

# **The assimilation and dilution of dairy shed effluent pond discharges in Taranaki**

A study and discussion of  
in-stream environmental effects  
below a treatment pond system discharge

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## Executive summary

In October 2006 the Taranaki Regional Council released a report on the characteristics of dairy shed oxidation pond discharges in Taranaki (*Dairy shed oxidation pond discharges in Taranaki: a study and discussion of oxidation pond performance, management and environmental effects*, Taranaki Regional Council, October 2006). The Taranaki Regional Council's *Regional Freshwater Plan for Taranaki* specifies that if ponds satisfy certain criteria relating to pond sizing and dilution capacity in receiving waters (amongst other matters), then an application for a resource consent allowing discharge from those ponds may be assessed as a 'controlled' activity- that is, the consent must be granted by the Council (while the Council may still impose conditions upon the nature of the pond's operation and the level of environmental performance required). Given that by definition the Council has no option but to allow a 'controlled' activity to proceed, the purpose of the study was primarily to relate actual performance against conformance with the Council's criteria, to determine whether the criteria providing for this category of activity give adequate protection against unacceptable adverse environmental effects.

The results demonstrated that a pond system designed and sized generally in accordance with the Council criteria, and consistently achieving a dilution ratio of 100:1 or greater, is unlikely to result in effects on the environment that are more than negligible, in either duration or degree of severity.

Effects on in-stream biological quality reflected the variations between pond systems in terms of their design and operation, and in dilution ratios. Biological effects ranged from undetectable to significant in nature. Some data indicated that causes other than the degree of biological treatment were having an effect e.g. the presence of elevated copper in the discharge. It was also noted that other factors, such as shading from riparian vegetation, appear to influence the potential effects. Where downstream riparian vegetation is good, effects from a dairy pond discharge on macroinvertebrates and other indicators of in-stream ecology can be attenuated. Significant recovery from effects, where they were shown, was noted to occur generally within 150 metres.

However, the potential for cumulative effects of multiple discharges entering any particular water body is noted. This was not a component of the study reported in 2006.

Accordingly, a consequent study was designed and commissioned, to look more closely at the rate of assimilation and/or dilution of a discharge, in order to ascertain whether criteria can be developed for managing cumulative effects i.e. controlling the number and effects of multiple discharges in close proximity into the same receiving environment.

The study was focused on a pond discharge located south-east of Mt Taranaki, that is the highest point source discharge within its particular catchment. The Tuikonga Stream arises within farmland on the lower slopes of the mountain, and is fed by ground seepage.

The significant findings of this study are as follows:-

Under the Council's *Regional Freshwater Plan for Taranaki*, the dilution required for a dairy discharge to be assessed as a 'controlled' activity is 1:100 at all times. At this site, the dilution prevailing for the bio-monitoring investigation conducted ahead of the physico-chemical sampling programme was 1:360, with the stream receiving a relatively high-strength waste

(representative of an under-sized rather than correctly sized pond system) due to the presence within the pond of a large volume of accumulated sludge that reduced its effective volume. Under these circumstances, a high quality in-stream ecosystem was found present at the first downstream site, 120 metres below the discharge point. The in-stream dilution during the first sampling run for physico-chemical analysis was approximately 1:200. The flow from the pond was prolonged for several hours on this discharge occasion. When the discharge pipe was subsequently cleared, the dilution rate fell to 1:30-1:40 at peak flow rates, lasting a couple of hours- which would not have been open for consideration as a 'controlled' activity, even though the daily mass discharge of contaminants under the two regimes (and therefore presumably the in-stream effects) would be identical.

It can be noted that a 24-hour discharge at a dilution of 1:360 provides the same daily mass discharge as two 2-hour discharges at a dilution of 1:60.

The implication is that a short duration high strength dairy pond discharge of low dilution will have only a negligible effect beyond the standard mixing zone. However, this hypothesis was not tested further, and a 'controlled' activity provision requires a high degree of certainty and robustness. Thus, the current Plan's provision of 1:100 'at all times' for a controlled activity may appear conservative but is considered appropriate in the level of protection it affords. The Plan's criterion of 1:100 should be applied as a 24-hour average rather than an instantaneous limit applicable at times of peak discharge.

The biological survey showed that the stretch of stream studied, located close to the head waters of a lowland stream, was of very high ecological quality under preceding conditions of high wastes dilution. This is of significance when considering the value of first-order streams. The effects of riparian vegetation were especially apparent at some of the sites, confirming the valuable contribution of riparian vegetation to enhancing in-stream ecosystems.

Typically, MCI values in ringplain streams decline with increasing distance from their source, due to diffuse and point source discharges and changes in stream morphology and riparian shading. For a stream of the sort in this study, a typical rate of decline is considered to be 1 to 2 MCI units per kilometre (*pers comm* C Fowles). For the stream in question, there was actually an increase from Site 1 to Site 5 (MCI 102 increasing to 105), with significantly higher values at the site with the greatest degree of riparian shade, when a decline of 1.5-3 MCI units would have been expected given the distance between Sites 1 and 5. With marginal (insignificant) declines between Sites 1 and 5 in a couple of water quality parameters, and others consistent between the two sites, other environmental factors such as riparian planting must be playing a role in the improvement in ecological condition observed below the discharge.

In determining the in-stream removal of contaminants such as nutrients, it was assumed in this study that the strength of the discharge measured within the pond was unchanged as it flowed down the bank to the stream. It is more than likely that a measure of attenuation actually occurred within this zone when the flow from the pond was constricted. However, once the blockage was cleared (February), the flow was rapid and any attenuation from overland flow would be comparatively minor. Given that the strength of the pond effluent was higher than typical for a pond system sized according to the Council's criteria for a 'controlled' activity, it is considered that the findings of this study still have a wider relevance.

It was also assumed that all changes in chloride and conductivity in the stream below the discharge point (which were used for calculating dilution rates) were due to the overland flow from the pond. The question arises as to whether part of the increase was due to seepage from infiltration. Such a flow would typically be of lower strength than a direct flow, and thus initial in-stream concentrations of contaminants would have been lower than calculated. However, examination of the changes in chloride concentration in March (when there was no discharge) show that in-stream chloride changes were trivial (12.7 gm<sup>-3</sup> above the discharge zone, 12.8-13.1 gm<sup>-3</sup> below the discharge zone) compared with the period of pond discharge (February: 12.4 gm<sup>-3</sup> above, 16.5 gm<sup>-3</sup> below), so any confounding contribution from seepage was negligible.

The study found that the removal of ammonia (including the mechanism of transformation to nitrate) occurs at a very significant rate (43-95%) within 120 metres of the discharge point, even under conditions of very low dilution (high in-stream concentration). The removal of nitrate proceeded at a lower rate, with continuing removal of nitrate evident between Site 2b (120 metres below discharge) and Site 4 (450 metres below discharge), and further removal between Site 4 and Site 5 (1.55 kilometres below the discharge point). At Site 5, nitrate levels were the same as at the upstream site, Site 1, during periods of discharge (i.e. the nitrate was fully assimilated by this point), and after discharge ceased, nitrate levels at Site 5 were lower than at Site 1.

High nitrate levels were found throughout the stream in April, after the pond discharge had long since ceased, following a prolonged period of heavy rain. It appears this nitrate was driven by high groundwater tables. This is consistent with other Council data that shows high nitrate concentrations to be a wet weather/winter event in Taranaki, rather than a summer issue when the potential for the proliferation of undesirable aquatic growths is at its highest.

It was found that the removal of biochemical oxygen demand (a measure of the organic content) occurs at a very significant rate (33-77%) within 120 metres of the discharge point, even under conditions of very low dilution (high in-stream concentration). Even given that the discharge was higher than typical in BOD, at this downstream site all results except one met the Council's criterion for the permitted effects of a 'controlled' activity on in-stream BOD. Further reductions, to return to background concentrations, occurred by Site 4. That is, by 450 metres below the discharge point the BOD from the pond discharge was fully assimilated.

Because of high variability in indicators of bacteriological contamination such as counts of faecal coliforms, caution needs to be applied to the interpretation of the study's data. However, at the first downstream site (120 metres), faecal coliform removal was found to be between 0 and 100%- the lowest removal rate apparently being at the lowest dilution rate and in the morning, and high removal rates at greater dilution and in the afternoon. On most occasions while discharge was occurring, the counts of faecal coliforms were lower at the downstream site than the upstream site.

It was found that the removal of reactive dissolved phosphorus (a nutrient that can cause undesirable growths in higher concentrations) occurs at a very significant rate (84-100%) within 120 metres of the discharge point, even under conditions of very low dilution (high in-stream concentration). It was also found that even upstream of the discharge point DRP and TP always exceeded the ANZECC guideline for the maximum DRP and TP to avoid undesirable growths, yet the ecological quality of the stream's ecosystems was found to be

very high. The rate of removal of total phosphorus was lower than for DRP; this is not surprising given that a proportion of TP is present in insoluble form, and is therefore less readily available. At 120 metres, removal of TP lay in the range 19-69%; at Site 4 a further 20% was generally removed during the period when discharge was still continuing. Further reduction of TP and DRP occurred through to Site 5, 1.55 kilometres below the discharge point. Once discharge ceased, sites 4 and 5 were very similar to the upstream site i.e. levels of TP and DRP were stable throughout the stream, suggesting that these concentrations were residual levels (even though above ANZECC guidelines).

Overall, there was effective attenuation within 120 metres for ammonia and DRP, and within 450 metres for BOD and faecal coliforms, and within 1.55 kilometres for TP and nitrate.

While both nitrate and phosphorus concentrations exceeded the ANZECC guidelines for avoidance of adverse effects upon aquatic ecosystems at both upstream and downstream sites throughout the study, ecological monitoring showed that in fact the stream is of high value, even within 120 metres but more so further downstream and within areas of riparian screening.

A comparison of daily mass loadings of various contaminants from the pond system with those present in the stream during a heavy rainfall event, found that while the pond system contributed a larger daily ammonia loading than was flowing down the stream during the rainfall event, the total nitrogen loading during the rainfall event in question was well over 30 times greater than that originating from the pond system. In other words, a single rainfall event can cause as much nitrogen loading on a stream, as a month of discharge from a treatment pond. The highest in-stream nitrate concentration occurred in the absence of any pond discharge.

The loadings of total phosphorus and dissolved phosphorus due to the rainfall event were both higher than occur due to a pond discharge, but in this case the difference was only 60%. The organic loading due to the rainfall event was again much higher than occur due to the pond discharge. In this case the difference was 8 times greater. In other words, a single rainfall event can cause as much organic loading on a stream, as more than a week of discharges from a treatment pond. Undue significance should not be placed on these figures (they are site- and event-specific, and do not consider the likely consequences for aquatic ecology), but assist in illuminating the range of considerations that must be applied in aquatic resource management.

Given that streams in Taranaki tend to be phosphate-limited, this study suggests that for avoidance of cumulative effects, specific consideration should be given to the possible consequences of multiple treatment pond discharges if they are located within 120 to 450 metres of each other.

The Taranaki Regional Council wishes to express its appreciation to the farmers who allowed Council staff access to the site throughout the season, and without whose co-operation this study would not have been possible.

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# **1. Introduction**

Staff of the Taranaki Regional Council ('the Council') undertook field investigations and chemical, biological, and hydrological monitoring of a dairy shed effluent discharge and the receiving stream environment during summer 2008 as part of on-going research into the environmental significance and the appropriate management of such discharges. This report describes the findings of that study. The general location of the farm dairy pond system evaluated within this project is shown in Figure 1, together with a stylised description of the stream's features. Confidentiality applies to the particular farm.

## **1.1 Purpose of study**

This study was undertaken to provide a greater understanding of, and to determine the appropriateness or otherwise of, the Council's management of dairy effluent pond discharges, to ensure an adequate level of environmental protection. While the Council provides recommended pond construction and operational criteria in its Regional Freshwater Plan for Taranaki (RFP), and for in-stream dilution and maximum concentration requirements within an initial stipulated mixing zone, the Plan does not directly take into account attenuation or the potential for multiple discharges to have a cumulative effect.

From the Council's 'state of the environment' monitoring work, it is recognised that some water quality parameters increase in concentrations downstream, while others tend to remain consistent; for those that increase it is not always clear whether the increase is driven by local point sources, the cumulative effects of multiple point sources, diffuse sources, or groundwater inflows, or some permutation of all four effects.

This study is intended to provide data that informs considerations around this question.

## **1.2 Structure of this report**

Section 1 of the report sets out the background to the study. Section 2 describes the results of the study of the hydrology of the stream and the discharge, and Section 3 the biological state of the stream. The physicochemical results and discussion arising are set out in Section 4, while Section 5 draws out conclusions.

