Examination of species composition did, however, show some interesting differences. For example, the caddisflies *Helicopsyche* and *Olinga* dominated the invertebrate community in the Mangakotukutuku River (contributing 15% and 11% respectively of total density), whereas these animals in comparable streams composed only 3.2% and 0.16% respectively.

### 2.2.3. Hydrological analysis

Table 4 shows hydrological statistics for the unmodified flows at the Water Treatment hydrological site and for the effect of the Mangakotukutuku dam option.

**Table 4: Hydrological statistics for the unmodified flows at the Water Treatment hydrological site and for the various options downstream of the take.**

| **Waikanae at Water treatment** | | **1976-2009** | **Current take** | **With flow from dam** |
|---|---|---|---|---|
| Maximum flood | $m^3 s^{-1}$ | 381 | 381 | 381 |
| Mean annual flood | $m^3$ s | 155 | 155 | 155 |
| 5% exceedance | $m^3$ s | 13.6 | 13.4 | 13.4 |
| 25% exceedance | $m^3$ s | 5.12 | 4.86 | 4.86 |
| Mean flow | $m^3$ s | 4.79 | 4.53 | 4.53 |
| Median flow | $m^3$ s | 2.97 | 2.71 | 2.71 |
| 75 % exceedance | $m^3$ s | 1.79 | 1.52 | 1.52 |
| 95% exceedance | $m^3$ s | 1.02 | 0.754 | 0.754 |
| 7 day MALF | $m^3$ s | 0.923 | 0.785 | 0.750 |
| MALF | $m^3$ s | 0.928 | 0.792 | 0.792 |
| Minimum flow | $m^3$ s | 0.539 | 0.539 | 0.539 |
| FRE3 | Exceed $y^{-1}$ | 11.3 | 11.8 | 11.8 |
| (mean daily flow, 7 days between floods) | | | | |

Examination of Table 2 shows that there is very little difference in the hydrological statistics of the residual flows downstream of the take when low flows are augmented with release from the proposed dam. The small difference in FRE3 between the unmodified flow and the dam-modified flow would not be ecologically significant. The flow distribution curve (Figure 11) shows that the flow duration curve of the Waikanae River above the treatment plant, and below after the dam recharge option are very similar, as they overlap each other on the plot below. The flow duration curve shows that the flows for the options are flat lined for 5% of the time at ~750 L $s^{-1}$. Flat lining for this duration does not represent any ecological concerns.

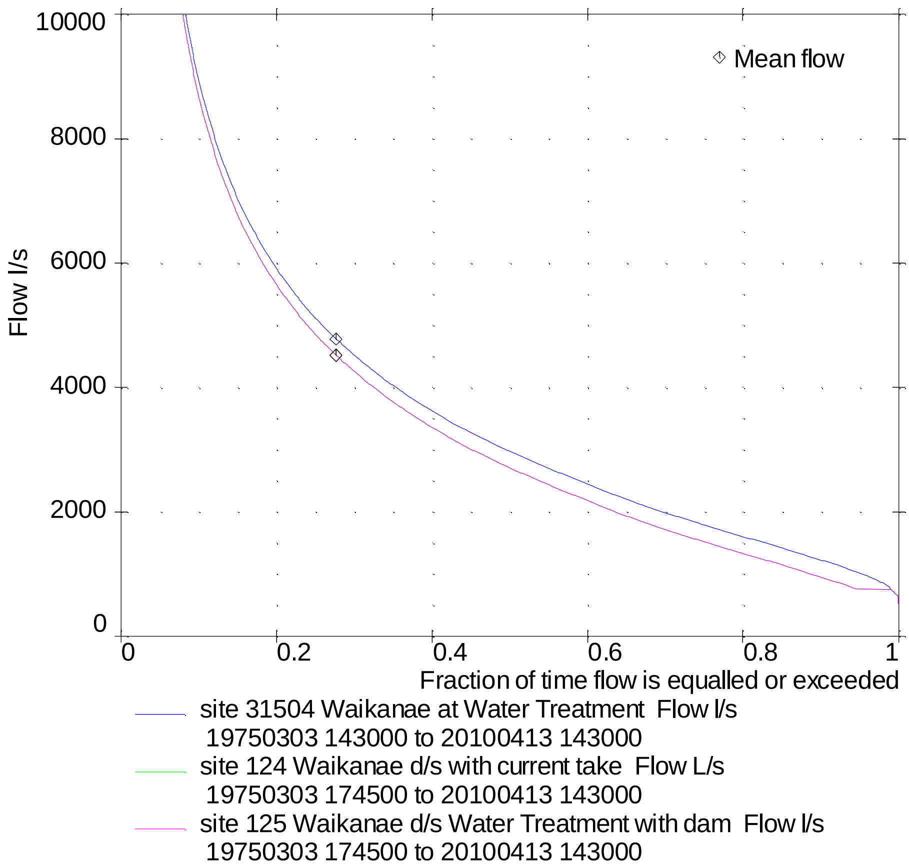


**Figure 11. Flow distribution curves for the unmodified flow in the Waikanae River, and the flows downstream of the take with the Maungakotukutuku dam option. Note the over plotting of the flows from the Waikanae River downstream of the current take and those from the proposed dam option.**

The dam option has hydrological and ecological advantages and disadvantages: The major disadvantage is that fish passage is blocked by the dam. In addition, downstream flows below the Maungakotukutuku dam would be held at 130 L $s^{-1}$ while this dam is filling, and that this low flow period could last for only ~ 17 days. Such a small period is unlikely to adversely affect benthic communities in this river, especially as algal biomass is unlikely to accumulate in this already shaded system.

Thus, although the dam option will disrupt natural flows in the Maungakotukutuku by increasing the time the river is at low flow, the effects are thought to be negligible.

However, the dam option would also supplement natural low flows when those in the Waikanae can not meet the demand and minimum flow requirements. Provided that per capita use is capped at ~ 500 l/d/person, the dam will not be called on to provide water very often and so the dam will usually be full and inflows will equal outflows - albeit with some lag. From the data provided, it appears that after the dam water has been released, the dam will fill quite quickly with the capture of just a few floods, so that the number of flushing flow events provided by the dammed tributary will usually be sufficient to maintain stream health. Most dam filling will take place in winter when water temperatures are lower and there is less risk of algal proliferations.

### 2.2.4. Issues with dam construction

#### (i) Potential changes to water quality, especially as flooded vegetation decays

This stream supports a large amount of tall native vegetation in its immediate riparian area, which would be flooded above any dam. If vegetation upstream of the dams is left in situ, then water quality in the reservoir may be affected as flooded vegetation decomposes. A decision needs to be made as to whether large trees would be removed prior to dam filling, or whether they would be simply left to slowly decompose. Potential water quality changes need to be considered if vegetation is removed prior to dam filling, as care is needed to ensure that excess sediment runoff does not occur as a result of vegetation removal, particularly given the steep nature of the gorge that the Maungakotukutuku flows along.

If a surface outlet structure is proposed, then the lake could undergo stratification. However, a deep-water off-take may minimise the likelihood of stratification, but could have potentially adverse effects to water chemistry below the outfall. Given the large amount of vegetation in this catchment, and around the river, there is a chance that the water could go anoxic as vegetation decays. Release of this anoxic water below the dam may have significant detrimental effects to stream organisms, as initially occurred with the Opuha dam in South Canterbury. Thus it is strongly recommended that a multi-level outlet structure be included in the dam design to allow the release of both surface oxygenated water, and some deeper water to avoid any adverse effects.

#### (ii) Loss of habitat as running water is replaced by deep, standing water

Most of the invertebrates currently present in the Maungakotukutuku stream (for example filter feeding mayflies, stoneflies and caddisflies) require shallow, fast flowing water, and will not tolerate conditions typical of standing water behind the dam. There will be a total loss of this community following dam construction, and a replacement to a community more typical of standing (= lentic) water. This fauna is likely to be dominated by snails, midges, and zooplankton. Results of the ordination showed that the fauna of the Maungakotukutuku was similar along its length, so loss of a section of river as a result of creation of the dam will not necessarily lead to a reduction to the invertebrate biodiversity values of this river. Moreover, fauna of the Maungakotukutuku was similar to that found in other streams in the region (although it contained a higher proportion of some taxa such as caddisflies), and so on a regional scale, loss of the riverine invertebrate community within the proposed reservoir area would not lead a reduction in invertebrate biodiversity values

Fish such as redfin bullies and torrent fish and koaro require relatively fast flowing shallow water, so habitat for these species will be lost by the creation of a reservoir behind the dam. However, trout, giant kokopu and eels can tolerate lentic conditions.

**(iii) Necessity to maintain residual flow below the dam**

The stream below the proposed dam in the Maungakotukutuku is fairly long (ca 3.5 km), so it will be important to ensure that an adequate residual flow is maintained below the dam to ensure the protection of habitat in this area. Construction of a dam would inevitably lead to reduced flows below the dam until it fills, where-after it is expected that dam inflows will match outflows. Our analysis showed that residual flows below the dam during this filling period would only be 130 L $s^{-1}$ and is expected to last for ~108 days, which may adversely affect benthic communities, especially if algal biomass was able to accumulate. Once the dam is filled; however, the flow regime below the dam should mostly mirror that which would naturally occur. During times when flows at the water treatment plant cannot keep up with demand, excess water from the dams will be released to top off flows in the Waikanae River. This would result in an enhancement of flows in the river below the dam, which may have beneficial ecological effects.

**(iv) Potential effects of construction**

Most of the effects associated with construction would stem from sedimentation, and this can best be ameliorated by use of best practice techniques. Moreover, many native fish appear to be highly tolerant of suspended sediments in water, as are invertebrates. However, many invertebrates may actively drift downstream from areas exposed to sedimentation, with a potential reduction in food supply for fish populations. Potential sources of sediment include activities associated with dam construction, as well as potential run-off from the catchment should vegetation be cleared prior to dam filling.

### 2.2.5. Summary of effects of Option # 18 Maungakotukutuku dam

**Overview of evaluations**

The biological communities of the Maungakotukutuku stream were investigated. Six fish species were found, the most common of which were longfin eels and redfin bullies. The fish fauna appears typical to that of other rivers in the area. The invertebrate community was dominated by invertebrates indicative of streams in good – excellent condition, with low-nutrient water. Community composition changed little along the river. Hydrological analysis of data from the Waikanae River shows that there would be very little difference in flow statistics of the residual flows downstream of the take when low flows are augmented with release from the proposed dam.