## **1.3 Farm pond and stream description**

The study stream arises some 4.2 km above the discharge point of the dairy farm's oxidation pond system. The discharge is the first point source discharge within the stream below its point of origin. There are no further point source discharges to the lowest sampling point used in this study. The stream banks above the discharge pond are a mix of riparian vegetative cover giving way to more scattered/open scrub and spaced trees within pasture along the banks of the stream. The predominant land use is dairy farming.

The pond system is a two pond anaerobic- aerobic system. Sampling commenced in late January. In late February the second pond was emptied out and the contents spread over farmland, so that from this time onwards there was no discharge from the pond system into the stream at all. This meant that changes in the characteristics of the stream following this event could be related to the cessation of discharge (as well as seasonal changes in groundwater quality). There were two sampling runs prior to and two following the cessation of pond discharge.

From the pond discharge pipe, the discharge flows approximately 15 metres down the bank slopes through grass and over bare soil, to enter the stream.

Photograph 1 shows the upstream landscape, while photograph 2 shows the stream in the zone where the discharge enters it.



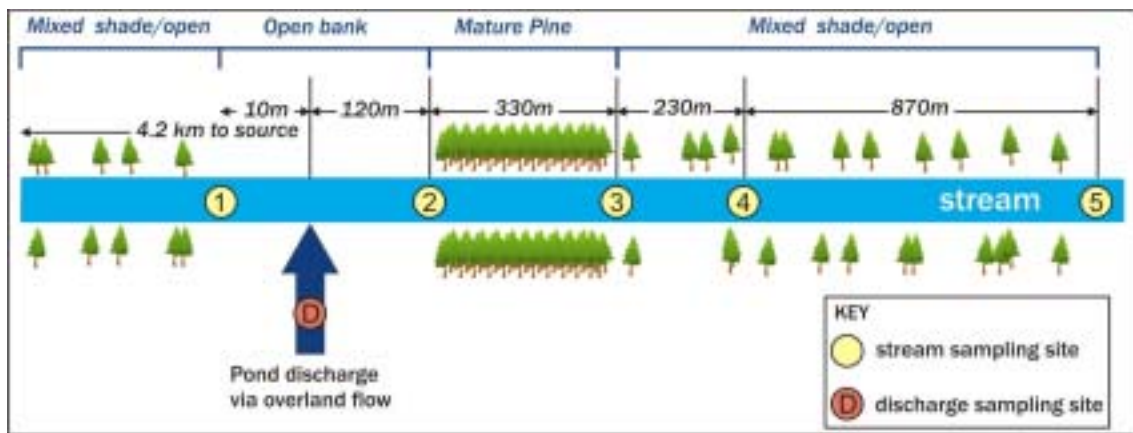
**Photograph 1** Pond discharge point and upstream landscape  
(stream runs from upper mid photograph down valley to mid right side of photograph)



**Photograph 2** Discharge zone and stream (flowing left to right)

Below the pond discharge, the stream flows through open land for 120 metres. The banks on each side are wide and relatively high- some ten metres or so. Animals occasionally graze the banks, which are unfenced on the stream perimeter. There is then an established pine plantation on both sides of the stream, with continuous canopy over-arching the stream. This extends for some 330 metres. Beyond this point, there is a mix of dense plantings, scattered trees and bushes, and open banks, for another 1100 metres to the lowest sampling point. As far as could be ascertained, there are no significant discharges to the stream throughout the stretch of water. Two very minor abstractions were noted, while staff noted several areas of bank seepage into the stream. Hydrological measurements were used to check stream flows down its length.

A schematic representation of the stream and its features is presented in Figure 1.



**Figure 1** Representation of study discharge and stream

## 1.4 Sampling regime

Both physico-chemical (four sites) and biological monitoring (five sites) of the stream was conducted, together with physico-chemical monitoring of the discharge.

The up-stream site was approximately ten metres above the area of bank down which the discharge flowed.

The first down-stream site (site 2b) was approximately 120-125 metres below the discharge zone, below a stretch of stream that was open-banked and immediately prior to the stream flowing through a zone of mature riparian back growth with continuous canopy cover. The rationale for this location was that the study behind the 2006 report had focused on the downstream stretch within 150 metres of a discharge, and had identified that significant impacts of discharges had largely dissipated within 150 metres. The primary question to be addressed within this study was therefore the extent to which residual concentrations varied subsequently. The downstream site used for bio-monitoring (referenced as Site 2 in this report) was a few metres above this site.

The second down-stream site used for biological monitoring (Site 3) was some 330 metres further down-stream, within a section shaded by mature pines.

The second down-stream site used for physicochemical monitoring, and also as a further biological site, (Site 4) was some 680 metres below the discharge zone, beyond a stretch of mature pines shadowing the stream and within a more open stretch. This site was chosen for ease of access for the sampling gear, and to determine the effects of riparian shading on the stream.

The final site used for physico-chemical sampling (site 5) was some 870 metres further downstream again (i.e. 1.55 km below the discharge).

The sampling protocol was designed to focus on fine-weather flow conditions only i.e. to remove the confounding influence of overland flow (wet weather run-off) into the stream.

On the basis that there were no significant time-dependent effects upstream that would influence the up-stream water quality, grab samples were used to show water quality at this point. The assumption of upstream water quality remaining consistent for the 24 hours duration of each separate sampling period was verified at the start of the study.

Pond discharges were sampled by grab sampling from the final (aerobic) pond at point of discharge.

Water quality at the downstream sites would be affected by the rate of discharge from the pond, which was expected to vary according to the time of day (i.e. following the washing down of the milking shed at the conclusion of morning and afternoon milkings). Accordingly, quarter-hourly samples were collected and composited automatically into hourly samples, for 24 hours, at each of the three down-stream sites studied for physico-chemical parameters, with initial sampling commencing at the time grab samples of the discharge and up-stream samples were being taken. These samples were stabilised by ice during the period of collection of all 24 samples on each occasion.

There were a total of four sampling runs conducted-two initially, and then two more following the emptying of the aerobic pond and the cessation of all discharge to the stream.

The study of the stream's ecology was conducted using the standard biomonitoring techniques of the Council. These consist of 'kick sampling' to obtain 400 ml of streambed invertebrates, before sorting according to abundance and sensitivity scoring to obtain a macroinvertebrate index (MCI) and semi-quantitative macroinvertebrate index (SQMCI). The 'kick-sampling' technique is very similar to Protocol C1 (hard-bottomed, semi-quantitative) of the New Zealand Macroinvertebrate Working Group (NZMWG) protocols for macroinvertebrate samples in wadeable streams (Stark et al, 2001).

Five sites were used for biomonitoring purposes- the four used for physico-chemical water quality monitoring, together with a fifth site located within the pine plantation.

## 1.5 Council requirements for a dairy shed pond discharge as a 'controlled' activity

In its *Regional Freshwater Plan for Taranaki* (2001), the Council provides for the discharge of treated farm effluent to water to be either a 'controlled' (the Council **must** grant consent for the activity) or a 'discretionary' (the Council **may** grant consent for the activity) activity. For the activity to enter the 'controlled' category, there are requirements it must satisfy in respect of the minimum dilution of the discharge in the receiving waters and the sizing of the anaerobic and aerobic ponds (amongst other requirements also). Failure to meet the 'controlled' entry requirements in no way means that the Council will decline the consent, or that environmental effects will be more than minor. It means that the Council will consider the activity on a case by case basis rather than provided automatic approval.

**Dilution:** the Plan provides that 'a dilution rate of 1:100 shall be maintained at all times at the point of discharge' for controlled activities. As set out below (sections 2.1.1 and 4.3), it was found during the study that the dilution of the pond discharge in question was about 1:220 when discharging through a partially blocked outlet pipe (with the effect that the duration of the discharge resulting from yard washdown was prolonged for several hours), but once the obstacle was removed, the in-stream dilution at times of peak flows ranged from 1:28 to 1:56. That is, under these circumstances it no longer met the Council's requirements for a controlled category of activity in respect of dilution.

**Pond sizing:** the Plan provides that for a herd size of 150 cows (as is the case on the farm in question), the primary pond should be the equivalent of 18m x 21m in surface dimensions (and 4m deep); and the secondary pond should be 18m x 31m (and 1.2m deep), if the pond system is to satisfy the requirements for consideration under a 'controlled' activity category of the Plan. Upon measurement, it was found that the two ponds were 19m x 21m and 20m x 25m. On this basis, the primary pond was correctly sized, but the secondary pond was 10% under-sized. It was also noted by the farmer that the secondary pond was in need of de-sludging to recover its hydraulic retention capacity. Thus, at the time the pond system did not meet the sizing/volume specifications for a controlled activity.

**Treatment efficacy:** the degree of treatment provided by the pond system, by comparison with other pond systems in Taranaki (both under-sized, and sized in accordance with the 'controlled' activity specifications), is evaluated further in Section 4.2 below. The results show that the pond system was not performing to the same level (in terms of the quality of the discharge) as could be expected from a system correctly sized and operated to meet the requirements of the Plan for a 'controlled' activity. The effluent from the pond was higher than typical in parameters such as its organic strength (BOD), nutrients (phosphorus and nitrogen, in various forms), and suspended solids.

Thus, overall this study involved a pond system with a higher strength than typical wastewater discharging into a stream where dilution was less than recommended.

Further to the above, it can be noted in passing that over the last three years, the Council has processed 239 consents for discharges to water of dairy shed effluent; of

these, 70% met the entry requirements for consideration as a 'controlled' activity, and 30% were considered on a 'discretionary' basis.

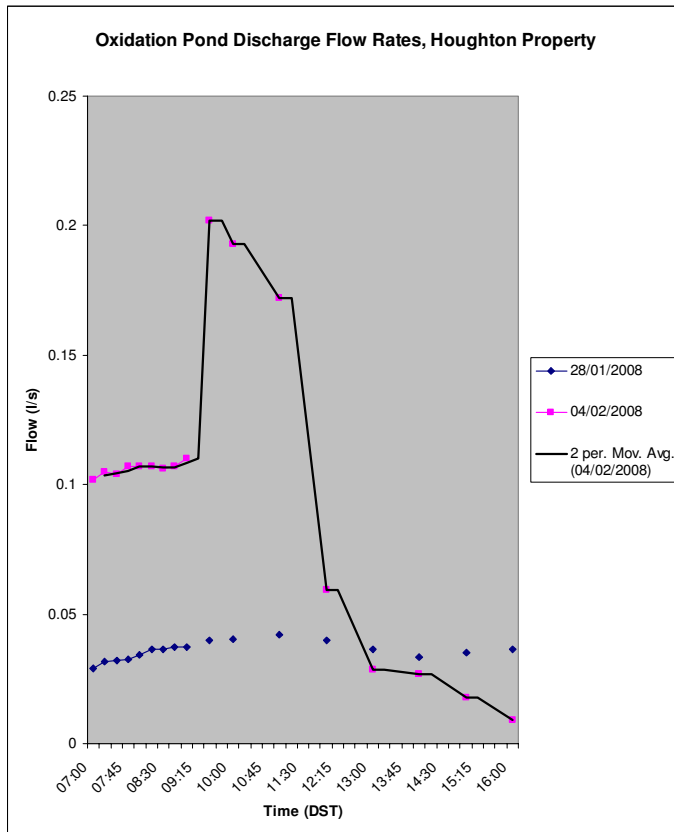
This study of in-stream assimilation therefore represents a 'worse case' scenario than would apply in the majority of cases of dairy treatment pond discharge in Taranaki.

## 2. Results

### 2.1 Hydrological results

#### 2.1.1 Discharge hydrology

The rate of discharge from the farm oxidation pond was measured throughout the days of 28 January and again on 4 February, co-incident with the first two of the four extended sampling runs downstream. The results of the two days' data are shown in Figure 2.



**Figure 2** Flow rates of discharge

On 28 January it was noted that the discharge pipe from the pond seemed to be partially blocked. The hydraulic loading into the pond would have occurred following the washdown of the shed yard in the morning around 0630-0730 and again in the afternoon, around 1500; with a delay for flow to pass through the primary and secondary ponds a peak in the discharge would have been expected a short time later on each occasion. Instead, on 28 January there was only a slight increase in discharge rate that was extended in duration, already increasing at 0700 (when sampling started), peaking at about 1030, and continuing through to 1430.

Examination of in-stream parameters from water quality data for 28-29 January suggests strongly that the blockage cleared at some time later during the day or overnight, because there were sharply defined peaks in a number of parameters downstream from 0630 onwards on 29 January.