**Key Issues encountered**

1. Dam construction would potentially disrupt movement of native fish to and from the sea. In particular, there is a high risk that eels will encounter the dam when migrating downstream. Survival of, or damage to eels moving past the dam will be an issue.

2. Water quality in the reservoir may be affected as flooded vegetation at the proposed site decomposes. A decision needs to be made as to whether large trees would be removed prior to reservoir filling, or whether they would be left to decompose. If vegetation is removed, sedimentation may become an issue.

3. There will be a total loss of river habitat, displacing fish such redfin bullies and torrent fish and koaro, and invertebrates from the flooded river. Other fish species such as trout, giant kokopu and eels, however, can tolerate lentic conditions.

**Mitigation**

1. Fish passage can be assisted by constructing a bypass pipe/channel such that when water gets close to crest/spill levels, an open pipe through the dam provides safe passage down to the riverbed.

2. A multi-level outlet structure could be included in the dam design to allow the release of both surface oxygenated water, and deeper water to minimise against release of poor quality water.

### 2.3. Option #27 and #23/38 Changing flood frequency (Lower Waikanae River)

Flow harvesting in the Waikanae (either for aquifer storage and recovery (Option 27), or aboveground storage (Option 23/38)) has the potential to reduce the number, or intensity of beneficial floods that cleanse the river of excess plant material or fine sediments. Floods also help wash young native fish out to sea as part of their normal life cycles. The implication of changes to the flow regime of the Waikanae arising from flow harvesting was addressed by detailed analysis of changes to the hydrology arising from these options, and our knowledge of the interaction of flow and fish, invertebrates, and algae.

**Table 5. Hydrological statistics for the unmodified flows at the Water Treatment hydrological site and for the various options downstream of the take.**

| Waikanae at Water treatment ($m^3$ $s^{-1}$) | 1976-2009 | Current take | Abstraction at WT plant to storage |
|---|---|---|---|
| Maximum flood | 381 | 381 | 381 |
| Mean annual flood | 155 | 155 | 155 |
| 5% exceedance | 13.6 | 13.4 | 13.4 |
| 25% exceedance | 5.12 | 4.86 | 4.86 |
| Mean flow | 4.79 | 4.53 | 4.50 |
| Median flow | 2.97 | 2.71 | 2.67 |
| 75 % exceedance | 1.79 | 1.52 | 1.49 |
| 95% exceedance | 1.02 | 0.754 | 0.751 |
| 7 day MALF | 0.923 | 0.785 | 0.789 |
| MALF | 0.928 | 0.792 | 0.783 |
| Minimum flow | 0.539 | 0.539 | 0.539 |
| FRE3 | 11.3 | 11.8 | 11.8 |

Analysis of the long-term (33 year) flow record in the Waikanae River showed that potential changes to the hydrological regime of the Waikanae River as a result of flow harvesting were very small (Table 5). These changes are highly unlikely to have any demonstrable effects on the fish or invertebrate communities in the Waikanae River.

The flow distribution curve (Figure 12) shows the similarity of flow between that which is now observed, and that which would occur with this option. The flow duration curve shows that the flow harvesting options would result in a slight flat lining of the river for 5% of the time at ~750 L $s^{-1}$. Flat lining for this duration is not a concern.

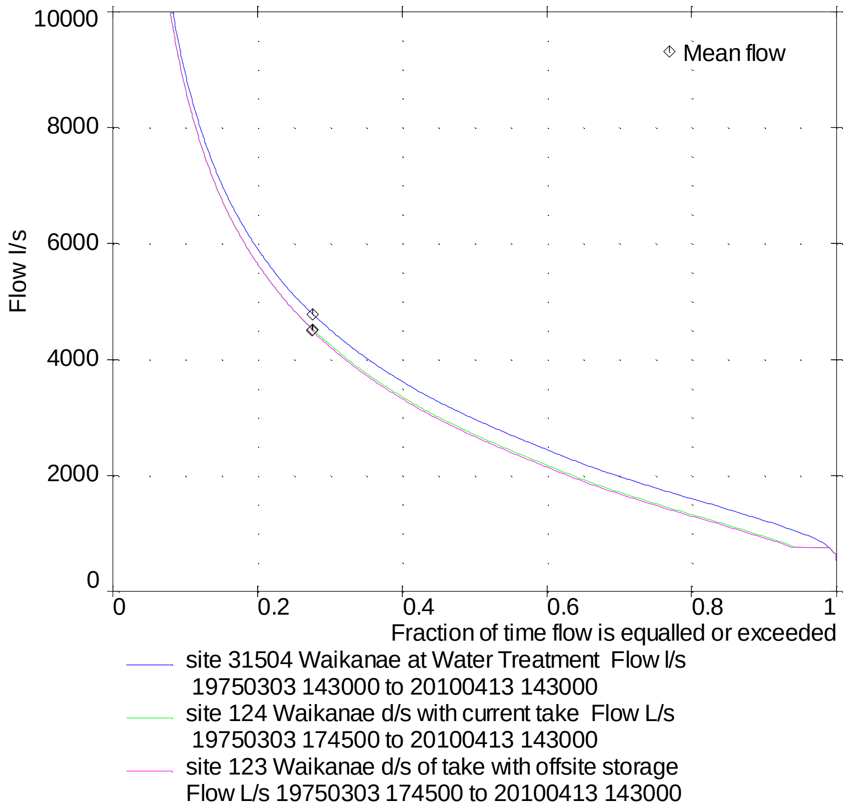


**Figure 12: Flow distribution curves for the unmodified flow in the Waikanae River, and the flows downstream of the take with the flow harvesting option. Note the similarity of the flow distribution curves between the current take, and that proposed with flow harvesting and either aquifer storage and recovery (Option 27), or aboveground storage (Option 23/38)).**

### 2.3.1. Biological communities

Five fish species (four native species and brown trout) were found in the Waikanae River (Table 6), the most common of which were longfin eels and redfin bullies. Highest approximate densities were at the upstream 2 site, below the confluence with the Maungakotukutuku.

**Table 6: List of the fish species encountered in the Waikanae River, as well as the area fished, and estimated fish density (based on a single pass).**

| Location | Site | Brown Trout | Inanga | Longfin eel | Redfin bully | Torrent fish | Area | Total | Density |
|---|---|---|---|---|---|---|---|---|---|
| Upstream | 1 | | 1 | 16 | 25 | | 175 | 42 | **0.24** |
| Upstream | 2 | 2 | | 46 | 14 | 2 | 90 | 64 | **0.71** |
| Downstream | 1 | | | 19 | 14 | 2 | 60 | 35 | **0.58** |

Examination of the freshwater fisheries database showed that all these fish had previously been found in the Waikanae River. Other fish found in the Waikanae River include both giant and short jaw kokopu, koaro and dwarf galaxias, as well as common and bluegill bullies. The occurrence of short jaw kokopu in the river is of some conservation interest, as this animal is listed as being vulnerable in the IUCN red list. However, this fish was found that only one site in the river, approximately 2 km along the Mangaone walkway.

The invertebrate communities in the Waikanae were dominated by the mayflies *Deleatidium* and *Coloburiscus,* six species of caddisfly (*Pycnocentrodes, Olinga, Psilochorema, Helicopsyche, Aoteapsyche* and *Costachorema*), elmid riffle beetles, the snail *Potamopyrgus* and orthoclad midges. Many of these taxa (e.g., *Helicopsyche*, *Olinga*, *Coloburiscus* and *Deleatidium*) are indicative of streams in good conditions, with low-nutrient water. Calculated metrics describing the invertebrate community in this river showed that the average number of EPT taxa at this site was relatively high (15), as was the average % of EPT (59%). Calculated MCI scores (average = 126) were indicative of streams in “pristine” condition, as were the average QMCI scores (6.8). These metrics were slightly higher than streams in the same REC class (Cool wet / Lowland / Hard Sedimentary / Pasture) sampled by the Wellington Regional Council as part of their SOE monitoring, where for example the % of EPT was only 43%, and the average MCI was only 103 (indicative of streams in "good" condition: Stark 1993). This means that ecological condition of the Waikanae River was somewhat better than similar streams of the same REC class.

The DCA ordination scores of the samples collected from the Waikanae River in this survey were very similar to those collected by the Wellington regional Council as part of their SOE monitoring (Figure 13). This suggests that both studies accurately and consistently described the invertebrate communities found in this river.

### 2.3.2. Issues with Changing flood frequency

The only demonstrable changes to the flow regime as a result of flow harvesting reflect slight reductions in some of the low flow statistics, such as a reduction in MALF by 9 L $s^{-1}$. Given these minor changes, it is highly unlikely that there would be any measureable effects on the fish or invertebrate communities.

Any modifications to the inlet structure of the water treatment plant needed to accommodate the greater water demand may need to be designed to minimise the number of fish that get drawn into it by incorporating appropriate fish screens.

Any flow harvesting from the Waikanae used for above ground storage (Option 23/38)) will require construction of a pond for the water to be stored in. There is the potential for such ponds to influence existing wetlands in the area, with either beneficial or detrimental affects depending on the pond design and location.