The pattern of discharge on 4 February was much more as expected, with a clear and sizeable increase in flow from the pond from 0630 onwards- a timing co-incident with the time of the in-stream changes noted on 29 January.

When the in-stream dilution is calculated from the measured discharge and in-stream flow rates on each occasion, and compared with the in-stream dilution rates calculated from chloride and conductivity measurements, there is remarkably close consistency- the in-stream dilution calculated from flows on 28 January was 1:225, whilst it was 1:180 calculated from chloride; on 4 February the in-stream dilution calculated from flows was 1:40 whilst it was between 1:49 and 1:56 calculated from chloride concentrations.

When inspecting the discharge from the pond prior to sampling, Council staff noted that there was no clear single flow path down the bank between the pond and the stream (some 10-15 metres away). While there were wetted areas along a short stretch of the bank, the question was whether this represented areas of seeps of groundwater fed from the pond system, or a diffuse surface discharge flow. From the results of flow measurements and dilution calculations, it appears that indeed it was predominantly an overland flow of pond discharge.

### **2.1.2 Stream hydrology**

Measurements were made of flow rates at 3 stream sampling sites on each sampling occasion, primarily to determine the extent of inflows from groundwater between each site.

It was found that with marshy banks at the first downstream site (Site 2b), it was impossible to obtain an accurate gauging of instream flow volumes.

Previous rainfall was found to play a significant role in influencing the flow volumes and inflow rates.

Reasonably heavy rain (17.5 mm) had fallen on one day one week prior to 29 January. Flows on 29 January were measured at 9 litres per second (l/s) at Site 1 (4.2 km from the point of origin of the stream), 11 l/s at Site 4 (an increase of 2 l/s over a distance of 680 metres), and 12 l/s at Site 5 (an increase of 1 l/s over a distance of 870 metres).

There was then no further rain for the next week, to the period of sampling on 4-5 February. On this occasion it was found that flow at all 3 sites had decreased, and there was no significant inflow throughout the stretch of stream in the survey. The flow was 8 l/s at all points of measurement.

Rain on the first 5 days of March was greater than had occurred for the entire month in either January or February (69.5 mm in total). No further rainfall fell before the next flow measurements on 13 March. The pattern of flow in this occasion was very similar to that of 29 January, with 7 l/s at Site 1, 9 l/s at Site 4, and 11 l/s at Site 5.

There was further very heavy rainfall on 30-31 March (171 mm), and between 14-17 April a further 76 mm of rain fell, which was itself more than the total of January and February combined. That is, while January- March were dry months (especially if the first 5 days of March are excluded), April was quite the reverse. There was no further rain before flow measurements on 22 April, 5 days after the last rainfall. Flows on this

occasion were much higher. The flow measured at each site was 58 l/s, with an uncertainty in the flow measurement of 6 l/s. This was an increase in the baseline flow of around 500% over any recorded during the previous three months. The previous three months. As noted further below, the notable feature of the water quality on this occasion was a significant increase in the concentration of stream nitrate at all sites. Further aspects of the changes in water quality concurrent with increased inflow are explored in Sections 4.1 and 5 of this report.

### 3. Biological results

#### 3.1 Macroinvertebrate survey

##### Introduction

The biomonitoring survey was conducted on 15 January 2008. The survey was carried out under recession conditions, 21 days after a fresh that had resulted in a flow in excess of 3 times the median flow at the site. In-stream flow was assessed at 9 l/s on this occasion. The flow at Site 1 was around 9 litres per second, which is identical to the flow rate gauged two weeks later (under a very similar hydrological/meteorological pattern of a day's rain followed by a week of dry weather prior to sampling).

Very thin periphyton mats and patchy moss were observed on the gravel-cobble-boulder bed at sites 1 to 3. Patchy filamentous algae were present only at site 2, the site immediately downstream of the discharge zone. Site 3 was completely shaded by trees, whereas sites 1 and 2 (above and below the discharge) were completely open and situated between eroding banks with aquatic macrophytes on the stream edges and areas of seepage inflows visible at intervals through this reach. Sites 4 and 5, downstream of Opunake Road, were partially shaded by bank-side vegetation. They had primarily cobble-boulder substrates, and were found to have patchy periphyton mats, filamentous algae and moss and areas of instream aquatic macrophytes.

Stream water temperatures ranged from 13.5°C to 14.2°C at sites 1 and 2, 13.9°C to 14.1°C at sites 3 and 4, to 15.7°C at the furthest downstream site (5) during this mid-morning survey.

Samples were preserved with Kahle's Fluid for later sorting and identification under a stereomicroscope according to Taranaki Regional Council methodology using protocol P1 of NZMWG protocols for sampling macroinvertebrates in wadeable streams (Stark et al. 2001).

Macroinvertebrate taxa found in each sample were recorded as:

R (rare)	= less than 5 individuals;
C (common)	= 5-19 individuals;
A (abundant)	= estimated 20-99 individuals;
VA (very abundant)	= estimated 100-499 individuals;
XA (extremely abundant)	= estimated 500 individuals or more.

Stark (1985) developed a scoring system for macroinvertebrate taxa according to their sensitivity to organic pollution in stony New Zealand streams. Highly 'sensitive' taxa were assigned the highest scores of 9 or 10, while the most 'tolerant' forms scored 1. Sensitivity scores for certain taxa have been modified in accordance with Taranaki experience. Averaging the scores assigned to the taxa found at a site, and multiplying the average by a scaling factor of 20, produces a Macroinvertebrate Community Index (MCI) value.

The MCI was designed as a measure of the overall sensitivity of macroinvertebrate communities to the effects of organic pollution. It is based on the presence/absence of

taxa with varying degrees of sensitivity to environmental conditions. MCI results can also reflect the effects of warm temperatures, slow current speeds and low dissolved oxygen levels, because the taxa capable of tolerating these conditions generally have low sensitivity scores. Usually more 'sensitive' communities (with higher MCI values) inhabit less polluted waterways.

A semi-quantitative MCI value (SQMCI<sub>s</sub>) has also been calculated for the taxa present at each site by multiplying each taxon score by a loading factor (related to its abundance), totalling these products, and dividing by the sum of the loading factors (Stark, 1998 and 1999). The loading factors were 1 for rare (R), 5 for common (C), 20 for abundant (A), 100 for very abundant (VA) and 500 for extremely abundant (XA). Unlike the MCI, the SQMCI<sub>s</sub> is not multiplied by a scaling factor of 20, so that its corresponding range of values is 20 times lower. The SQMCI<sub>s</sub> takes into account taxa abundance as well as sensitivity to pollution, and may reveal more subtle changes in communities. Significant differences in either the MCI, the SQMCI<sub>s</sub>, or the number of taxa, between sites indicate the degree of adverse effects (if any) of the discharges being monitored.

The EPT (ephemeroptera, plecoptera, trichoptera) index is the total of the 'sensitive' mayfly, stonefly and caddisfly taxa in the community, while %EPT taxa expresses the EPT total as a percentage of the overall taxa number found in the community.

The results of the biomonitoring survey are summarised in Table 1.

**Table 1** Results of biomonitoring survey 15 January 2008

	Site 1	Site 2	Site 3	Site 4	Site 5
No of taxa	34	30	29	34	27
MCI	102	100	114	102	105
SQMCI <sub>s</sub>	6.8	6.2	6.4	5.1	5.9
EPT (taxa)	13	11	12	12	10
%EPT (taxa)	38	37	41	35	37

### Site 1 (above the discharge)

A very rich macroinvertebrate faunal community (34 taxa) was recorded at this site, well above the median (22 taxa) and one taxon above maximum richnesses found from 33 surveys of 'control' sites at similar altitudes in Taranaki ringplain streams sourced outside of the National Park (TRC, 1999 (updated 2006)). Relatively good preceding physicochemical water quality of this small stream was indicated by the presence of five 'highly sensitive' taxa at this site, three of which were abundant in numbers. The community at this site was characterized by three 'highly sensitive' taxa (with mayflies being very abundant); six 'moderately sensitive' taxa (mayflies, elmids beetles, dobsonfly and free-living caddisfly); and four 'tolerant' taxa (oligochaete worms, a net-building caddisfly, a sandfly and empidid flies). This was a relatively high number of characteristic taxa, particularly for the upper reaches of such a small stream under very low flow conditions.

The presence of a relatively significant number of 'tolerant' taxa (35% of richness) was reflected in the moderate MCI score of 102 units, which was 7 units above the median

score found by 33 previous surveys of 'control' sites at similar altitudes in Taranaki ringplain streams sourced outside of the National Park [TRC, 1999 (updated, 2006)]. The higher individual taxon abundances of 'sensitive' mayfly taxa (including two 'highly sensitive' taxa) and lack of very or extremely abundant 'tolerant' taxa, resulted in a relatively high SQMCI<sub>s</sub> value (6.8 units).

### **Site 2 (below discharge zone)**

Again a relatively rich macroinvertebrate faunal community (30 taxa) was found at this site, representing a small reduction of 4 taxa between sites 1 and 2 just beyond the boundary of the mixing zone specified in the consent for the dairy discharge. The reduction in taxa number related only to the absence of rarities (i.e. taxa having less than 5 individuals) at site 2, and was typical of variability found in communities. However, there were a few significant between-site differences in individual taxon abundances, which probably reflected limited impacts of the highly-diluted wastes discharge. These related to reductions in four 'sensitive' mayfly taxa numbers (all decreasing in abundances), and the appearance of the 'very tolerant' bloodworm midge *Chironomus*; the only site at which this midge was found (Table 1).

These more subtle changes in community diversity resulted in a small decrease of 0.6 SQMCI<sub>s</sub> unit at the downstream site 2. The continued presence of several 'highly sensitive' taxa (five in total) was indicative of minimal deterioration in physicochemical water quality, in terms of either severity or duration, below the discharge zone, consistent with the high dilution rate apparent at the time of the survey. (It should be noted that the duration of discharge was prolonged, so that the volume of discharge was equivalent to a very low dilution rate if the discharge had been occurring over a more typical timeframe).

The community was characterized by fewer 'sensitive' taxa [one 'highly sensitive' taxon, three 'moderately sensitive' taxon (elmid beetles, caddisfly, and tanypod midge); and four 'tolerant' taxa (oligochaete worms, net-building caddisfly, orthoclad midges and sandfly), than found at the upstream 'control' site.

Overall community composition was similar to that at the upstream 'control' site 1 (with 'tolerant' taxa comprising 33% of total richness), and this was reflected in the similar MCI scores (within 2 units) for these two sites.

### **Site 3 (450 metres downstream of discharge zone)**

A relatively rich community (29 taxa) was found at this site, located in a reach of the stream with significant riparian cover. Although this number of taxa represented minimal change in terms of richness between sites 1, 2 and 3, there were several more subtle differences in community composition. A small increase in the number of 'highly sensitive' taxa was found, together with a small decrease in the proportion of 'tolerant' taxa (29%) comprising the community.

The community was characterized by one 'highly sensitive' taxon (mayfly (*Deleatidium*)); four 'moderately sensitive' taxa (mayflies, elmid beetles, and the *Zephlebia* group, which was extremely abundant); and three 'tolerant' taxa (oligochaete worms, net-building caddisfly and a sandfly taxon). There were several significant differences in individual taxon abundances between the two downstream

adjacent sites (2 and 3), in particular increased abundances of one 'highly sensitive' free-living caddisfly taxa and three 'moderately sensitive' mayfly taxa, and decreased abundances of 'tolerant' empidid flies and bloodworm midge, at Site 3. Overall this resulted in a small increase in SQMCI<sub>s</sub> scores at the third site.

The increased proportion of 'sensitive' taxa (72% of richness) in the community coincided with an increase in MCI scores between the 'control' site and this site (12 units,) and between adjacent sites 2 and 3 (14 units), coincident with improved riparian cover, particularly increased shading. The increase in MCI is considered significant (Stark, 1998). The score at this site (114 units) was also a significant 19 units above the median score (although 15 units below the maximum score) found by 33 previous surveys of 'control' sites at similar altitudes in Taranaki ringplain streams sourced outside the National Park (TRC, 1999 (updated, 2006)).

That is, the results from this site, located within a stretch of the stream with mature riparian shading, indicates that there is a significant enhancement in a stream that is already of high ecological value. It also indicates recovery of the stream by this point (450 metres) from any of the subtle effects of the dairy discharge.

#### **Site 4 (700 metres downstream of discharge zone)**

A very rich community (34 taxa) was found at this slightly more open site (where increased algal substrate cover was present). This represented an increase in 5 taxa (although mainly as rarities) between adjacent sites 3 and 4, and no change in richness when compared with the upstream 'control' site.