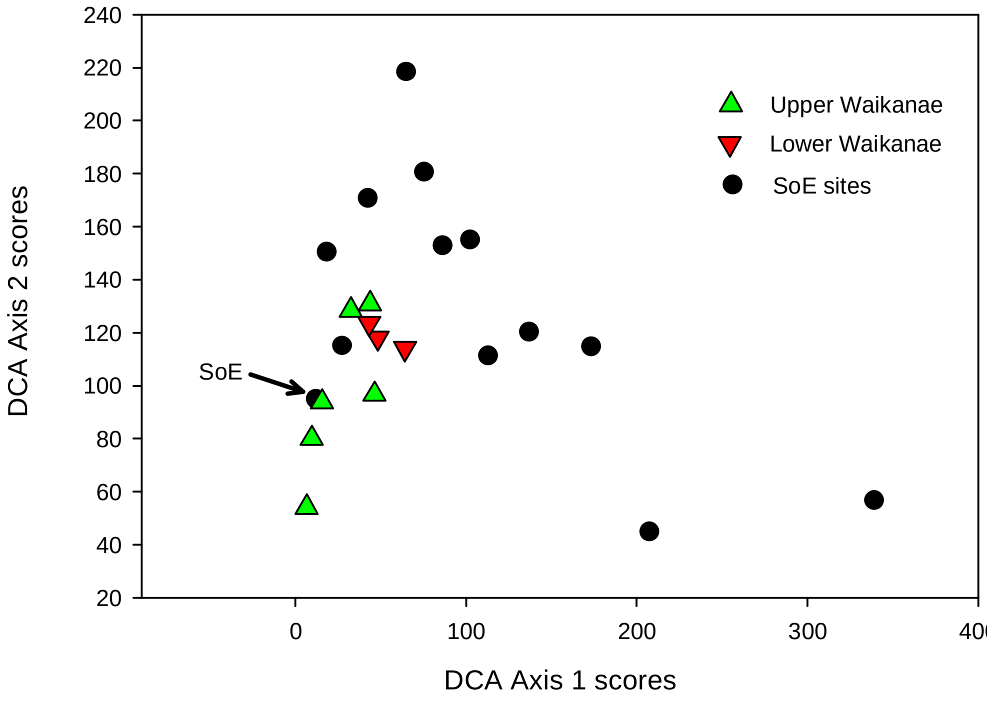


**Figure 13: Graphical representation of invertebrate communities found in samples collected from the upper and lower Waikanae River (triangles) and those collected by the Wellington Regional Council as part of their state of environment surveys. Note the similarity between our Waikanae River samples and those collected for the SOE work (arrow).**

### 2.3.3. Summary of effects of Options #27 and #23/38 Changing flood frequency (Lower Waikanae River)

#### Overview of evaluations

The biological communities of the Waikanae River were investigated. Four native fish and brown trout were found, the most common of which were longfin eels and redfin bullies. The invertebrate communities here were indicative of streams in better condition than similar streams in the region. The communities found were very similar to those collected by the Wellington Regional Council, suggesting that both studies consistently described them.

The hydrological effects of flow harvesting either for aquifer storage and recovery (Option 27), or aboveground storage (Option 23/38)) may potentially reduce the number, or intensity of beneficial floods. Analysis of the long-term flow record however showed potential changes to the flow regime were very small, and unlikely to have any demonstrable adverse effects on the fish or invertebrate communities.

**Key Issues encountered**

1. Any modifications made to the inlet structure of the water treatment plant needed to accommodate the greater water demand may result in more fish becoming drawn into it.

2. The location and design of the water storage pond needs to be considered to minimise any potential adverse effects on any wetlands, if nearby.

**Mitigation**

1. The inlet structure needs to be designed to minimise the number of fish that get drawn into it. This may involve the use of fish screens.

## 2.4. Option # 29 Bore water discharge

Augmenting flows below the water treatment plant with bore water would allow extraction of relatively more river water than is currently permitted. The main issue to be considered for this option include changes to the water chemistry of the Waikanae River as a result of the bore water discharge, and potential effects of these changes on the river's ecology. Changes to the water chemistry of the Waikanae River will depend mainly on the size and magnitude of the discharge plume, and how various water quality parameters change within this plume.

### 2.4.1. Plume dispersal pattern

Results of the dye test conducted on 22 April clearly showed the pattern of mixing and dilation rate of bore water along the Waikanae River (Figure 14, Table 7). The dye plume remained on the right-hand of the river as it moved downstream towards a right angle bend, approximately 100 m below the discharge (Figure 14). The highest concentration observed was found 10 m below the bore water discharge, where the maximum concentration of the plume was 86% that of the discharge. The plume gradually became more diluted as it moved downstream from here. Approximately 100 m below the discharge, the river flowed into a deep pool, and turned at right angles. The results showed that the bore water became more evenly mixed at this stage across the entire river (as expressed as the Standard Deviation of the Rhodamine concentration: Table 7), with dye present in all samples across the stream at each transect. Rhodamine concentrations here were only 1% those at the bore discharge. By 600m, we collected a sample without any detectable Rhodamine (WT) in it, highlighting the large degree of dilution at this location.

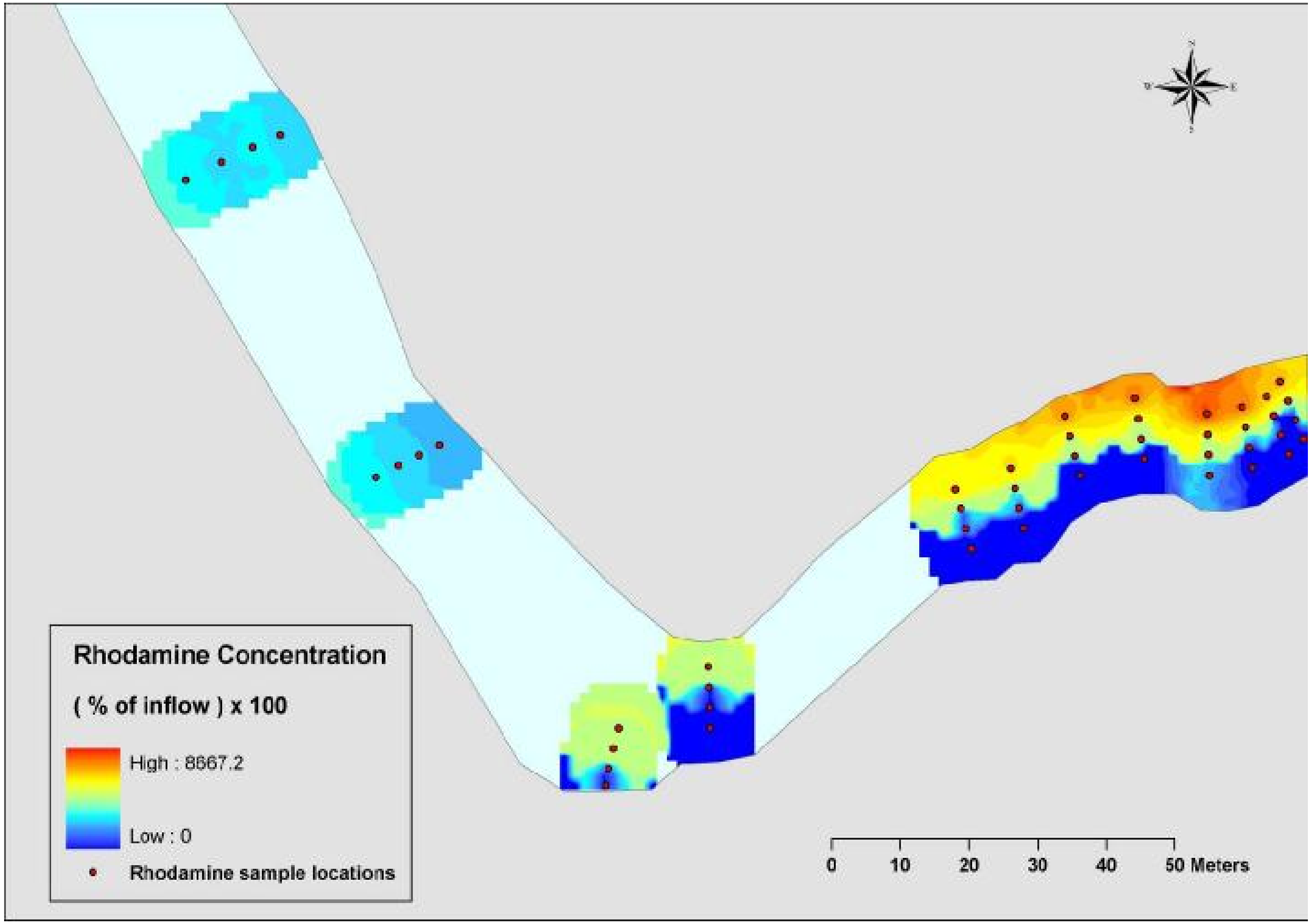


**Figure 14:** **Graphical representation of the dye plume, as assessed by Rhodamine Dye, showing the relative dilution as a % of the original inflow at sites along the Waikanae River. Note that sites at the 300m 400m and 600m distances are not shown for clarity. These sites showed a high degree of dilution; indeed at one of the 600m sites, no Rhodamine was detected.**

**Table 7: Results of the dye monitoring study conducted on 22 April 2010 showing the average dilution of Rhodamine across the river (as % of inflow), as well as the maximum concentration at each sampling point. Also shown is the variability of the dye concentration (expressed as standard deviation), and the number of times no Rhodamine was detected in samples at each transect.**

| Distance from bore water discharge | Average dilution(as % of bore water input) | Maximum concentration (as % of bore water input) | Standard deviation | Number of zero readings at each transect |
|---|---|---|---|---|
| 0 | 10.53 | 42.14 | 21.07 | 3 |
| 3 | 8.56 | 34.24 | 17.12 | 3 |
| 6 | 18.26 | 73.02 | 36.51 | 3 |
| 10 | 23.16 | 86.67 | 42.34 | 0 |
| 20 | 17.36 | 68.95 | 34.40 | 2 |
| 30 | 15.38 | 59.14 | 29.19 | 2 |
| 40 | 6.82 | 27.29 | 13.65 | 3 |
| 50 | 4.91 | 19.63 | 9.82 | 3 |
| 88 | 2.33 | 9.34 | 4.67 | 3 |
| 100 | 3.71 | 8.14 | 4.33 | 2 |
| 150 | 1.74 | 2.15 | 0.30 | 0 |
| 200 | 1.92 | 2.15 | 0.28 | 0 |
| 300 | 1.80 | 1.92 | 0.14 | 0 |
| 400 | 1.62 | 2.15 | 0.49 | 0 |
| 600 | 0.90 | 1.68 | 0.71 | 1 |

### 2.4.2. Characterisation of bore and river water chemistry

KCDC has measured the bore water chemistry several times between 2004 and 2010. The bore water chemistry was also measured during the pump test discharges to the Waikanae River. This data is compared to KCDC monitoring data in Tables 8 and 9 and shows the bore water has high levels of dissolved cations (calcium, magnesium), some anions (carbonate), hardness and alkalinity. The bore water also has elevated manganese. The recent pump test data shows that bore water has moderate amounts of dissolved reactive phosphorus (DRP) in it (Table 8), whereas previous assays did not measure this. The bore water also had low, but detectable concentrations of ammoniacal-nitrogen and nitrite-nitrogen, species of nitrogen that are found under reducing conditions (i.e., where there is low oxygen). Nitrite-N is not usually found in stream and river water, and is likely to oxidize to nitrate-nitrogen once discharged into the river water.

Higher concentrations of nitrite-N and nitrate-N were detected during the pump test monitoring than those measured from 2005-2010 by KCDC. There is no obvious reason for this difference, but it may be due to seasonal changes in groundwater chemistry. The bore water from K4 appears to have changed slightly in quality, with higher pH, calcium, magnesium, bicarbonate and alkalinity measured during pump tests than that measured previously. Previous monitoring data for trace metals of toxicological concern was limited to sampling undertaken on 24 February 2010. At that time, copper and zinc were the only metals detected in K6 and Kb4, respectively (Table 9). Monitoring during the pump tests agreed with this data, again, with only zinc detected in Kb4 (28 April 2010), and all other metals below the detection limits (Table 9).

This comparison of data from previous monitoring and from the pump tests shows some differences in the water chemistry over time. If the bore water is used to supplement the Waikanae River, further monitoring of the bore water discharges should be undertaken, as the previous monitoring data may not fully reflect the chemistry or variability in chemistry of the bore water.

The water quality in the Waikanae River was measured upstream and downstream of the discharge during the pump tests. The samples were collected within the bore water plume before it mixed completely with river water. At this location, the plume was approximately 70% bore water and 30% river water. These samples thus show the water quality downstream prior to complete mixing of bore water with river water.

The data (Tables 10 and 11) shows an increase in several parameters, particularly pH, alkalinity, hardness, manganese (dissolved and total), ammoniacal-N and DRP. No trace metals / metalloids were detected in the river water, either upstream or downstream of the discharge.

Sondes were installed upstream and downstream of the bore water discharge to monitor conductivity, temperature, pH and dissolved oxygen during the pump test trials (Figure 15). Figure 16 shows the sonde data along with river flow and the contribution of bore water, during, before and after the pump tests. River flow (Figure 16a) was measured at the Waikanae water treatment plant. The contribution of bore water (Figure 16a) was calculated as a percentage of the river flow based on constant discharge rates of 58, 35 and 70 L $s^{-1}$ for the three tests. The bore water contribution assumes complete mixing. The sondes were located within the plume, estimated at 70% bore water at the time of testing, and not at a location with complete mixing, however that percentage would change with river flow. While not accurate for the sonde location, the bore water contribution based on complete mixing provides an indication of the relative bore water contribution at the sonde location under the different flow regimes

**Table 8: Chemistry of the bore water discharges into the Waikanae River during pump tests compared with monitoring by KCDC from 2005 to 2010.**

| | K6 | Kb4 | | | K4 | | |
|---|---|---|---|---|---|---|---|
| | Median (range) of KCDC data | Median (range) of KCDC data | 17 April | 28 April | Median (range) of KCDC data | 6 May | 18 May |
| pH | 7.8 (7.7 - 8.2) | 7.9 (7.7 - 8.1) | 8.2 | 8.2 | 7.5 (7.5 - 7.9) | 8.2 | 7.9 |
| Electrical conductivity (mS $m^{-1}$) | 118 (107 - 120) | 123 (110 - 148) | No data | No data | 62 (51 - 63) | No data | No data |
| Total Suspended Solids | No data | No data | 3.6 | < 3 | No data | < 3 | < 3 |
| Total Alkalinity (as $CaCO_3$) | 231.5 (210 - 270) | 184 (141 - 202) | 200 | 194 | 103 (84 - 108) | 142 | 111 |
| Bicarbonate (g $m^{-3}$) | 281 (252 - 328) | 223 (171 - 245) | 240 | 230 | 124 (102 - 132) | 170 | 135 |
| Dissolved Calcium (g $m^{-3}$) | 39.2 (33.2 - 40) | 45 (36 - 52) | 33 | 31 | 4.4 (2.6 - 4.7) | 23 | 4.8 |
| Dissolved Magnesium (g $m^{-3}$) | 13.8 (13.4 - 15.7) | 16 (12 - 18) | 10.9 | 10.3 | 4.9 (3.4 - 5.1) | 8.4 | 5.5 |
| Hardness (as $CaCO_3$) | 154.5 (139 - 163) | 181 (138 - 199) | 127 | 120 | 31 (21 - 33) | 92 | 35 |
| Total Ammoniacal-N (g $m^{-3}$) | 0.25 (0.21 - 0.34) | 0.05 (0.04 - 0.08) | 0.041 | 0.031 | 0.01 (0.01 - 0.02) | 0.029 | 0.012 |
| Nitrite-N (g $m^{-3}$) | All <0.002 | All <0.002 | 0.0027 | 0.0024 | <0.002 (<0.002 - 0.003) | < 0.002 | < 0.002 |
| Nitrate-N (g $m^{-3}$) | All <0.002 | <0.002 (<0.002 - 0.01) | 0.0143 | 0.081 | 0.002 (<0.002 - 0.004) | 0.087 | 0.013 |
| Nitrate-N + Nitrite- N (g $m^{-3}$) | All <0.002 | All <0.002 | 0.017 | 0.083 | 0.003 (<0.002 - 0.005) | 0.088 | 0.013 |
| Dissolved Reactive Phosphorus (g $m^{-3}$) | No data | No data | 0.024 | 0.025 | No data | 0.023 | 0.092 |
| Dissolved Iron (g $m^{-3}$) | All <0.02 | 0.02 (0.02 - 0.09) | < 0.02 | < 0.02 | 0.02 (0.01 – 0.02) | < 0.02 | < 0.02 |
| Total Iron (g $m^{-3}$) | 0.61 (0.19 - 2.5) | 0.21 (0 - 2.8) | 0.031 | 0.03 | 0.09 (0.03 - 1.2) | 0.07 | <0.021 |
| Dissolved Manganese (g $m^{-3}$) | 0.082 (0.076 - 0.085) | 0.02 (0.02 - 0.16) | 0.015 | 0.0017 | 0.15 (0.12 - 0.19) | 0.013 | 0.15 |
| Total Manganese (g $m^{-3}$) | 0.087 (0.079 - 0.13) | 0.03 (0.02 - 0.21) | 0.021 | 0.018 | 0.15 (0.13 - 0.19) | 0.014 | 0.16 |

**Table 9: Metals and metalloids in bore water discharges into the Waikanae River during pump tests compared with previous monitoring by KCDC (24 February 2010).**

| | K6<br>KCDC data | Kb4<br>KCDC data | Kb4<br>Pump test data | Kb4<br>Pump test data | K4<br>KCDC data | K4<br>Pump test data | K4<br>Pump test data |
|---|---|---|---|---|---|---|---|
| **Dissolved metal/ metalloid ($g\ m^{-3}$)** | **24 Feb** | **24 Feb** | **17 April** | **28 April** | **24 Feb** | **6 May** | **18 May** |
| Arsenic | No data | No data | < 0.0010 | < 0.0010 | No data | < 0.0010 | < 0.0010 |
| Cadmium | <0.0002 | <0.0002 | < 0.00005 | < 0.00005 | <0.0002 | < 0.00005 | < 0.00005 |
| Chromium | <0.001 | <0.001 | < 0.0005 | < 0.0005 | <0.001 | < 0.0005 | < 0.0005 |
| Copper | 0.0006 | <0.0005 | < 0.0010 | < 0.0010 | <0.0005 | < 0.0005 | < 0.0005 |
| Lead | <0.0005 | <0.0005 | < 0.00010 | < 0.00010 | <0.0005 | < 0.00010 | < 0.00010 |
| Nickel | <0.0005 | <0.0005 | < 0.0005 | < 0.0005 | <0.0005 | < 0.0005 | < 0.0005 |
| Zinc | <0.002 | 0.002 | < 0.0010 | 0.0019 | <0.002 | < 0.0010 | < 0.0010 |

**Table 10: Water quality of the discharge from Kb4 and in Waikanae River upstream and downstream of the discharge.**

| | 17 April | | | | 28 April | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Discharge** | **Upstream** | **Downstream** | **Increase** | **Discharge** | **Upstream** | **Downstream** | **Increase** |
| pH | 8.2 | 7.2 | 8.0 | 0.8 | 8.2 | 7.4 | 8.1 | 0.7 |
| Total Alkalinity | 200 | 20 | 116 | 94 | 194 | 17.4 | 96 | 79 |
| Bicarbonate | 240 | 25 | 139 | 114 | 230 | 21 | 115 | 94 |
| TSS | 3.6 | < 3 | < 3 | None | < 3 | < 3 | < 3 | None |
| Dissolved Calcium | 33 | 5 | 22 | 17 | 31 | 4.8 | 16.2 | 11.4 |
| Dissolved Magnesium | 10.9 | 1.8 | 7.0 | 5.2 | 10.3 | 1.7 | 5.9 | 4.24 |
| Hardness | 127 | 20 | 84 | 64 | 120 | 19 | 65 | 46 |
| Dissolved Iron | < 0.02 | < 0.02 | < 0.02 | None | < 0.02 | 0.033 | < 0.02 | None |
| Total Iron | 0.031 | < 0.021 | < 0.021 | None | 0.03 | 0.053 | 0.046 | -0.007 |
| Dissolved Manganese | 0.015 | 0.00055 | 0.0105 [a] | 0.0100 | 0.0017 | < 0.0005 | 0.0033 | 0.0033 |
| Total Manganese | 0.021 | 0.00071 | 0.0104 [a] | 0.0097 | 0.018 | 0.0016 | 0.0086 | 0.0070 |
| **Nutrients g m$^{-3}$** | | | | | | | | |
| Total NH4-N | 0.041 | < 0.010 | 0.02 | > 0.01 | 0.031 | < 0.010 | 0.017 | 0.017 |
| Nitrite-N | 0.0027 | < 0.002 | < 0.002 | None | 0.0024 | < 0.002 | 0.0026 | 0.0026 |
| Nitrate-N | 0.0143 | 0.18 | 0.10 | -0.08 | 0.081 | 0.24 | 0.168 | -0.072 |
| DIN | 0.058 | 0.18 | 0.12 | -0.06 | 0.11 | 0.24 | 0.19 | -0.05 |
| DRP | 0.024 | 0.0066 | 0.016 | 0.0094 | 0.025 | 0.0075 | 0.0156 | 0.0081 |
| **Dissolved metals/ metalloids g m$^{-3}$** | | | | | | | | |
| Arsenic | < 0.0010 | < 0.0010 | < 0.0010 | None | < 0.0010 | < 0.0010 | < 0.0010 | None |
| Cadmium | < 0.00005 | < 0.00005 | < 0.00005 | None | < 0.00005 | < 0.00005 | < 0.00005 | None |
| Chromium | < 0.0005 | < 0.0005 | < 0.0005 | None | < 0.0005 | < 0.0005 | < 0.0005 | None |
| Copper | < 0.0005 | < 0.0005 | < 0.0010 | None | < 0.0010 | < 0.0005 | < 0.0005 | None |
| Lead | < 0.00010 | < 0.00010 | < 0.00010 | None | < 0.00010 | < 0.00010 | < 0.00010 | None |
| Nickel | < 0.0005 | < 0.0005 | < 0.0005 | None | < 0.0005 | < 0.0005 | < 0.0005 | None |
| Zinc | < 0.0010 | < 0.0010 | < 0.0010 | None | 0.0019 | < 0.0010 | < 0.0010 | None |

Note: Although the concentration of dissolved manganese is higher than total manganese, this is within the analytical variation.