However, there was a small decrease in the number of 'highly sensitive' taxa found and an increase in the proportion of 'tolerant' taxa (38% of richness) between this and the adjacent upstream site, although there were minimal differences in composition between this site's community and that of the 'control' site upstream. The community was characterized by one 'highly sensitive' taxon (mayfly); three 'moderately sensitive' taxa (mayfly and elmids beetles); and four 'tolerant' taxa (oligochaete worms, net-building caddisfly, algal-piercing caddisfly, and orthoclad midges). The most significant differences in individual taxon abundances between adjacent sites 3 and 4 included lower numbers of two 'moderately sensitive' mayfly taxa and one 'highly sensitive' caddisfly taxon, and increased numbers of two 'tolerant' taxa (algal-piercing caddisfly and muscid flies) at the downstream site. These differences, associated with increased algal substrate cover, resulted in a significant decrease in SQMCI<sub>s</sub> value of 1.3 units between adjacent sites 3 and 4, and a 1.7 unit decrease between the upstream 'control' site and site 4.

The increased proportion of 'tolerant' taxa in site 4's community resulted in a significant 12 unit decrease in MCI score between adjacent sites 3 and 4, but no difference in comparison of site 4 with the score at the 'control' site, site 1. The MCI score (102 units) remained 7 units above the median score found by 33 previous surveys of 'control' sites at similar altitudes in Taranaki ringplain streams sourced outside the National Park [TRC, 1999 (updated, 2006)].

It may be noted that Sites 1 and 4 are both partially open sites, with very similar biological condition of a comparatively high value, but not so high as is evident at Site 3.

#### **Site 5 (1.45 km downstream of discharge zone)**

A moderately rich fauna (27 taxa), seven fewer taxa than found at site 4 (some 800m upstream), was recorded at this more open site. Patchy periphyton mats and filamentous algae were present on the hard substrate of the stream. A number of 'highly sensitive' taxa (five) were present, two of which were abundant, indicative of good preceding physicochemical water quality in this reach of the small stream. The community was characterized by two 'highly sensitive' taxa, one of which was extremely abundant, four moderately sensitive' taxa (mayflies, elmids beetles and free-living caddisfly); and four 'tolerant' taxa (oligochaete worms, net-building caddisfly, orthoclad midges, and sandfly); this composition was not too dissimilar to the characteristic taxa found at the 'control' site (1) some 1.4km upstream. Very few significant differences in individual taxon abundances were recorded between adjacent sites 4 and 5, with an increase of 0.8 SQMCI<sub>s</sub> unit due mainly to a downstream increase in the number of the 'highly sensitive' mayfly *Deleatidium*. An overall decrease of 0.9 units in SQMCI<sub>s</sub> scores between the 'control' site, site 1, and site 5 was due to more subtle decreases in most mayfly taxon abundances and increases in at least two 'tolerant' taxa abundances.

The MCI score (105 units) was three units higher at Site 5 than the scores at the nearest upstream site (4) and the 'control' site, indicative of no significant deterioration in stream 'health' between adjacent sites or along the length of the stream surveyed.

There were subtle declines in several indicators from Site 3 through to Site 5. While these changes are mostly non-significant in statistical or ecological terms (but the significant MCI and SQMCI decline from Site 3 to Site 4 should be noted), the associated change in riparian cover from full shading to more open and intermittent planting in this stretch should be noted. Given that physico-chemical water quality was improving throughout this stretch, it would appear that the variations in in-stream ecological condition noted by the bio-monitoring would most likely be driven by the variation in riparian cover.

Overall, the sites in the stream showed high values of biological condition indicators. This is even more notable given that the survey was conducted in mid-summer, when such indicators normally decline due to warmer temperatures, lower flow velocities and volumes, and prolonged sunlight.

Typically, MCI values in ringplain streams decline with increasing distance from their source, due to diffuse and point source discharges and changes in stream morphology and riparian shading. For a stream of the sort in this study, a typical rate of decline is considered to be 1-2 MCI units per kilometre (*pers comm* C Fowles). For the stream in question, there was actually an increase from Site 1 to Site 5 (102 increasing to 105), when a decline of 1.5-3 MCI units would have been expected in the distance between Sites 1 and 5. With marginal (insignificant) declines between Sites 1 and 5 in a couple of water quality parameters, and others consistent between the two

sites, environmental factors other than changes in water quality must be playing a role in the increase observed.

### **3.2 Microscopic heterotrophic assessment**

Microscopic heterotrophic assessments of the five sites through the 1.5km reach of the stream found no trace of heterotrophic growths on the streambed at any of the five sites. This indicated no recent organic overloading of the assimilative capacity of the receiving waters downstream of the discharge from the dairy shed wastewater treatment ponds, consistent with the high dilution rate estimated at the time of the survey (and in spite of the extended duration of each discharge event).

The full bio-monitoring report is attached to this report as Appendix I.

## **4. Physico-chemical results**

### **4.1 Site 1**

Samples were collected from Site 1, above the discharge zone, on 8 occasions, with sequential sampling on some of those occasions: 15 January, 22 January, 28 January (4 separate samples at 2-hourly intervals), 4 February (4 samples at 2-hourly intervals), 12 March, 13 March (these two samples bracketed the start and the conclusion of a 24-hour sampling run using automatic samplers at downstream sites), 21 April (two samples were collected, above and below a culvert used for cattle movement across the stream, to check for run-off from the cattle race), and 22 April (two samples, as for 21 April). The two sets of samples collected respectively on 21 and 22 April bracketed the start and the conclusion of a 24-hour sampling run using automatic samplers at downstream sites, similar to the sampling programme on 12 and 13 March.

The sample collected on 15 January was analysed for temperature, chloride, and conductivity only, for the purpose of calculating dilution from the discharge. On all other occasions, the samples were analysed for a suite of parameters as shown in Table 2.

Table 2 presents a summary of results, including the average and range of multiple samples collected during the course of one day or one continual 24-hour sampling run. A full set of results for site 1 is attached to this report in Appendix II.

**Table 2** Site 1 (upstream site)

Parameter	15 01 08	22 01 08	28 01 08	04 02 08	(12-13) 03 08	(21-22) 04 08	Water quality criteria*	Effect addressed
Ammonium nitrogen N gm <sup>-3</sup>		0.038	0.028 (0.025-0.032)	0.035 (0.031-0.039)	0.027-0.028	0.022-0.033	<b>0.9</b>	Aquatic ecosystem health
BOD gm <sup>-3</sup>			1.1 (composite)	0.5 (composite)	0.5-0.5	0.5-0.8	<b>3</b>	Contact recreation
Chloride gm <sup>-3</sup>	12.9	13.1	13.0 (12.7-13.2)	12.4 (12.3-12.5)	12.7-12.7	13.4-13.1		
Conductivity mSm <sup>-1</sup>	13.3	14	13.8 (13.7-14.0)	13.7 (13.4-14)	13.6-13.7	11.8-11.7		
DRP gm <sup>-3</sup>			0.039 (0.038-0.041)	0.031 (0.027-0.042)	0.038-0.039	0.029-0.03	<b>0.03</b>	Prevention of undesirable growths
E coli /100 ml			1100 (880-1400)	2875 (2500-3500)	210-450	110-220	<b>550</b>	Contact recreation
F coliforms /100 ml			1200 (930-1600)	2875 (2500-3500)	220-470	110-220	<b>1000; 100 (median)</b>	Stock drinking water
Nitrite-nitrate gm <sup>-3</sup>			0.61 (0.57-0.70)	0.57 (0.54-0.60)	0.53-0.54	1.91-1.85	<b>0.7; 80% below 0.6</b>	Aquatic ecosystem health; prevention of undesirable growths
Temperature °C	13.5		15.7 (12.8-18.6)	17.7 (15.2-20.3)	-	-	<b>25</b>	Aquatic ecosystem health
TP gm <sup>-3</sup>			0.048 (0.044-0.051)	0.048 (0.043-0.052)	0.145-0.151	0.06-0.066	<b>0.03</b>	Prevention of undesirable growths
Turbidity NTU			1.4 (1.0-2.2)	2.5 (2.1-3.0)	1.6-2	3.6-4.8		
pH			7.5 (7.4-7.5)	7.7 (7.7-7.7)	7.6-7.6	7.4-7.5		

Key: BOD Carbonaceous biochemical oxygen demand  
 TP Total phosphorus F coliforms faecal coliforms

DRP Dissolved reactive phosphorus

\*As referenced in 'Trends in the quality of the surface water of Taranaki', Taranaki Regional Council February 2006

**Diurnal variation:** the samples collected throughout the days of 28 January and 4 February from 0818 to 1416 and from 0845 to 1505, respectively, showed few variations in water quality at this upstream site. The temperature of the stream rose throughout each day, from 12.8 to 18.6 °C and from 15.2 to 20.3 °C, rises of 5.8 and 5.1 °C. The weather on each day was fine and sunny, so this is not unexpected. While turbidity trended downwards throughout 4 February, the change was negligible, and did not occur on 28 January. While sunlight is known to inactivate faecal bacteria, the concentrations of E coli and faecal coliforms were highly variable on 28 January, and almost as high in the last sample of 4 February as the first, indicating that variations in the source(s) rather than in-stream attenuating processes were the dominant factor. The concentrations of ammoniacal ammonia remained constant throughout both days, and were very similar on both days (and on the other sampling occasions). The removal of ammonia by in-stream algae and vegetation is the principal route for its removal/transformation to other nitrogenous species, and this result indicates that the levels of ammonia found might represent a residual level.

**Seasonal variation:** all results for each parameter remained consistent throughout summer, with the exception of nitrite-nitrate and (to a much lesser extent) the ratio of dissolved reactive phosphorus:total phosphorus. This parameter rose relatively sharply in the final sampling run (April), having been stable during the preceding three months. The increase meant that the water quality at this time exceeded ANZECC guideline values for nitrate for avoidance of changes to in-stream ecology (see next section below). While the reason for the increase has not been investigated further, the most likely cause is that, following an extended dry period throughout February and March, very heavy rain (150mm in two days) fell at the end of March (3 weeks prior to the final sampling run), with further heavy rain (85 mm in four days) 1 week prior to the final sampling run. From the Council's 'state of the environment' monitoring programme for freshwater quality, extended wet weather often results in elevated nitrate levels in groundwater entering the region's streams, as a consequence of nitrate flushing from the root zone of pasture under such conditions, and changes in the ratio of dissolved to total phosphorus due to increased mobilisation and transport of solid particles.

**Water quality:** the water quality criteria provided in Table 1 are drawn variously from the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*, Australian and New Zealand Environment and Conservation Council 2000, *Taranaki-our place our future* (the 2003 State of the Environment Report prepared by the Taranaki Regional Council), and *Microbiological guidelines for marine and freshwater recreational areas*, Ministry for the Environment 2003.

It should be noted that the stream under study is too shallow and small for contact recreation. The guidelines for the prevention of undesirable growths are considered to be 'necessary but not sufficient' – that is, if the guideline is exceeded it does not mean that undesirable in-stream growths will actually occur, only that the concentration of a nutrient has reached a level that is necessary for such growths to occur. A combination of favourable nutrient levels, warmth, sunlight, stream bed type, and stream flow characteristics must all co-incide for undesirable growths to occur. So while the dissolved and total phosphorus concentrations exceeded the guidelines for prevention of undesirable growths on all occasions, and the nitrate

level was around the guideline value, the bio-monitoring results at Site 1 show that the aquatic ecosystems are in fact of very high quality, with no undesirable growths.

The results of the analysis of water quality at Site 1 show that the water generally meets the guidelines for aquatic ecosystem health, with an exceedance in the last sampling run of the nitrate guideline for avoiding undesirable growth.

With no point source discharges above this site, water quality is influenced by the nature of the source (lowland infiltration and seepage), together with overland flow during wet conditions. All samples collected in this study were gathered in dry weather, and therefore represent base flow water quality. Clearly the quality of the base flow deteriorated following an extended wet period.

**Culvert effects upon water quality:** On 21 and 22 April (4 days after heavy rain and 2 days after light showers), samples were collected from both above and below the culverted cattle crossing of the stream, in order to determine whether run-off or deposition from the crossing was having an effect upon in-stream water quality. It was found that water quality parameters changed only by negligible amounts. More particularly, ammonium increased (by 0.006-0.017  $\text{gm}^{-3}$ ), dissolved reactive phosphorus fell (by 0.002-0.004  $\text{gm}^{-3}$ ), total phosphorus increased (by 0.001-0.006  $\text{gm}^{-3}$ ), while E coli and faecal coliforms fell once by 10 counts/100 mls, and increased once by 90 counts /100 mls. Biochemical oxygen demand was unchanged, remaining at 0.5 and 0.6  $\text{gm}^{-3}$  on the two days, respectively.

## 4.2 Discharge

Samples were collected from the discharge on three occasions: 15 January, 28 January, and 4 February. Single samples were collected on each occasion, as the hydraulic retention period of a secondary pond means that it is not subject to rapid changes in character or quality (the primary pond acts as a buffer). After 4 February, the pond was pumped out and all discharge ceased. The sample collected on 15 January was analysed for chloride and conductivity only, for the purpose of calculating dilution from the discharge. On all other occasions, the samples were analysed for the suite of parameters shown in Table 3.

Table 3 presents a full set of results for the discharge.

The quality of the discharge from the pond, as shown in Table 3, indicates a heavily loaded pond system. The pond was due for de-sludging, and thus at the time of the survey the hydraulic retention, and hence the treatment efficacy, were reduced. De-sludging would increase residence time and could be expected to lead to reductions in BOD, suspended solids, and total phosphorus in particular.

By comparison with the pond systems studied by the Council in 2000-2001 (*Dairy shed oxidation pond discharges in Taranaki*, Taranaki Regional Council 2006), the discharge from this farm is relatively concentrated (high chloride), high BOD, typical bacteriological quality, and high ammonia and suspended solids. The system was thus performing at a level equivalent to that of an under-sized pond system.



**Photograph 3** Secondary pond system

**Table 3** Discharge quality

Parameter	15 01 08	28 01 08	04 02 08
Ammonium nitrogen N gm <sup>-3</sup>		130	84.3
BOD gm <sup>-3</sup>		180	130
Chloride gm <sup>-3</sup>	195	248	250
Conductivity mSm <sup>-1</sup>	257	264	269
DRP gm <sup>-3</sup>		34.8	34.3
E coli /100 ml		77000	130000
F coliforms /100 ml		77000	130000
Nitrite-nitrate gm <sup>-3</sup>		0.65	0.05
Suspended solids		480	400
TP gm <sup>-3</sup>		51.8	51.3
Turbidity NTU		560	-
pH		7.7	7.9

Key: BOD Carbonaceous biochemical oxygen demand (unfiltered)

DRP Dissolved reactive phosphorus

TP Total phosphorus

F coliforms faecal coliforms

The pond effluent is characteristic of dairy treatment pond systems in having almost all nitrogen present as ammonium rather than nitrate, and in having the total phosphorus concentration significantly higher than the dissolved fraction (ie associated with the high suspended solids concentration).

### 4.3 Sites 2 and 2b

A sample was collected from Site 2, 70 metres below the discharge zone, on one occasion, on 15 January. The sample was collected to provide a calculation of dilution

of the discharge on the day in question. At Site 2b, some 120 metres below the discharge zone, an automatic sampler was set up on four occasions: 28-29 January, 4-5 February, 12-13 March, and 21-22 April. The sampler was set to collect 4 samples at quarter hourly intervals into the same bottle, before advancing to the next bottle of the sequence. Sampling continued for 24 hours on each sampling occasion.

A full set of laboratory results is attached in Appendix III, while the results are graphed against time in Appendix IV.

The sample of 15 January at Site 2 was analysed for the suite of parameters shown in Table 4.

Photograph 4 shows the location of Sites 2 and 2b in relation to the discharge zone.



**Photograph 4** Stream between discharge zone and Sites 2 and 2b  
(Discharge foreground of photograph, lower left, and sites 2/2b located towards entrance to pine plantation upper centre of photograph.)

**Table 4** Water quality at site 2

Parameter	15 01 08
Temperature °C	14.2
Chloride gm <sup>-3</sup>	13.8
Conductivity mSm <sup>-1</sup>	13.5

The in-stream dilution achieved on 15 January was between 1:200 and 1:1000.

The hydrological record of the discharge on 28 January (section 2.1 above) showed that the rate of discharge was essentially constant throughout the day, at about 0.037 litres per second. The last measurements of flow were taken at 4 pm on 28 January. It had been observed by Council staff that the outlet from the secondary pond was partially blocked, so that the discharge flow had shown a slight and prolonged

increase over the course of the day instead of following the hydraulic loading on the pond system from the milking shed yard washdown (around 7-8 am and again around 3 pm each day). However, the pattern of in-stream parameters shows a significant change in in-stream characteristics at 8 am on 29 January, and it is considered highly likely that this reflects an unimpeded flow on this occasion. Discharge flow monitoring on 4 February found the more typical pattern of two short peak discharge periods, following each milking session. Flow rates on 4 February reached a peak of about 0.2 litres per second, subsiding over a period of 3 hours.

**Ammonia:** the analytical results for ammonia are shown in figures 4-7 in Appendix IV.

During the afternoon of 28 January, the stream showed a slight peak in chloride concentration at about 3.30 pm (i.e. there was a peak in the pond discharge into the stream evident at this time). The dilution of the discharge at this point in the stream (including bank seeps entering the stretch above Site 2b) at this time was 1:180. This means that without any in-stream assimilation, the theoretical in-stream concentration of ammonia due to the pond discharge should have been  $0.72 \text{ gm}^{-3}$  at this point. However, the level of ammonia had in fact reduced to  $0.03 \text{ gm}^{-3}$ , or by 95% of the theoretical increase, by this point about 120 metres below the discharge zone. This level represents a residual level i.e. this was also the level of ammonia present above the discharge point.

That is, at a dilution rate of 1:180, the concentration of ammonia in the stream had been attenuated to background levels within 120 metres below the pond discharge point.

The 28-29 January monitoring also showed a short sharp peak of in-stream ammonia at  $2.66 \text{ gm}^{-3}$ , at about 8 am in the morning of 29 January. This level represents an un-ionised ammonia concentration of  $0.030 \text{ gm}^{-3}$ , above the Council's guideline value for protection of in-stream ecology of  $0.025 \text{ gm}^{-3}$ . However, it must be noted that this peak lasted for only an hour, and that almost all values throughout the 24 hours were less than  $0.1 \text{ gm}^{-3}$  (expressed as ammonium). The bio-monitoring conducted upstream of and close to this site found a very high quality in-stream ecological community at this point.

Review of the dilution data shows that during the time of peak discharge on the morning of 29 January, the dilution of the discharge at this point in the stream was 1:28. This means that without any in-stream assimilation, the theoretical in-stream concentration of ammonia should have been  $4.6 \text{ gm}^{-3}$  at this point. However, as described above, the level of ammonia was in fact lower than this value by  $2 \text{ gm}^{-3}$ , or by 43%, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of 1:28, the concentration of ammonia in the stream had been attenuated by 43% within 120 metres below the pond discharge point.

Review of the data for the monitoring conducted on 4-5 February shows two peaks, at about 10.30 pm and again at 1030 am the next morning (the latter occasion showing the highest levels of ammonia during this particular monitoring period). The dilution of the discharge within the stream at these times was 1:56 and 1:49, respectively. This means that without any in-stream assimilation, the theoretical in-stream

concentration of ammonia should have peaked at  $1.5 \text{ gm}^{-3}$  and  $1.7 \text{ gm}^{-3}$  at this point. However, the level of ammonia had in fact reduced to  $0.58 \text{ gm}^{-3}$  and  $0.91 \text{ gm}^{-3}$ , a reduction of about  $0.9 \text{ gm}^{-3}$  or by 61% and 46% respectively, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of around 1:50, the concentration of ammonia in the stream had been attenuated by about 45-60% within 120 metres below the pond discharge point on this occasion.

The data in Table 5 indicates that the higher the initial concentration, the greater the reduction in the concentration of ammonia (while noting that the residual concentration remaining is higher).

**Table 5** Rates of in-stream ammonia removal at 120 metres

Dilution rate	Calculated in-stream ammonia, $\text{gm}^{-3}$	Ammonia removal	
		Absolute, $\text{gm}^{-3}$	% of initial
1:28	4.6	2.0	43
1:49	1.7	0.8	46
1:56	1.5	0.9	61
1:180	0.72	0.7	95

Discharge from the pond system ceased after 4 February. The results of analyses for ammonia in the downstream samples collected on 12-13 March and 21-22 April confirm that there is no evidence of high background levels of ammonia entering the stream via groundwater seeps in the vicinity of the pond, as the results are identical to the concentrations of ammonia found upstream of the discharge zone.

**Nitrite/nitrate:** the analytical results for nitrite/nitrate nitrogen (NNN) are shown in figures 28-31 in Appendix IV.

Any increase in NNN at this point in the stream could derive from one of two possible sources: nitrate discharged from the pond, or conversion of ammonia to nitrate within the stream. From the discussion of ammonia above, the theoretical increase in NNN due to the conversion of ammonia should have been  $0.72 \text{ gm}^{-3}$ . The contribution directly from the pond discharge was so small as to be negligible. This means that without any in-stream assimilation, the theoretical in-stream concentration of NNN due to the discharge of ammonia from the pond in mid-afternoon should have been increased by  $0.72 \text{ gm}^{-3}$  at this point. However, the level of NNN in fact remained at its baseline concentration of around  $0.9 \text{ gm}^{-3}$  at this point about 120 metres below the discharge zone, throughout the afternoon. This is higher than was found upstream ( $0.65 \text{ gm}^{-3}$ ) during the sampling run, by about  $0.25 \text{ gm}^{-3}$ . This is about 35% of the increase that would have occurred without assimilation. With no concurrent increase in ammonia downstream, this data indicates that at a dilution rate of 1:180, the concentration of NNN in the stream had been reduced by about 65% of its potential increase, within 120 metres below the discharge.

The 28-29 January monitoring showed a short sharp peak of in-stream NNN of  $1.86 \text{ gm}^{-3}$ , for an hour between 7.30 and 8.30 am on 29 January, before a rapid decline back to baseline levels for this site.

The dilution of the discharge at this point in the stream was 1:28. This means that without any in-stream assimilation, the theoretical in-stream concentration of total

nitrogen due to the background NNN upstream, the ammonia and NNN in the discharge, and the conversion of some ammonia to NNN, should have been increased to  $5.29 \text{ gm}^{-3}$  at this point. However, the level of NNN was in fact  $1.86 \text{ gm}^{-3}$  at its peak. Taken together with the residual ammonia concentration of  $2.66 \text{ gm}^{-3}$ , this indicates that  $0.8 \text{ gm}^{-3}$  of nitrogen, or 15% of the total nitrogen, had been removed from the stream by this point about 120 metres below the discharge zone.

National water quality guidelines indicate that total nitrogen should remain below  $0.6 \text{ gm}^{-3}$  (80% of all results) for the protection of streams against undesirable aquatic growths. The total nitrogen at this point was  $4.5 \text{ gm}^{-3}$ , well above the ANZECC guideline. It should be noted however that the bio-monitoring conducted upstream of and close to this site found a very high quality in-stream ecological community at this point.

Review of the data for the monitoring conducted on 4-5 February shows two peaks in NNN, at about 10.30 pm and again at 10.30 am the next morning (the latter showing the highest level of NNN during this monitoring particular period). Review of the data for ammonia and nitrate upstream, in the discharge, and downstream, shows that on this occasion there was no overall removal of nitrogen within the 120 metres immediately downstream of the discharge.

That is, at a dilution rate of around 1:50, the concentration of total nitrogen (ammonia and nitrite/nitrate) in the stream was not attenuated within 120 metres below the discharge on this occasion. The reduction in ammonia was matched by an equivalent increase in nitrate.

**Table 6** Rates of in-stream nitrogen removal (ammonia plus nitrite-nitrate) at 120 metres

Dilution rate	Removal	
	Absolute, $\text{gm}^{-3}$	% of initial
1:28	0.8	15
1:49	0	0
1:56	0	0
1:180	0.45	65

Discharge from the pond system ceased after 4 February. The results of analyses for NNN in the downstream samples collected on 12-13 March and 21-22 April confirm that there is no evidence of high background levels of NNN entering the stream via groundwater seeps, as the results are identical to the concentrations of NNN found upstream of the discharge zone. These results also indicate negligible attenuation of the in-stream nitrate levels between the upstream and downstream sites on these occasions.

Interestingly, the nitrate levels upstream and downstream on 12-13 April were relatively much higher than earlier in the season- they were in fact even higher on 12-13 April, when there was no discharge from the pond affecting the downstream site, than they were on 4 February at the downstream site when the greatest contribution from the ammonia in the discharge to the downstream nitrate concentration was evident, and further, on 12-13 April the NNN levels remained constant over the course of 24 hours, instead of peaking briefly and returning to a lower level as they did during the period of discharge. That is, while the presence of ammonia in the dairy yard effluent discharge resulted in an increase in downstream

total nitrogen, the level was only of the same order of magnitude and actually less than occurred later in the season when there was no discharge i.e. the worst nitrite-nitrate in the stream was found when there was no discharge.