**Table 11: Water quality of the discharge from K4 and in Waikanae River upstream and downstream of the discharge.**

| | 6 May | | | | 18 May | | | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Discharge** | **Upstream** | **Downstream** | **Increase** | **Discharge** | **Upstream** | **Downstream** | **Increase** |
| pH | 8.2 | 7.6 | 8.2 | 0.6 | 8.2 | 7.4 | 8.1 | 0.7 |
| Total Alkalinity | 142 | 20 | 210 | 190 | 194 | 17.4 | 96 | 79 |
| Bicarbonate | 170 | 24 | 250 | 226 | 230 | 21 | 115 | 94 |
| TSS | < 3 | < 3 | 14 | 14 | < 3 | < 3 | < 3 | None |
| Dissolved Calcium | 23 | 5.4 | 32 | 27 | 31 | 4.8 | 16.2 | 11.4 |
| Dissolved Magnesium | 8.4 | 2 | 11.5 | 9.5 | 10.3 | 1.7 | 5.9 | 4.24 |
| Hardness | 92 | 22 | 127 | 106 | 120 | 19 | 65 | 46 |
| Dissolved Iron | < 0.02 | < 0.02 | < 0.02 | None | < 0.02 | 0.033 | < 0.02 | None |
| Total Iron | 0.07 | 0.058 | 0.099 | 0.041 | 0.03 | 0.053 | 0.046 | -0.007 a |
| Dissolved Manganese | 0.013 | < 0.0005 | 0.017 | 0.017 | 0.0017 | < 0.0005 | 0.0033 | 0.0033 |
| Total Manganese | 0.014 | 0.0015 | 0.028 | 0.026 | 0.018 | 0.0016 | 0.0086 | 0.0070 |
| **Nutrients (g m$^{-3}$)** | | | | | | | | |
| Total $NH_4$-N | 0.029 | < 0.010 | 0.034 | 0.034 | 0.031 | < 0.010 | 0.017 | 0.017 |
| Nitrite-N | < 0.002 | < 0.002 | < 0.002 | None | 0.0024 | < 0.002 | 0.0026 | 0.0026 |
| Nitrate-N | 0.087 | 0.22 | 0.015 | -0.20 | 0.081 | 0.24 | 0.168 | -0.072 |
| DIN | 0.12 | 0.22 | 0.049 | -0.17 | 0.11 | 0.24 | 0.19 | -0.05 |
| DRP | 0.023 | 0.0078 | 0.028 | 0.020 | 0.025 | 0.0075 | 0.0156 | 0.0081 |
| **Dissolved metals/ metalloids (g m$^{-3}$)** | | | | | | | | |
| Arsenic | < 0.0010 | < 0.0010 | < 0.0010 | None | < 0.0010 | < 0.0010 | < 0.0010 | None |
| Cadmium | < 0.00005 | < 0.00005 | < 0.00005 | None | < 0.00005 | < 0.00005 | < 0.00005 | None |
| Chromium | < 0.0005 | < 0.0005 | < 0.0005 | None | < 0.0005 | < 0.0005 | < 0.0005 | None |
| Copper | < 0.0005 | < 0.0005 | < 0.0010 | None | < 0.0010 | < 0.0005 | < 0.0005 | None |
| Lead | < 0.00010 | < 0.00010 | < 0.00010 | None | < 0.00010 | < 0.00010 | < 0.00010 | None |
| Nickel | < 0.0005 | < 0.0005 | < 0.0005 | None | < 0.0005 | < 0.0005 | < 0.0005 | None |
| Zinc | < 0.0010 | < 0.0010 | < 0.0010 | None | 0.0019 | < 0.0010 | < 0.0010 | None |

**Figure 15** **Photograph of the dye test conducted on 22 April 2010 in the Waikanae River, showing the location of the downstream data sonde, clearly within the bore water plume.**

Conductivity upstream of the discharge was stable, changing little over time, though there was a slight diurnal fluctuation of approximately 2 $\mu S\ cm^{-1}$ from minima to maxima (Figure 16b). However conductivity downstream of the discharge increased dramatically, from approximately 100 $\mu S\ cm^{-1}$ prior to discharge to 340 $\mu S\ cm^{-1}$ at the start of the first pump test, slowly rising to 450 $\mu S\ cm^{-1}$ over the next 8 days. This slow increase was due to the river flow dropping and consequently the bore water proportion increasing in the river. The conductivity immediately decreased when the discharge ended, returning to pre-pump test levels. The slight dip in conductivity on the 14 April is associated with a high flow event (reaching up to 10000 $L\ s^{-1}$) on that day (see Figure 16a).

During the second pump test, the conductivity again dramatically increased, with measured values ranging between 300-350 $\mu S\ cm^{-1}$. Conductivity decreased almost to pre-pump test levels on the 25 April as the river flow increased to ~2800 $L\ s^{-1}$. During the third pump test the conductivity increased to 220-270 $\mu S\ cm^{-1}$ and was quite variable as river flows first dropped slowly ($6^{-1}4$ April) then rapidly rose with a small event on $14^{th}$ May.

The pH of the water upstream of the discharge varied somewhat, from around 6.7 at the start of monitoring to a low of 5.7 and a high of 7.3 (Figure 16c). The daily average ranged from 6.4 to 7.3. There were several large drops in pH of up to 1 pH unit that are not explained by river flow or the discharge. The pH also showed small daily fluctuations, most likely attributable to increased dissolved carbon dioxide due to respiration at night.

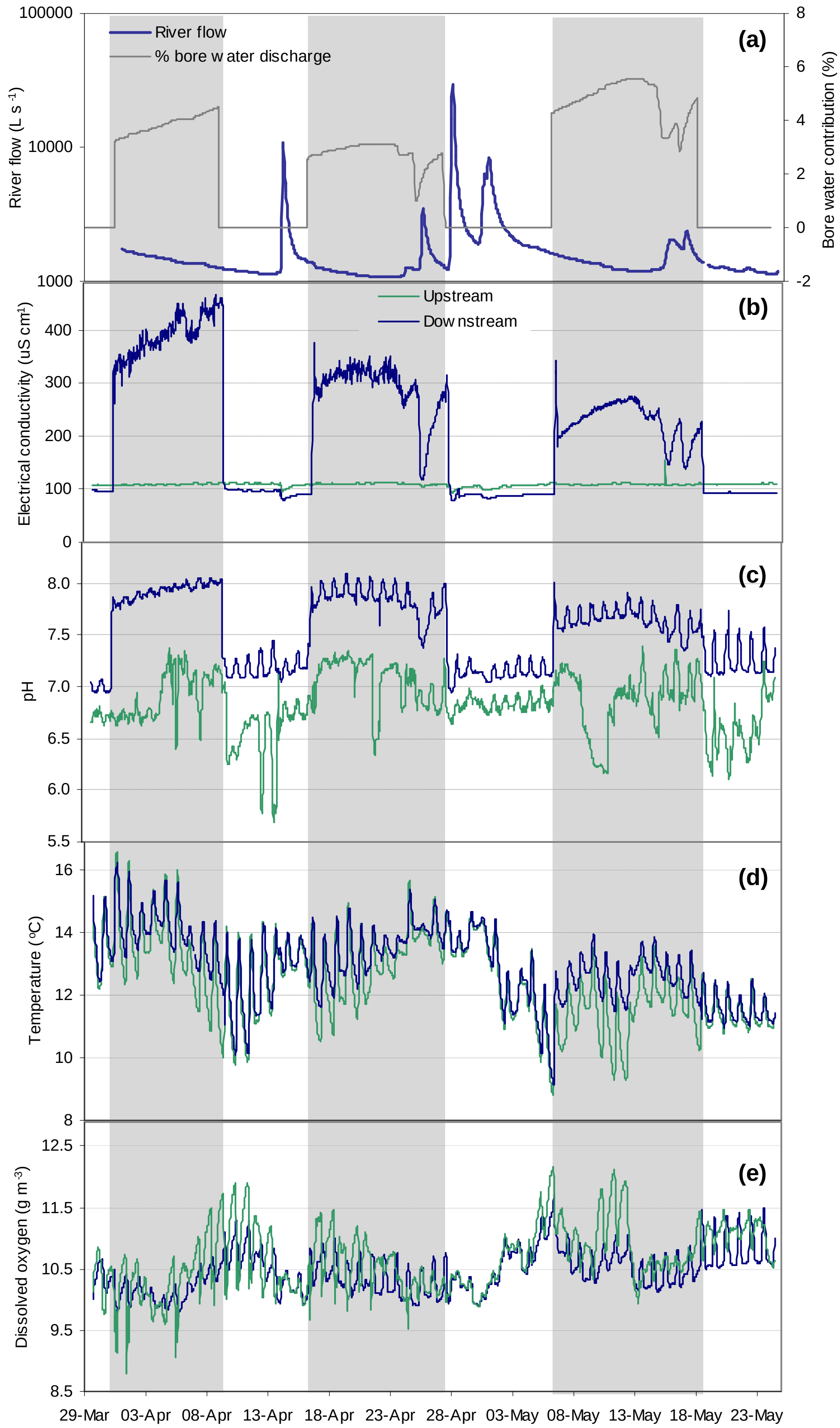


**Figure 16:** **River water flow, bore discharge, river water temperature, pH, conductivity and dissolved oxygen at sites above (green) and below (blue) the bore water discharge into the Waikanae River showing changes during the pump tests (grey shading). (Flow data kindly supplied by Wellington Regional Council)**

The water pH was slightly higher downstream than upstream when the bore water was not being discharged, with daily averages of 7.1 to 7.3. The pH was also more stable at this site. During the first pump test, pH increased to an average of 7.8 then slowly increased up to 8.0, reflecting the decrease in river flow and consequently the higher proportion of bore water. During the second pump test, pH increased a similar amount, averaging ~7.8 over the course of the test. A slightly lower increase was observed during the third pump test, with a daily average of 7.6. The proportion of bore water was highest during this pump test, and the lower pH must be due to lower pH of the bore water rather than flow. The river water pH rapidly returned to pre-pump test values when the bore water discharges ceased.