**Carbonaceous filtered biochemical oxygen demand:** the analytical results for CFBOD are presented in Table 7 and in Appendix VII. CFBOD was analysed on composite samples, prepared by further compositing six one-hour composite samples. Table 6 also presents 'unassimilated' data. These data are calculated on the basis of the prevailing rate of dilution of the discharge for the time period over which each sample was collected, and represent the CFBOD that would be expected in the stream if there was no mechanism of assimilation and attenuation.

**Table 7** CFBOD at Site 2b

Sampling run	Time	Result gm <sup>-3</sup>	'Unassimilated' result	% reduction
28-29 Jan	1015-1600	2.2		
	1615-2200	1.5	2.1	33%
	2215-0400	1.4		
	0415-1000	1.8	7.5	74%
4-5 Feb	1015-1600	0.9		
	1615-2200	0.7	2.8	75%
	2215-0400	1.0		
	0415-1000	0.7	3.1	77%
12-13 March	1015-1600	0.7	Not applicable	
	1615-2200	0.6		
	2215-0400	0.8		
	0415-1000	0.6		
21-22 April	1015-1600	1.0		
	1615-2200	0.7		
	2215-0400	0.6		
	0415-1000	0.8		

The data in Table 7 shows that CFBOD is being rapidly attenuated within the stream, with particularly significant rates of reduction at higher concentrations, within 120 metres of the discharge point.

The Council's Freshwater Plan includes, for a dairy shed effluent discharge activity to be categorised as a 'controlled' activity, a requirement that the discharge shall not cause the in-stream CFBOD to exceed 2.0 gm<sup>-3</sup> at or beyond the downstream boundary of the mixing zone. Table 6 shows that one sample, out of 8 composite samples collected during periods of pond discharge, exceeded this limit (by 0.2 gm<sup>-3</sup>). An examination of other parameters of water quality for this particular period showed no indication of a non-negligible effect caused by the pond discharge upon the stream, for any except coliforms, which showed a small but distinct peak at about 1430 (which is well after the time of a morning yard washdown, but before the afternoon washdown). Given the timing of the peak in coliforms, and the absence of any other indicator of a pond discharge influencing stream water quality during this period, it is more likely that the CFBOD result of 2.2 gm<sup>-3</sup> recorded between 1015 and 1600 on 28 January is due to an animal voiding wastes in or near the stream, rather than an effect from the pond discharge.

Other than for the anomalous peak discussed above, the CFBOD at this site remained constant throughout each day regardless of the peak discharge periods from the pond. There is no evidence at this site of the discharge having any effect upon the CFBOD of the stream (other than perhaps a trivial increase in the stream during the

period 0415-1000 on 29 January. The 'increase' is within the margin of uncertainty for a CFBOD measurement).

The results for 12-13 March and 21-22 April at this downstream site are identical to the CFBOD measurements from the upstream site, indicating that these concentrations represent a 'baseline' level in a stream under non-discharge conditions.

**Dissolved reactive phosphorus:** the analytical results for dissolved reactive phosphorus (DRP) are shown in figures 16-19 in Appendix IV.

During the afternoon of 28 January, the stream showed a slight peak in chloride concentration at about 3.30 pm (i.e. there was a peak in a discharge into the stream evident at this time). The dilution of the discharge at this point in the stream (which includes bank seeps entering the stretch above Site 2b) at this time was 1:180. This means that without any in-stream assimilation, the theoretical in-stream concentration of DRP should have been increased by  $0.19 \text{ gm}^{-3}$  at this point. However, the level of DRP had in fact returned to its baseline DRP concentration of  $0.1 \text{ gm}^{-3}$  by this point about 120 metres below the discharge zone.

That is, at a dilution rate of 1:180, the concentration of DRP in the stream had been attenuated to background levels within 120 metres below the discharge.

The 28-29 January monitoring showed a short sharp peak of in-stream DRP at  $0.3 \text{ gm}^{-3}$ , for an hour between 7.30 and 8.30 am on 29 January, before a rapid decline back to baseline levels for this site ( $0.1 \text{ gm}^{-3}$ ). However, it must be noted that the peak lasted for only an hour. The bio-monitoring conducted upstream of and close to this site found a very high quality in-stream ecological community at this point.

The dilution of the discharge at this point in the stream (which allows for bank seeps entering the stretch above Site 2b) was 1:28. This means that without any in-stream assimilation, the theoretical in-stream concentration of DRP should have been increased by  $1.24 \text{ gm}^{-3}$  at this point. However, as described above, the level of DRP was in fact  $0.31 \text{ gm}^{-3}$  at its peak- that is, it had been increased by only  $0.21 \text{ gm}^{-3}$ . Effectively the DRP had been reduced by  $1.03 \text{ gm}^{-3}$ , or by 84%, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of 1:28, the concentration of DRP in the stream had been attenuated by 84% within 120 metres below the discharge.

Review of the data for the monitoring conducted on 4-5 February shows two peaks in DRP, at about 10.30 pm and again at 10.30 am the next morning (the latter showing the highest level of DRP during this monitoring particular period). The dilution of the discharge within the stream at these times was 1:56 and 1:49, respectively. This means that without any in-stream assimilation, the theoretical in-stream concentration of DRP should have peaked at  $0.62 \text{ gm}^{-3}$  and  $0.71 \text{ gm}^{-3}$  above baseline level ( $0.1 \text{ gm}^{-3}$ ) at this point. The levels of DRP in fact increased by  $0.08 \text{ gm}^{-3}$  and  $0.11 \text{ gm}^{-3}$  respectively, a reduction in the expected increase of about  $0.5-0.6 \text{ gm}^{-3}$  or by 87% and 85% respectively, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of around 1:50, the concentration of DRP in the stream had been attenuated by about 85% within 120 metres below the discharge on this occasion.

The attenuation of DRP at Site 2b under various rates of initial dilution are shown in Table 8.

**Table 8** Rates of in-stream DRP removal at 120 metres

Dilution rate	DRP removal	
	Absolute, gm <sup>-3</sup>	% of initial
1:28	1.03	84
1:49	0.60	85
1:56	0.54	87
1:180	0.19	100

Discharge from the pond system ceased after 4 February. The results of analyses for DRP in the downstream samples collected on 12-13 March and 21-22 April confirm that there is no evidence of high background levels of DRP entering the stream via groundwater seeps, as the results are identical to the concentrations of DRP found upstream of the discharge zone.

The upstream site had DRP levels of around 0.04 gm<sup>-3</sup>. These levels are above the ANZECC guideline value for protection of in-stream ecology of 0.03 gm<sup>-3</sup>. As noted in the discussion on levels of ammonia, an exceedance of a guideline value does not imply there will actually be adverse effects, only that the potential for such effects increases. The bio-monitoring conducted upstream of and close to this site found a very high quality in-stream ecological community at this point.

**E coli and faecal coliforms:** results for E coli and faecal coliforms were almost identical, which is not surprising as almost all faecal coliforms are found to be E coli in freshwater systems with animal sources of excreta.

The analytical results for bacteriological monitoring are shown in figures 20-27 in Appendix IV.

During the afternoon of 28 January, the stream showed a slight peak in faecal coliform numbers at about 2.30 pm (i.e. there was a peak in a discharge into the stream evident at this time), with a lesser peak at about 6.30 pm. With animals grazing above the stretch of stream between the discharge from the pond and the sampling point, there could have been deposition of animal excrement at any time. This could confuse interpretation of data.

The dilution of the discharge at this point in the stream (which includes bank seeps entering the stretch above Site 2b) at this time was 1:180. This means that without any in-stream assimilation, the theoretical in-stream concentration of faecal coliforms should have been increased by 425/100 ml at this point. However, the numbers of faecal coliforms, while variable, had in fact returned to the range of values for faecal coliforms found above the discharge, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of 1:180, the numbers of faecal coliforms in the stream appear to have been attenuated to background levels within 120 metres below the discharge.

The 28-29 January monitoring showed a short sharp peak of in-stream faecal coliform numbers to 4100/100ml, at 7.30 on 29 January, before a decline back to baseline levels for this site.

The dilution of the discharge at this point in the stream was 1:28. This means that without any in-stream assimilation, the theoretical in-stream concentration of faecal coliform numbers should have been increased by about 2750 at this point. This was in fact the increase found. This result is not surprising, as faecal coliforms are inactivated by sunlight and this discharge occurred in the early morning.

Review of the data for the monitoring conducted on 4-5 February shows two peaks in numbers of faecal coliform, at about 10.30 pm and again at 9.30 am the next morning. For faecal coliforms, the evening count showed the highest level during this monitoring particular period. The dilution of the discharge within the stream at these times was 1:56 and 1:49, respectively. This means that without any in-stream assimilation, the theoretical in-stream counts of faecal coliforms should have peaked at 2300 and 2700 counts above the baseline count at this point. However, all counts throughout the sampling period (even the peak counts) were below the numbers of faecal coliforms found above the discharge zone during this sampling period. Clearly there has been significant reduction in faecal coliforms within the stretch of stream above the sampling point.

Using an alternative approach to estimating potential concentrations below the discharge point, it is noted the baseline counts at Site 2b on 4-5 February are around 600/100 ml. Using this count rather than the upstream count, then at the times of peak increase in faecal coliform counts downstream, counts of 2900 and 3300 could have been expected, against actual counts of 2600 at 10.30 pm and 2100 at 9.30 am. This indicates there was a reduction in the expected increase, in the order of about 300/100ml for the evening sample and 1200/100ml for the morning sample, or a reduction of 13% and 44% respectively, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of around 1:50, the numbers of faecal coliforms in the stream had been attenuated by between 13 and 44% within 120 metres below the discharge on this occasion (noting that depending on upstream counts at this time, the reduction could have been as high as 100%). Given the uncertainties inherent in monitoring faecal coliform numbers over a diurnal cycle, the figures in Table 9 below should be treated with caution, and the lower rates of removal during darkness should be noted.

**Table 9** Rates of in-stream faecal coliform removal at 120 metres

Dilution rate	faecal coliform numbers removal		
	Absolute, #/100ml	% of initial	comments
1:28	0	0	Early morning
1:49	1200 or more	44-100	Morning
1:56	300 or more	13-100	night
1:180	425	100	Afternoon

Discharge from the pond system ceased after 4 February. The results of analyses for numbers of faecal coliforms in the downstream samples collected on 12-13 March and 21-22 April are generally constant and consistent with counts from upstream, with small sharp peaks (e.g. at 1.30 am on 22 April) indicating some intermittent source (such as an animal defecating).

**Total phosphorus:** the analytical results for total phosphorus (TP) are shown in figures 32-35 in Appendix IV.

The pattern of in-stream TP at site 2b closely resembled that of dissolved reactive phosphorus, across all four sampling occasions, although generally at about double the DRP concentration.

During the afternoon of 28 January, the stream showed a slight peak in chloride concentration at about 3.30 pm (i.e. there was a peak in a discharge into the stream evident at this time). The dilution of the discharge at this point in the stream (which includes bank seeps entering the stretch above Site 2b) at this time was 1:180. This means that without any in-stream assimilation, the theoretical in-stream concentration of TP should have been increased by  $0.29 \text{ gm}^{-3}$  at this point. However, the level of TP in fact remained at a baseline TP concentration of about  $0.1\text{-}0.15 \text{ gm}^{-3}$  throughout the afternoon at this point about 120 metres below the discharge zone. This baseline level was marginally higher than measured upstream ( $0.048 \text{ gm}^{-3}$ ). Assuming that the difference between upstream and downstream sites indicates an actual increase through this stretch due to the pond discharge, then 69% of the TP was removed (through either sedimentation or uptake) by this point.

That is, at a dilution rate of 1:180, the concentration of TP in the stream had been attenuated by  $0.25 \text{ gm}^{-3}$ , or 69%, within 120 metres below the discharge.

The 28-29 January monitoring showed a short sharp peak of in-stream TP at  $0.80 \text{ gm}^{-3}$ , for an hour between 7.30 and 8.30 am on 29 January, before a rapid decline back to baseline levels for this site.

The dilution of the discharge at this point in the stream (which allows for bank seeps entering the stretch above Site 2b) was 1:28. This means that without any in-stream assimilation, the theoretical in-stream concentration of TP should have been increased by  $1.83 \text{ gm}^{-3}$  at this point. However, the level of TP was in fact  $0.80 \text{ gm}^{-3}$  at its peak- that is, it had been increased by only  $0.75 \text{ gm}^{-3}$ . Effectively the TP had been reduced by  $1.08 \text{ gm}^{-3}$ , or by 60%, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of 1:28, the concentration of TP in the stream had been attenuated by 60% within 120 metres below the discharge.

National water quality guidelines indicate that TP should remain below  $0.03 \text{ gm}^{-3}$  (80% of all results) for the protection of streams against undesirable aquatic growths. The TP at this point was above this value at all times, generally about  $0.1\text{-}0.15 \text{ gm}^{-3}$  and reaching a peak of  $0.8 \text{ gm}^{-3}$ . (The TP at the site above the discharge was also at all times above the national guideline). It should be noted however that the bio-monitoring conducted upstream of and close to this site found a very high quality in-stream ecological community at this point. As noted in the discussion on levels of

ammonia, an exceedance of a guideline value does not imply there will actually be adverse effects, only that the potential for such effects increases.

Review of the data for the monitoring conducted on 4-5 February shows two peaks in TP, at about 10.30 pm and again at 1030 am the next morning (the latter showing the highest level of TP during this monitoring particular period). The dilution of the discharge within the stream at these times was 1:56 and 1:49, respectively. This means that without any in-stream assimilation, the theoretical in-stream concentration of TP should have peaked at  $0.92 \text{ gm}^{-3}$  and  $1.05 \text{ gm}^{-3}$  above baseline level ( $0.048 \text{ gm}^{-3}$ ) at this point. The levels of TP in fact increased by  $0.52 \text{ gm}^{-3}$  and  $0.86 \text{ gm}^{-3}$  respectively, a reduction in the expected increase of about  $0.4\text{-}0.2 \text{ gm}^{-3}$  or by 57% and 19% respectively, by this point about 120 metres below the discharge zone.

That is, at a dilution rate of around 1:50, the concentration of TP in the stream had been attenuated by about 20-60% within 120 metres below the discharge on this occasion.

**Table 10** Rates of in-stream TP removal at 120 metres

Dilution rate	TP removal	
	Absolute, $\text{gm}^{-3}$	% of initial
1:28	1.08	60
1:49	0.20	19
1:56	0.40	57
1:180	0.25	69

Discharge from the pond system ceased after 4 February. The results of analyses for TP in the downstream samples collected on 12-13 March and 21-22 April confirm that there is no evidence of high background levels of TP entering the stream via groundwater seeps, as the results are similar to the concentrations of TP found upstream of the discharge zone. In the sampling run of 12-13 March, the downstream results were about half of those found upstream, while in the 21-22 April run the downstream results were close to although marginally lower than those at the upstream site.

**Turbidity:** the analytical results for turbidity are shown in figures 36-39 in Appendix IV.

Turbidity levels followed a pattern similar to that shown for ammonia, chloride and conductivity, indicating that the pond discharge was one source of turbidity in the stream. The highest result during the period when the pond was discharging occurred on the afternoon of 28 January; other than at peak discharge periods turbidity at this site 120 metres below the discharge averaged around 4 NTU during the time the pond was discharging. While turbidity was lower on 12-13 March (no discharge), turbidity levels on 21-22 April included one maximum result (10 NTU) and an overall average turbidity (6-7 NTU) that were both higher than when there was a discharge i.e. the worst turbidity in the stream was found while there was no discharge.

The ANZECC guidelines suggest a target value for turbidity in unmodified or slightly modified streams, of 5.6 NTU, with the median turbidity to be compared with this guideline. During the period while a discharge was occurring, the turbidity at Site 2b met this guideline. After discharge had ceased, the turbidity at Site 2b met

this guideline during one period of sampling and did not meet it for the second period. Turbidity at Site 2b was higher than at Site 1 upstream, on all occasions.

#### 4.4 Site 4

An automatic sampler was set up at Site 4, some 630 metres below the discharge zone, on four occasions: 28-29 January, 4-5 February, 12-13 March, and 21-22 April. The sampler was set to collect 4 samples at quarter hourly intervals into the same bottle, before advancing to the next bottle of the sequence. Sampling continued for 24 hours on each sampling occasion.

The full set of results for Site 4 is given in Appendix V.

Photograph 5 shows the features of Site 4.



**Photograph 5** Sampling site 4

**Ammonia:** the analytical results for ammonia at Site 4 are shown in figures 40-43 in Appendix VI.

For 28-29 January, all ammonia levels at Site 4 remained below  $0.03 \text{ gm}^{-3}$ , and averaged around  $0.02 \text{ gm}^{-3}$ . This is the same concentration that was found at Site 1, above the discharge. The peak of  $2.66 \text{ gm}^{-3}$  that occurred at Site 2b in the morning of 29 January from 6.30 onwards was not detected at Site 4 at any time, although sampling continued until 9.45 am. For the sampling period 4-5 February, it was found that the pattern of peaks at Site 2b was repeated at Site 4. The evening peak at 10.30 pm at Site 2b was repeated at 2.30 am at Site 4 (i.e. 4 hours later), while the morning peak at 10.30 am at Site 2b was repeated at 12.30 at Site 4 (2 hours later). However, the key point is that the peaks at Site 4 were only at 10% of the values at Site 2b, and if the baseline concentration of ammonia (as found at Site 1 and at the minimum concentrations found at Site 4) is taken into account, the removal of ammonia between Sites 2b and 4 was greater than 95% during this period.

The ammonia levels at Site 4 in March and April were at the same levels as Sites 1 and 2b. That is, any infiltration from bank seepages that might have been occurring was being assimilated as quickly as it occurred.

**Nitrite-nitrate:** the analytical results for nitrite-nitrate nitrogen (NNN) are shown in figures 64-67 in Appendix VI.

For 28-29 January, there was no difference in NNN levels between Sites 2b and 4, except that a peak of NNN around 8.30 am on 29 January at Site 2b was not repeated at Site 4. The peak was about 1 gm<sup>-3</sup> above the baseline concentrations occurring at Site 2b.

On 4-5 February, the pattern of NNN at both of the sites was very similar, varying from below 1 gm<sup>-3</sup> to just above 2 gm<sup>-3</sup>, except for one result at Site 4 that spiked upwards by another 1 gm<sup>-3</sup> over the concentrations before and afterwards. Other than this anomaly, NNN levels at Site 4 were marginally lower than corresponding values at site 2b throughout the 24 hours of sampling. Taking into account the reduction in ammonia between Sites 2b and 4, of up to 1 gm<sup>-3</sup>, this indicates that there was significant removal of total nitrogen overall from the water column between the two sites during this period. However, in March and April there was no significant reduction in overall nitrogen between the two sites, with concentrations of both ammonia and NNN similar at both sites on both occasions.

Further analysis of the 'spike' in NNN at Site 4 at about 12.30 on 4 February indicates that its source was most likely other than the pond discharge i.e. an animal voiding into the stream between the two sites. There was a matching spike in chloride and conductivity concentrations at Site 4 at the same time, to levels much higher than occurred at Site 2b prior to the event at Site 4; and given its brevity the 'spike' indicates an instantaneous event rather than one that continued for even only a couple of hours. If this is the case, then it indicates that the ammonia within the animal wastes were fully nitrified within the distance from the point of discharge to Site 4, as the increase in ammonia at Site 4 at this time was trivial in absolute terms.

The peak on the afternoon-evening of 4 February occurred between 21.30 and 22.30 at Site 2b, and 3 hours later at Site 4; the morning peak of 5 February had a 2-hour delay in its manifestations between Site 2b and Site 4.

**Carbonaceous filtered biochemical oxygen demand:** the results for CFBOD are shown in Table 11 and in Appendix VII. CFBOD was analysed on composite samples, prepared by further compositing six one-hour composite samples. Table 11 also presents 'unassimilated' data. These data are calculated on the basis of the prevailing rate of dilution of the discharge for the time period over which each sample was collected, and represent the CFBOD that would be expected in the stream if there was no mechanism of assimilation and attenuation.

**Table 11** CFBOD at Site 4

Sampling run	Time	Result gm <sup>-3</sup>	'Unassimilated' result	% reduction
28-29 Jan	1015-1600	1.5		
	1615-2200	1.3	2.1	38%
	2215-0400	1.4		
	0415-1000	1.0	7.5	87%

Sampling run	Time	Result gm <sup>-3</sup>	'Unassimilated' result	% reduction
4-5 Feb	1015-1600	0.7		
	1615-2200	0.7	2.8	75%
	2215-0400	0.6		
	0415-1000	0.7	3.1	77%
12-13 March	1015-1600	0.7	Not applicable	
	1615-2200	0.6		
	2215-0400	0.6		
	0415-1000	0.9		
21-22 April	1015-1600	0.8		
	1615-2200	0.7		
	2215-0400	0.7		
	0415-1000	<0.5		

All CFBOD results satisfy the relevant concentration criterion within the Plan for a dairy shed pond discharge to be categorised as 'controlled'. There is no evidence at this site of the pond discharge having any effect upon the CFBOD of the stream. Concentrations remain consistent throughout each h 24 hour monitoring period.

The differences in CFBOD between Sites 2b and 4 (as between Sites 1 and 4) once pond discharge had stopped are negligible.

**Chloride and conductivity:** the analytical results for chloride and conductivity are shown in figures 44-51 in Appendix VI.

These parameters are conservative i.e. they are not affected by in-stream processes, and can therefore be reviewed to indicate discharges of a different nature to the existing in-stream quality. As noted above, a spike in chloride and conductivity (found in only one sample) at Site 4 indicates an instantaneous event, such as an animal voiding into or near the stream, between sites 2b and 4 around noon on 4 February.

Other than for these two specific events, chloride and conductivity at the two sites are almost identical for each of the 4 days of sampling, and across all four days (i.e. over three months). This is not surprising, as sampling was determined by fine weather (no overland runoff of rainwater) and the base flow in the stream is fed by groundwater seeps which will not vary markedly over one season or over a short distance of homogenous landform. There is some evidence of attenuation of the pond discharge in the record for 4-5 February, between the two sites. While the average chloride for the two sites is identical for this period, the range between the highest and lowest values is almost 50% greater at the higher site, closer to the discharge point.

**Dissolved reactive phosphorus:** the analytical results for dissolved reactive phosphorus (DRP) are shown in figures 52-55 in Appendix VI.

Review of the DRP data for Site 4 shows in-stream assimilation of DRP continues to occur between Sites 2b and 4. The peak in the value of DRP at Site 2b in the morning of 5 February, increasing from a baseline value of less than 0.1 gm<sup>-3</sup> to more than 0.3 gm<sup>-3</sup> for a couple of hours before returning to baseline, was not detected at Site 4. While this may have been because sampling at Site 4 concluded before the parcel of water containing the higher concentration of DRP arrived (although calculation of

travel times on other occasions indicated that this could have been expected), the DRP results on 4-5 February are consistently lower at Site 4 than at Site 2b (other than the brief spike detected at Site 4 but not at Site 2b that is discussed earlier), by 25%-0.109 gm<sup>-3</sup> instead of 0.142 gm<sup>-3</sup>.

Once discharge from the pond ceased, DRP concentrations at the two sites were very consistent, and also consistent with Site 1 above the ponds, indicating that a DRP concentration of around 0.03-0.04 gm<sup>-3</sup> represents a residual level for the stream.

**E coli and faecal coliforms:** the analytical results for E coli and faecal coliforms are shown in figures 56-63 in Appendix VI.

On most sampling periods there is evidence of continuing in-stream attenuation of levels of coliforms. A peak of 4400 cfu/100 ml at 7.30 am on 29 January at Site 2b had reduced to 2500 cfu/100 ml at 9.30 at Site 4. On 4 February, a count of 2600 cfu/100 ml at 22.30 at Site 2b had been reduced to 1500 cfu/100 ml at Site 4 when it arrived at Site 4 3 hours later, while a count of 1400 cfu/100 ml at 1.30 am on 22 April at Site 2b reduced to 630 cfu/100 ml at Site 4 an hour later. These reductions ranged between 42% and 55% of the original counts.

Counts at Site 4 in March and April were very similar to those at Site 1, as to be expected (with the exception of a small spike at Site 2b on 22 April that was still discernible when the water body arrived at Site 4, as discussed in the preceding paragraph).