The influence of the discharge on water temperature (Figure 16d) was less dramatic than for conductivity and pH. Water temperature varied diurnally at both sites, with similar daily minima and maxima. Upstream, the water temperature varied slightly over the monitoring period, probably due to climatic variations. The discharge appears to have slightly increased the temperature downstream, with daily maxima slightly higher than that upstream (up to 0.5 ºC), particularly towards the end of the discharge period, and more obviously, higher daily minima values at the downstream site (up to 1 ºC).

Dissolved oxygen (DO) varied diurnally (Figure 16e), reflecting algal photosynthesis and respiration in the river. The daily fluctuations were greatest when flows were low and decreased after high flow events, potentially due to removal of high algal biomass during these events. There was less DO variability at the downstream site. This may reflect water aeration as it cascaded over the small weir below the water offtake point or less algae and macrophytes at the downstream site. The bore discharge did not appear to greatly alter DO dynamics below the discharge location. During the pump test, DO concentrations downstream averaged 10.3 g $m^{-3}$ compared to 10.6 g $m^{-3}$ in the absence of the discharge, however the average upstream was also lower during the pump tests (average of 10.6 g $m^{-3}$) than before and after (average of 10.8 g $m^{-3}$). DO appeared to be affected more by flow and water temperature than by the bore water discharges.

### 2.4.3. Effects of the bore water discharge

Water is currently abstracted from the Waikanae River to meet demand. The Wellington Regional Council has implemented a minimum flow of 750 $Ls^{-1}$ below the water treatment plant. Given an average current demand of 270 $Ls^{-1}$, this means that the KCDC can take water until flows reach 1020 $Ls^{-1}$ (i.e., 750 + 270), Option # 29 considers taking more water from the river when it flows below the current 1020 L $s^{-1}$, and augmenting the difference between the upstream flow and the take. Thus, if the river drops to only 750 $Ls^{-1}$, and the KCDC still wants to take 270 $Ls^{-1}$, then they will need to augment the river below the take with 270 $Ls^{-1}$ of bore water.

If this option goes ahead, water will be abstracted from the Waikanae River to meet demand, which is currently expected to reach 301 $Ls^{-1}$. However, a maximum demand of 370 L $s^{-1}$ is also anticipated under some scenarios (K. Mandeno, Beca, pers. comm., 4 May 2010). Consequently, up to 370 L $s^{-1}$ of bore water could be pumped into the river to ensure a minimum downstream flow of 750 L $s^{-1}$. Note, however, that if river flows above the take fall below 750 $Ls^{-1}$, and the KCDC is still taking the maximum of 370 $Ls^{-1}$, then they are only required to replace what they are taking, and not put in more than the flow is upstream. Thus flows in the river could be reduced to less than 750 $Ls^{-1}$.

The lowest recorded flow in the Waikanae River (~ 35 years) is 540 L $s^{-1}$, and the predicted 50 year low flow is 517 L $s^{-1}$ (K. Mandeno, Beca, pers. comm., 4 May 2010). If 370 L $s^{-1}$ was abstracted, and the river supplemented with bore water at the same rate, this would comprise 69% of the flow under the lowest recorded flow and 72% under the 50 year low flow conditions. However, these scenarios represent extreme low flow conditions which will not occur regularly.

The grab samples collected during the pump tests were collected within the mixing zone, where the river water was approximately 70% bore water and 30% upstream river water. This is similar to the worst-case prediction outlined above, and therefore the measurements made during those pump tests can be used to assess the likely effects of the bore water augmentation option under a worse case scenario. No grab samples were collected during the pump test from bore K6, and so downstream water quality has been predicted based on KCDC monitoring data for the bore and upstream river water quality from the monitoring described above (Table 12).

Under most conditions there will be greater dilution of the bore water with the river water. Table 13 presents predicted water quality downstream with a bore water discharge of 245 L $s^{-1}$ and a low flow of 666 L $s^{-1}$. These values are based on modelling by Beca (K. Mandeno, Beca, pers. comm., 4 May 2010).

As can be seen in Tables $10^{-1}3$, there can be substantial changes in the water chemistry downstream with bore water augmentation of the Waikanae River, with dramatic increases in conductivity, alkalinity, dissolved calcium and hardness; increases in pH, ammonium-N and DRP and decreases in nitrate-N. However, this may not constitute an adverse effect on water quality. The implications of these measured and predicted changes in water quality are discussed in the flowing sections.

**Table 12: Water chemistry of K6 and in Waikanae River upstream and predicted downstream of the discharge.**

| Parameter | Upstream | K6 discharge | Predicted Downstream | Predicted Increase |
|---|---|---|---|---|
| Total Alkalinity (as $CaCO_3$) | 17.4 | 270 | 198 | 181 |
| Bicarbonate | 21 | 328 | 241 | 220 |
| TSS | 1.5 | Unknown [a] | Unknown [a] | Unknown [a] |
| Dissolved Calcium | 4.8 | 40 | 30 | 25 |
| Dissolved Magnesium | 1.7 | 16 | 12 | 10 |
| Hardness (as $CaCO_3$) | 19.0 | 163 | 122 | 103 |
| Dissolved Iron | 0.01 | 0.01 | 0.01 | None |
| Total Iron | 0.010 | 2.5 | 1.8 | 1.8 |
| Dissolved Manganese | 0.00025 | 0.085 | 0.061 | 0.061 |
| Total Manganese | 0.00071 | 0.13 | 0.093 | 0.093 |
| Zinc | <0.001 | <0.001 | <0.001 | None |
| **Nutrients g $m^{-3}$** | | | | |
| Total NH4-N | 0.005 | 0.34 | 0.25 | 0.24 |
| Nitrite-N | 0.001 | 0.001 | 0.001 | None |
| Nitrate-N | 0.18 | 0.001 | 0.052 | -0.13 [b] |
| DIN | 0.19 | 0.34 | 0.30 | 0.11 |
| DRP | 0.0066 | Unknown [a] | Unknown [a] | Unknown [a] |

**Table 13: Predicted water chemistry downstream of the discharge from K6, K4 and Kb4 after complete mixing under conditions of low flow (666 L $s^{-1}$) and moderate bore water discharge (245 L $s^{-1}$).**

| Parameter | D/S of K6 | D/S of Kb4 | D/S of K4 | Upstream | Maximum increase |
|---|---|---|---|---|---|
| Total Alkalinity (as $CaCO_3$) | 112 | 79 | 57 | 20 | 92 |
| Bicarbonate | 136 | 96 | 68 | 25 | 111 |
| TSS | 0.9 | 1.7 | 0.9 | 1.5 | 0.2 |
| Dissolved Calcium | 18 | 20 | 10 | 5.4 | 15 |
| Dissolved Magnesium | 7.0 | 7.1 | 3.5 | 2.0 | 5.1 |
| Hardness (as $CaCO_3$) | 74 | 78 | 39 | 22 | 56 |
| Dissolved Iron | 0.025 | 0.040 | 0.015 | 0.033 | 0.007 |
| Total Iron | 0.96 | 1.0 | 0.45 | 0.058 | 0.99 |
| Dissolved Manganese | 0.032 | 0.059 | 0.070 | 0.00055 | 0.069 |
| Total Manganese | 0.049 | 0.078 | 0.070 | 0.0016 | 0.076 |
| Zinc | 0.0005 | 0.0008 | 0.0003 | 0.0005 | 0.0003 |
| **Nutrients** | | | | | |
| Total NH4-N | 0.13 | 0.031 | 0.012 | 0.005 | 0.12 |
| Nitrite-N | 0.001 | 0.001 | 0.001 | 0.001 | 0.000 |
| Nitrate-N | 0.15 | 0.083 | 0.085 | 0.24 | -0.088 [b] |
| DIN | 0.28 | 0.11 | 0.10 | 0.25 | 0.035 |
| DRP | Unknown [a] | 0.011 | 0.036 | 0.0078 | 0.028 |

Note: [a] No data available for bore water quality. [b] Negative value indicates concentrations are lower downstream than upstream.

## pH, alkalinity and hardness

As mentioned, the most obvious effects of the bore water discharge (from all bores) are the increases in conductivity (as measured with the sonde), pH, alkalinity, dissolved calcium, dissolved magnesium and hardness.

The pH of the river increased by 0.4-0.7 pH units during the pump tests reaching average daily pH values of 7.9, 7.8 and 7.6 for bores K6, Kb4 and K4 respectively. There were also daily fluctuations of approximately 0.2 units. Water pH reached 8.1-8.2 and this may occur under worst-case low flow conditions. This value slightly exceeds the upper limit of 7.8 for pH of a lowland river (suggested by ANZECC 2000). These guidelines are trigger values; however, and are based on average New Zealand rivers. They do not imply toxicity or adverse effects will occur with exceedance of the value. Moreover, the ANZEEC guidelines caution against using pH as trigger values due to diurnal and seasonal variation. The maximum pH remains within water quality guidelines based on toxicity of 6.5-9 (USEPA 2009).

Calcium is an important trace element for fish and invertebrates, and as such increases in calcium can be considered to be favourable. Increases in calcium also reduce the bioavailability and toxicity of toxic trace metals such as lead, suggesting a further potential benefit from the bore water discharge. While these metals were not even at detectable levels in the Waikanae River at the monitoring locations, they may potentially be at higher concentrations downstream, as the river will receive stormwater from areas of urban development, which is likely to contain elevated metals such as copper and zinc. Increases in calcium, magnesium and hardness as a result of the bore discharge may thus confer a beneficial effect downstream, though this overall effect is likely to be only minor at best.

Overall, the bore water augmentation option will result in changes to the water chemistry of the Waikanae River to something that more closely resembles groundwater. Figure 17 shows cumulative frequency curves for the water chemistry of 96 New Zealand rivers and the New Zealand median values (Close & Davies-Colley, 1990). The Waikanae River has lower than average calcium, bicarbonate and pH. Downstream of the bore water discharge, the river will have higher than average calcium, bicarbonate and pH. Note the wide range in values of the downstream water chemistry (Figure 17) due to different mixing ratios and type of bore water used. The predicted values downstream are within the natural range measured in New Zealand rivers.

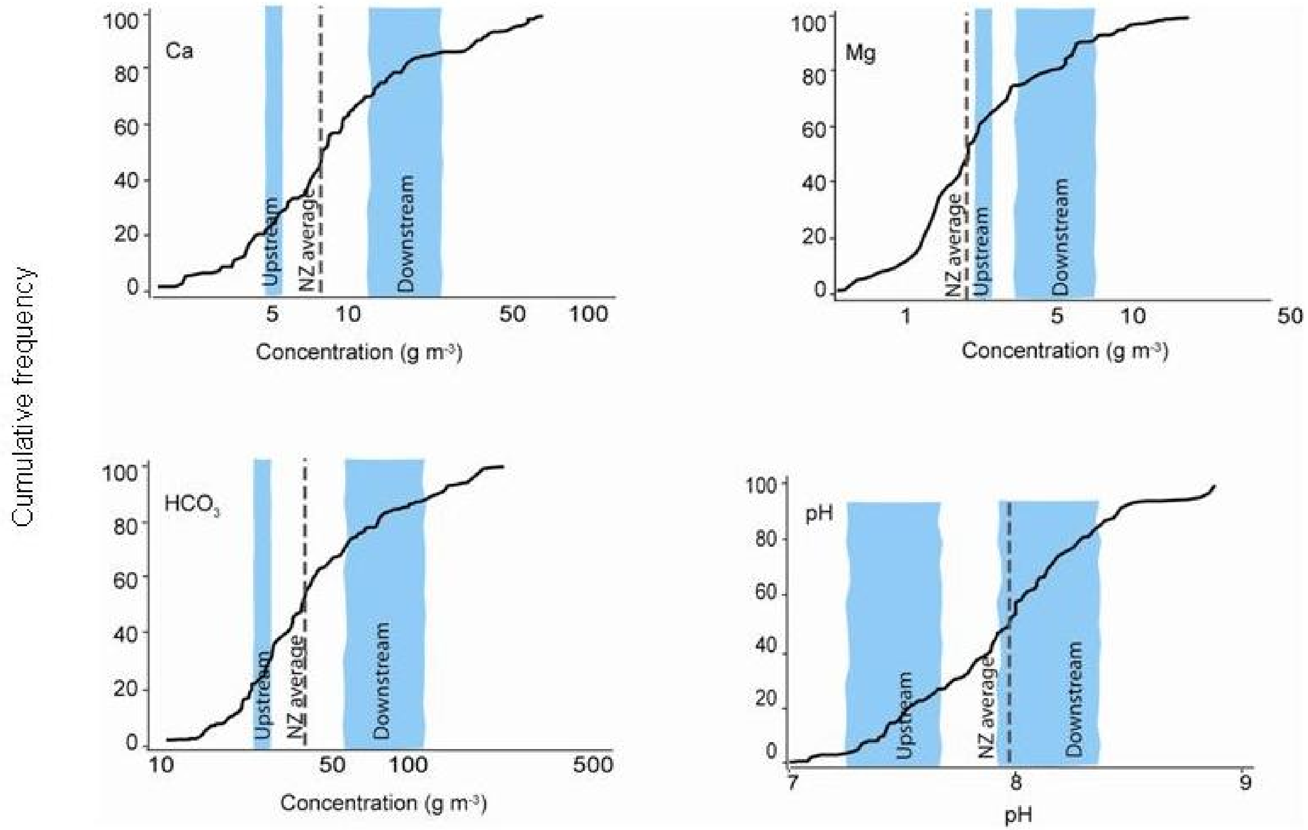


**Figure 17: Selected water chemistry parameters in Waikanae River upstream and downstream of the bore water discharge (blue bars) compared with cumulative frequency curves for New Zealand rivers (Close & Davies-Colley, 1990). Bars for Waikanae River are wide due to differences in water chemistry between bores, and under different flow regimes. Dotted line shows NZ average values.**

### Toxic contaminants

The monitoring data showed that trace metal concentrations were low in the bore water and subsequently downstream. Table 14 shows that the maximum concentrations detected in the bore water and downstream in the Waikanae River were below trigger values to protect aquatic ecosystems.

No trigger value is provided by ANZECC (2000) for iron, however a guideline of 1 g $m^{-3}$ is suggested by USEPA (1976) and the Ministry of the Environment, British Columbia (Phippen 2008) for total iron, while for dissolved iron the lower limit of 0.35 g $m^{-3}$ is recommended by Phippen (2008). The maximum total iron concentration measured in the discharge was 0.07 g $m^{-3}$, while 0.09 g $m^{-3}$ was measured downstream, with both values well below the guidelines of 1 g $m^{-3}$. Dissolved iron was not detected in the discharge or downstream during monitoring above a detection limit of 0.02 g $m^{-3}$, which is well below the guideline for dissolved iron (Phippen 2008). The maximum dissolved iron concentration measured in the bores was 0.09 g $m^{-3}$ in Kb4, which remains well below the guideline of 1 g $m^{-3}$.

**Table 14: Trigger values for toxicants for protection of aquatic ecosystems compared to river water quality.**

| Parameter | ANZECC guideline: Protection of 99% of species | ANZECC guideline: Protection of 95% of species | Maximum measured in discharge | Maximum measured or predicted downstream |
|---|---|---|---|---|
| Arsenic | 0.0008 | 0.013 | < 0.0010 | < 0.0010 |
| Cadmium [a] | 0.00016 | 0.0005 | < 0.00005 | < 0.00005 |
| Chromium | 0.0001 | 0.001 | < 0.0005 | < 0.0005 |
| Copper [a] | 0.0025 | 0.0035 | < 0.0005 | < 0.0005 |
| Lead [a] | 0.004 | 0.014 | < 0.00010 | < 0.00010 |
| Manganese | 1.2 | 1.9 | 0.19 | 0.078 |
| Nickel [a] | 0.020 | 0.028 | < 0.0005 | < 0.0005 |
| Zinc [a] | 0.006 | 0.020 | 0.002 | < 0.0010 |
| Ammoniacal-N | 0.32 | 0.90 | 0.34 | 0.25 |

Note: [a] Hardness dependent trigger value, trigger value used is for waters of moderate hardness ($60^{-1}19$ g $m^{-3}$ as $CaCO_3$).

For arsenic and chromium, the more stringent guideline (to protect 99% of species) was slightly lower than the detection limit used for these analyses. There is a chance that the arsenic and chromium may be found in the discharge at concentrations slightly above the trigger value for 99% protection, but still below the detection limit. However, once mixed with the Waikanae River water, the downstream concentrations would easily be below trigger values.

Ammoniacal-N is toxic to aquatic biota at elevated concentrations, with trigger values of 0.32 g $m^{-3}$ for protecting aquatic ecosystems (ANZECC 2000). Ammoniacal-N was at elevated concentrations in bore K6, measuring a maximum of 0.34 g $m^{-3}$ when measured by KCDC. Under worst-case conditions of maximum bore water from K6 and minimum flows (river comprising 72% bore water) and with the maximum ammoniacal-N concentration measured, the downstream river concentrations of ammoniacal-N would be 0.25 g $m^{-3}$, below the lowest trigger value for protecting even the most sensitive species (99% protection). The other bores had substantially lower ammoniacal-N concentrations, with a maximum of 0.08 g $m^{-3}$ measured from Kb4, well below the 99% trigger level.

In summary, this data shows that there is very low likelihood of adverse effects on the Waikanae River from toxic metals or ammoniacal-N.

**Plant nutrients**

The pump test data shows that the bore water has elevated concentrations of ammoniacal-N, nitrite-N and dissolved reactive phosphorus compared to the Waikanae River water. These species of nitrogen and phosphorus are readily bioavailable to plants as nutrients, along with nitrate-N. Under conditions of low flow and high sunlight, increases in nutrients can result in increases in plant growth, potentially to undesirable levels.

The New Zealand periphyton guidelines (Biggs 2000) provide maximum nutrient concentrations to prevent undesirable periphyton growth. Maximum concentrations provided for dissolved inorganic nitrogen and dissolved reactive phosphorus (referred to as soluble inorganic nitrogen (SIN) and soluble reactive phosphorus (SRP) respectively in the guidelines) are reproduced in Table 15. Because periphyton is often washed away during high river flows, guidelines are provided for different accrual periods (accrual periods are the length of time between flood events exceeding 3x the annual median flow (FRE3)).

Accrual periods in the Waikanae River can exceed 100 days during summer low flow periods, which are when the bore water would be discharged to supplement flows. DIN concentrations in the Waikanae River were elevated upstream of the bore water discharge, measuring 0.18-0.24 g $m^{-3}$, well above guidelines for all but the shortest accrual period. DRP concentrations upstream were between 0.0066-0.0078 g $m^{-3}$, also exceeding all guidelines except for the 20 day accrual period. This suggests that excessive growths of periphyton may occur in the absence of the bore water discharge, under conditions of low flows. Observations during the site visit suggest that diatom biomass at this site was high, possibly partially in response to the elevated DIN and DRP causing excess growth.

The bore water discharge approximately doubles the DRP concentration within the mixing zone, with concentrations of 0.016-0.028 g $m^{-3}$ measured, at times exceeding the guideline for a 20 day accrual period. This may result in increased and potentially excessive periphyton growth within the mixing zone. In the absence of more detailed assays of algal growth to see whether it is indeed nutrient limited, it is hard to really quantify the effect of increased DRP concentrations to algal biomass. However, the mixing zone covers only a relatively small proportion of the channel (see Figure 14), and is unlikely to result in any high algal blooms in the remainder of the river outside the mixing zone. Localised increases in algal biomass are consequently not considered to be a major issue.

The bore water discharge decreased DIN by 0.05-0.17 g $m^{-3}$ within the mixing zone, however DIN remained at levels that exceeded the guidelines. The reduction in DIN is unlikely to limit periphyton growth within the mixing zone.

Under the worst case scenario of 370 L $s^{-1}$ of bore water entering the river at a 50 year low flow state, the bore water would constitute 72% of flow below the discharge. Under such conditions, once the bore water is fully mixed with the Waikanae River water, the maximum DRP concentration would be 0.068 g $m^{-3}$ based on a discharge from bore K4, which has the highest DRP concentration (0.092 g $m^{-3}$). A less conservative scenario was 245 L $s^{-1}$ entering the river of 666 L $s^{-1}$, which would result in DRP concentrations of 0.036 g $m^{-3}$. Under the same flow conditions, the DIN concentration could increase from 0.25 g $m^{-3}$ upstream to 0.31 g $m^{-3}$ downstream, if the discharge was from bore K6, which has the highest DIN concentrations (up to 0.34 g $m^{-3}$). Under the less conservative scenario, the maximum DIN could be 0.28 g $m^{-3}$ based on the same bore. These increases suggest potential for increased periphyton growth downstream of the discharge when there are low flow events. They are however very conservative estimates, based on the highest concentrations measured in the bore water.

**Table 15: Guideline values for nutrients to prevent excessive growth of periphyton (Biggs 2000).**

| | For AFDM = 35, Chlorophyll *a* = 200 | |
|---|---|---|
| Days of accrual | DIN (g $m^{-3}$) | DRP (g $m^{-3}$) |
| 20 | < 0.295 | < 0.026 |
| 30 | < 0.075 | < 0.006 |
| 40 | < 0.034 | < 0.0028 |
| 50 | < 0.019 | < 0.0017 |
| 75 | < 0.010 | < 0.001 |
| 100 | < 0.010 | < 0.001 |

### 2.4.4. Changes to hydrology

The hydrological effects of augmenting river water with bore water during times of low flow are summarised in Table 16.

**Table 16: Hydrological statistics for the unmodified flows at the Water Treatment hydrological site and for bore water augmentation option.**

| Waikanae at Water treatment ($m^3 s^{-1}$) | 1976-2009 | Current take | Bore option |
|---|---|---|---|
| Maximum flood | 381 | 381 | 381 |
| Mean annual flood | 155 | 155 | 155 |
| 5% exceedance | 13.6 | 13.4 | 13.4 |
| 25% exceedance | 5.12 | 4.86 | 4.86 |
| Mean flow | 4.79 | 4.53 | 4.53 |
| Median flow | 2.97 | 2.71 | 2.71 |
| 75 % exceedance | 1.79 | 1.52 | 1.52 |
| 95% exceedance | 1.02 | 0.754 | 0.754 |
| 7 day MALF | 0.923 | 0.785 | 0.750 |
| MALF | 0.928 | 0.792 | 0.792 |
| Minimum flow | 0.539 | 0.539 | 0.539 |
| FRE3 | 11.3 | 11.8 | 11.8 |

As can be seen, there would be no difference in the low flow hydrological statistics of the residual flows downstream of the take and below the bore water discharge point. Furthermore, the maximum take (301 L $s^{-1}$) is such a small proportion of the flow that there is no difference in the high flow statistics. The differences in FRE3 between the unmodified flow and that which is now occurring is unlikely to be ecologically significant. The flow distribution curve (Figure 18) shows the similarity of flow between that which is now observed, and that which would occur with this option. The flow duration curve shows that the bore recharge option results in a slight flat lining of the river for 5% of the time at ~750 L $s^{-1}$. Flat lining for this duration is not a concern.

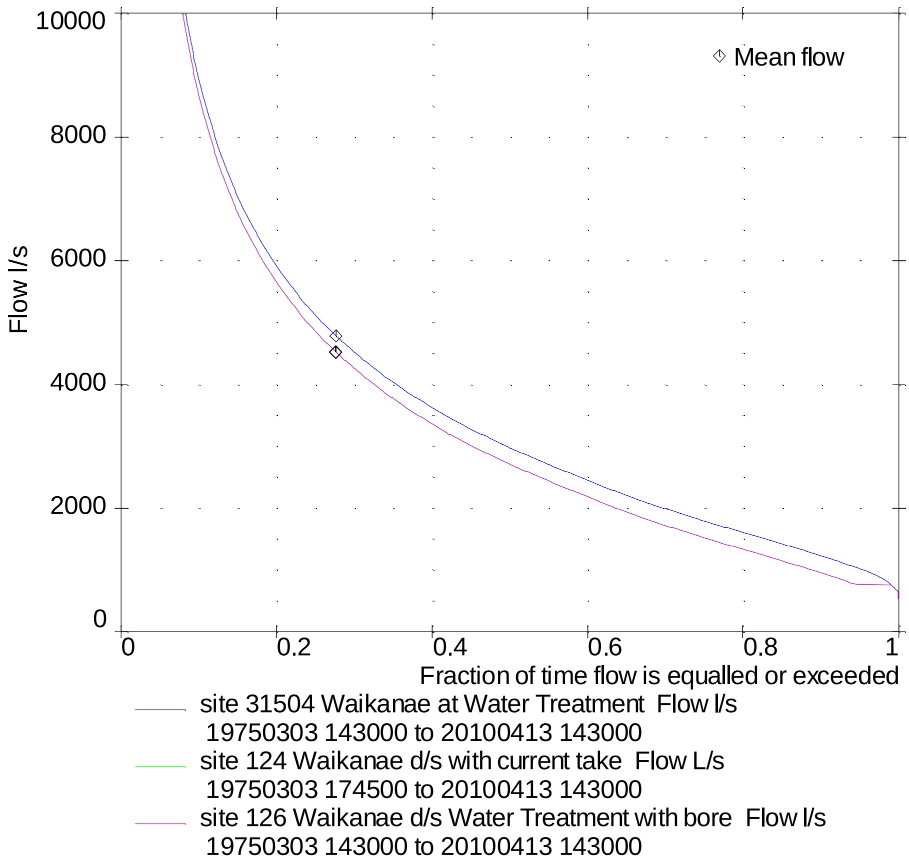


**Figure 18: Flow distribution curves for the unmodified flow in the Waikanae River, and the flows downstream of the take with the bore water river recharge option. Note the over plotting of the flows from the Waikanae River downstream of the current take and those from the proposed bore water river recharge option.**

### 2.4.5. Ecological implications

Based on these results, and on the relatively small size of the mixing zone as bore water became diluted with river water, it is unlikely that the groundwater recharge option will have any adverse ecological effects on fish and invertebrates. This contention was able to be tested to a limited extent by the invertebrate sampling conducted in the Waikanae River on April 21st, mid way through the second bore test. Here, we collected invertebrates at a site in an area 50 – 100 m below the bore outflow, well within the discharge plume. We also collected invertebrates at sites above the water treatment plant for comparison. We found no difference in any of the calculated biotic metrics (EPT, % EPT, MIC or QMCI), or in the DCA ordination scores at sites within the bore plume or at the upstream sites (Figure 19). This suggests that even within the plume, and before complete mixing has occurred, invertebrate communities were not responding in a demonstrable way to the discharge of bore water - at least in the short term (days to weeks). We also found no major differences in the fish communities at sites above and below the bore discharge point (see Table 6).

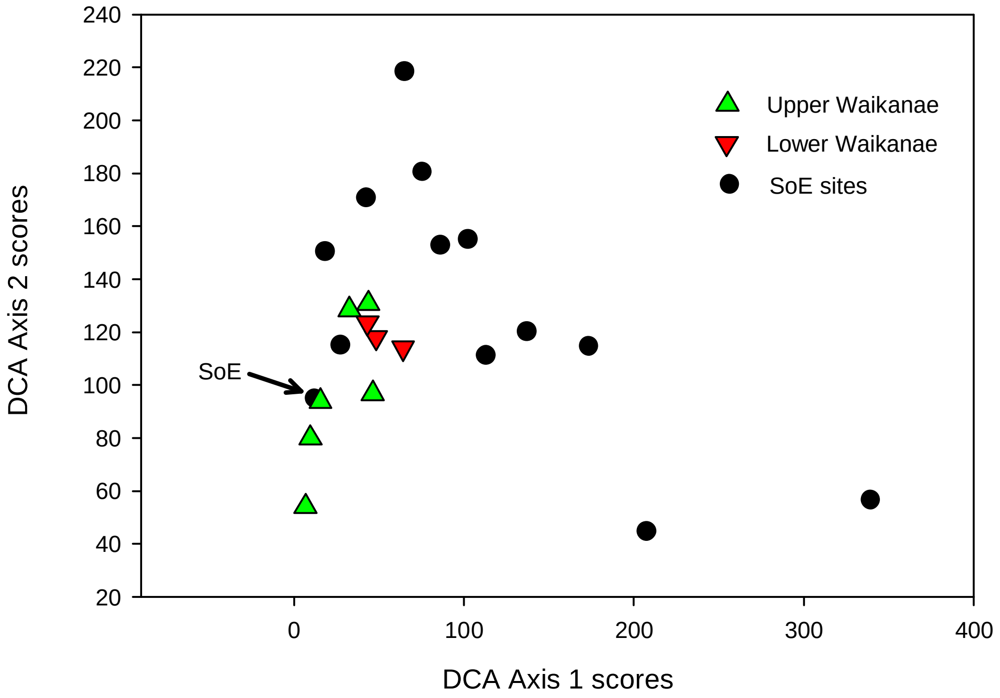


**Figure 19:** **Graphical representation of invertebrate communities found in samples collected from the upper and lower Waikanae River (triangles) and those collected by the Wellington Regional Council as part of their state of environment surveys. Note the similarity between samples collected below the bore discharge in the Waikanae Rifer (red symbols) and those collected above (green symbols).**

However, our water quality modelling work has indicated that there may be some potential for increases in periphyton biomass as a result of increases in nutrients (mainly DRP) arising from the discharge. Whether such increases would lead to demonstrable increases in algal biomass below the discharge point is unknown, as we do not know whether the algal communities in the river are nutrient limited (and in particular phosphorus limited). This can be determined best by nutrient diffusing assays.

### 2.4.6. Summary of effects of Option # 29 Bore water discharge

#### Overview of evaluations

Augmenting flows below the water treatment plant with bore water would allow extraction of more river water than present. The main issue for this option includes changes to the water chemistry of the Waikanae River from the bore discharge, and potential effects of these changes on the river's ecology. Data sondes (recording water temperature, pH, dissolved oxygen and conductivity) were deployed at two sites: one above the water treatment plant, and one below the discharge of bore water. Water samples were collected during bore water discharge tests from upstream and below the outflow of the bore. A dye test (using Rhodamine (WT)) was also conducted to document the flow and dilution dynamics of the bore water discharge.

**Key Issues encountered**

1. The dye plume became more diluted as it moved downstream, and complete mixing was observed after 100 m. Dye concentration here was only 1% of that at the discharge point.

2. Modelling showed that bore water augmentation to the Waikanae River would increase conductivity, alkalinity, dissolved calcium and hardness, pH, ammonium-N and DRP. Concentrations of the latter approximately doubled within the mixing zone.

3. Increased DRP concentrations, when combined with stable low flows may result in undesirable periphyton growth in the mixing zone.

**Mitigation**

1. The mixing zone covers only a relatively small proportion of the channel, and so it is unlikely that high algal blooms would occur in the remainder of the river outside the mixing zone. Localised increases in algal biomass are not considered to be a major issue.

2. Modification of the existing bore outlet structure to allow for discharge of bore water across the entire channel will maximise dilution, and further minimise the size of the mixing zone, and area of possible undesirable algal growth.

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