**Total phosphorus:** the analytical results for total phosphorus (TP) are shown in figures 68-71 in Appendix VI.

Review of the TP data for Site 4 shows in-stream assimilation of TP continues to occur between Sites 2b and 4. The peak in the value of TP at Site 2b in the morning of 5 February, increasing from a baseline value of around 0.15 gm<sup>-3</sup> during daylight and 0.1 gm<sup>-3</sup> overnight to more than 0.8 gm<sup>-3</sup> for an hour before returning to baseline, was not detected at Site 4. While this may have been because sampling at Site 4 concluded before the parcel of water containing the higher concentration of TP arrived (although calculation of travel times on other occasions indicated that this would have been expected), the TP results on 4-5 February are consistently lower at Site 4 than at Site 2b (other than the brief spike detected on 5 February at Site 4 but not at Site 2b that is discussed earlier), by 20%- 0.220 gm<sup>-3</sup> instead of 0.277 gm<sup>-3</sup>. DRP represents half of the TP at each site.

There is also some evidence of further attenuation of the pond discharge between the two sites in the record for 4-5 February. The range between the highest and lowest values of TP is more than 200% greater at Site 2b, closer to the discharge point, than at Site 4. That is, both attenuation and removal of TP is occurring in this stretch of the stream, at these levels of TP.

Once discharge from the pond ceased, TP concentrations at the two sites were very consistent, and also consistent with Site 1 above the ponds, indicating that a TP concentration of around 0.06-0.09 gm<sup>-3</sup> represents a residual level for the stream. On 4-5 March, results for TP at sites 2b and 4 were lower than upstream at Site 1. Interestingly enough, this baseline level of TP is still comparatively much higher than

the ANZECC guideline for TP for the purposes of preventing undesirable growths- $0.03 \text{ gm}^{-3}$ .

**Turbidity:** the analytical results for turbidity are shown in figures 72-75 in Appendix VI.

The periods of lowest turbidity occurred both on 28-29 January (discharge occurring) and on 12-13 March (no discharge). Turbidity levels on 21-22 April were found to have an overall average turbidity (6.5 NTU) that was both than when there was a discharge i.e. the worst turbidity in the stream at Site 4 was found while there was no discharge. Turbidity at Site 4 was higher than at Site 1 upstream, on all occasions i.e. turbidity increased in a downstream direction regardless of any point source discharge.

The ANZECC guidelines suggest a target value for turbidity in unmodified or slightly modified streams, of 5.6 NTU, with the median turbidity to be compared with this guideline. During the period while a discharge was occurring, the turbidity at Site 4 met this guideline (all results during 28-29 January, average of all results on 4-5 February). After discharge had ceased, the turbidity at Site 4 met this guideline during one period of sampling and was marginally above it for the second period (by 0.9 NTU).

## 4.5 Site 5

An automatic sampler was set up at Site 5, some 1.4 km below the discharge zone, on four occasions: 28-29 January, 4-5 February, 12-13 March, and 21-22 April. The sampler was set to collect 1 sample every hour into a separate bottle. Sampling continued for 24 hours on each sampling occasion. However, mechanical and software malfunctions with the sampler meant that a complete set of samples were not collected on each sampling run. The samples collected by the automatic sampler were supplemented with samples collected manually.

A full set of laboratory results is attached in Appendix VII, while the results are graphed against time in Appendix VI, on the same graphs that contain the data from Site 4.

**Ammonia:** the analytical results for ammonia are shown in figures 40-43 in Appendix VI.

The concentration of ammonia in all samples collected from Site 5 was about or below  $0.02 \text{ gm}^{-3}$ , the same concentrations present upstream above the farm pond discharge point. Concentrations were lower than those occurring at Site 4, but the latter were already very low and the difference is not meaningful environmentally. The short peak value in ammonia at Site 4 on 4 February (just above  $0.1 \text{ gm}^{-3}$ ) had dissipated fully by the time the water body reached Site 5.

**Nitrite-nitrate nitrogen:** the analytical results for nitrite-nitrate nitrogen (NNN) are shown in figures 64-67 in Appendix VI.

With only a couple of data points for NNN at Site 5 for the 28-29 January run, any interpretation is only tentative. It is noted that NNN measured at Site 5 was slightly

lower than any results at Site 4, suggesting a degree of removal. With ammonia also being lower at Site 5 than Site 4, this indicates that removal of total nitrogen, not just transformation of nitrogen species, was occurring.

On 4-5 February, the pattern of NNN at both of the sites was quite different, with the peak value at Site 5 being only one-third of that measured at Site 4. Generally the values of NNN at Site 5 were around the lowest of NNN values at Site 4. In conjunction with evidence of substantially lower relative ammonia concentrations at Site 5 (see above), removal of total nitrogen was again demonstrated. This continues the trend of removal of total nitrogen between sites 2b and 4 at this time. However, in March and April there was no significant reduction in overall nitrogen between the two sites 4 and 5, just as there was no significant removal between sites 2b and 4. This is particularly evident in April.

**Carbonaceous filtered biochemical oxygen demand:** the results for CFBOD at Site 5 are shown in Table 12 and in Appendix VII. Due to malfunctions of the composite sampler, at Site 5 CFBOD was analysed on both grab and composite samples.

**Table 12** CFBOD at Site 5

Sampling run	Time	Result gm <sup>-3</sup>
28-29 Jan	1030-2000 and 0830-1000	1.3
	0840 (grab)	1.1
	All samples, 28-29 Jan	1.7
4-5 Feb	Composited from grab samples at 0737, 0825, 1216, and 1530 (4 Feb) and 0914 (5 Feb)	0.7
12-13 March	1000-2400 (12 Mar)	0.8
	0930 (grab)	0.6
21-22 April	0930 (21 Apr) (grab)	0.6
	1030-1900	1.3
	1030 (22 Apr) (grab)	0.6

All CFBOD results satisfy the relevant concentration criterion within the Plan for a dairy shed pond discharge to be categorised as 'controlled'. There is no evidence at this site of the pond discharge having any effect upon the CFBOD of the stream. Concentrations remain consistent throughout each 24 hour monitoring period.

The differences in CFBOD between Sites 4 and 5 (as between Sites 1 and 5) are negligible throughout the survey.

**Chloride and conductivity:** the analytical results for chloride and conductivity are shown in figures 44-51 in Appendix VI.

The values for conductivity and chloride at Site 5 were identical to the baseline levels at Site 4, and at Site 1. A spike in conductivity and chloride at Site 4 at 12.30 on 4 February had dissipated fully by the time the water body reached Site 5.

**Dissolved reactive phosphorus:** the analytical results for dissolved reactive phosphorus are shown in figures 52-55 in Appendix VI.

DRP at Site 5 was lower (during the period of pond discharge) or similar (subsequent to discharge ceasing) to that at Site 4. The reduction between sites 4 and 5 was slightly greater than that between sites 2b and 4 (the distance between the two sites is also greater), but there is insufficient data to draw any conclusions about the rate of reduction.

The consistency in levels of DRP at the two sites once the discharge from the pond ceased, (and their similarity to sites 1 and 2b) indicates that these are residual levels for this waterway. This in turn calls into question the meaningfulness of a national guideline for the prevention of undesirable aquatic growths for DRP/TP of  $0.03 \text{ gm}^{-3}$ , lower than the concentrations found in the stream at any time at any site.

**E coli and faecal coliforms:** the analytical results for E coli and faecal coliforms are shown in figures 56-63 in Appendix VI.

Counts of E coli and faecal coliforms at Site 5 appeared consistently lower than at Site 4, although the disjointed samplings record during the first two runs in particular means that this cannot be conclusively demonstrated. Counts at Site 5 were also consistently lower than those at Site 1 above the discharge, even for the period when discharge was occurring. The highest bacteriological count at Site 5 in the January run was 500cfu/100 ml (cf 1600 at Site 1), in February 950cfu/100 ml (cf 3500), and in March 270cfu/100 ml (cf 470). Only in April were the two sites similar- 290cfu/100 ml at Site 5 cf 220 at Site 1.

**Total phosphorus:** the analytical results for total phosphorus (TP) are shown in figures 68-71 in Appendix VI.

Review of the TP data shows that on 2 of the sampling periods, attenuation of TP continued between sites 4 and 5, particularly on 4-5 February when there were pronounced peaks in TP at Site 4 (as there was also for DRP) that were absent at Site 5. TP had reduced by 20% between sites 2b and 4 on this occasion; the additional reduction between sites 4 and 5 was 45%.

During the sampling run of 12-13 March, TP was actually higher at Site 5 than at Site 4 for 3 of the 8 samples, even though DRP was lower; examination of the turbidity data (not yet discussed) shows that this was also higher at Site 5 on this occasion. The implication is that there was some small and intermittent discharge of soil into the stream between sites 4 and 5 on this occasion. This scenario is consistent with the fact that no other parameters showed an increase between sites 4 and 5 at this time.

On 21-22 April, concentrations of TP were very close for the 2 sites.

Concentrations of TP at Site 5 were very consistent throughout the survey, with the exception of the few samples on 12-13 March that showed a slight elevation. This indicates that TP at this site was at a baseline level for the stream, around double the level of DRP.

**Turbidity:** the analytical results for turbidity are shown in figures 72-75 in Appendix VI.

Review of the turbidity data shows that generally, turbidity is not attenuated between sites to the same extent as nutrients. Peaks in turbidity during the four sampling periods at sites 2b and 4 were not evident at Site 5, but otherwise the pattern and value of data at Site 5 were similar to and only slightly less than data for the other two sites. As noted above in the discussion of TP, there was one isolated spike in turbidity measured at Site 5 on 12 March. There was a similar spike at Site 2b (but not evident at Site 4) some three hours earlier; this may have been co-incident.

Turbidity at Site 5 on 21-22 April, a non-discharge period, was higher than during discharge periods monitored in January and February.

## 4.6 Mass loadings

Heavy rain on 21-22 April raised the stream flow at a time when there was no discharge from the effluent treatment pond system. This allows a comparison of the mass flows of contaminants discharged from the pond system and occurring under conditions of stormwater run-off.

Caution should be exercised in making the comparison, as to how indicative and significant the results are. Run-off into a stream is a function of many variables- rainfall intensity and duration, the preceding degree of saturation of the soil, the contour of the landscape, characteristics of vegetation cover across the landscape and on riparian margins, drainage patterns, and so on. In-stream concentrations of contaminants also change during a rainfall event, from a first flush peak.

With these provisos in mind, the daily mass discharge from the pond system in February is compared with the stream daily mass discharge during the rain event of 22 April, in the table below.

The volume discharged from the pond daily was calculated on the basis of the discharge monitoring of 4 February (Table 13), with an allowance for the afternoon milking session to produce a discharge volume that was 75% of that for the morning session. The calculated morning discharge volume was based on the entire discharge from 0930 to 1230.

**Table 13** Comparison of mass flows- pond discharge and in-stream flood conditions

Contaminant	Daily mass discharge- pond gday <sup>-1</sup>	Daily mass discharge-flooded stream gday <sup>-1</sup>
Ammonia	280	150
Nitrate	<1	3500
BOD	440	9600
DRP	114	150
TP	170	300

As can be seen, the mass loadings within the stream for almost all contaminants of interest are very substantially higher during the rainfall event than due to the pond

discharge. In other words, a rainfall event can impose a much greater loading of contaminants upon a stream system than a treatment pond discharge.

While the pond system is the source of a larger daily ammonia loading than a rainfall event, the total nitrogen loading during the rainfall event in question was well over 30 times greater than that originating from the pond system. In other words, a single rainfall event can cause as much nitrogen loading on a stream, as a month of discharge from a treatment pond.

The loadings of total phosphorus and dissolved phosphorus due to the rainfall event were both higher than occur due to a pond discharge, but in this case the difference was only 60%. The organic loading due to the rainfall event was again much higher than occur due to the pond discharge. In this case the difference was 8 times greater. In other words, a single rainfall event can cause as much organic loading on a stream, as more than a week of discharges from a treatment pond.

## 5. Discussion

As explained in Section 1.5, this study involved a higher strength than typical dairy shed pond system wastewater discharging into a stream where dilution was less than recommended. The study of in-stream assimilation therefore represents a 'worse case' scenario than would apply in the majority of cases in Taranaki.

Under the Council's *Regional Freshwater Plan for Taranaki*, the dilution required for a dairy discharge to be assessed as a 'controlled' activity is 1:100 at all times. At this site, the dilution prevailing at the start of the study was approximately 1:200, for a high-strength waste (representative of an under-sized rather than correctly sized pond system) due to the presence within the pond of a large volume of accumulated sludge. Under these circumstances, a high quality in-stream ecosystem was found to be present 120 metres below the discharge point. The flow from the pond was prolonged for several hours on each discharge occasion. When the discharge pipe was cleared, the dilution rate fell to 1:30-1:40 at peak flow rates- a dilution rate which would not have been open for consideration as a 'controlled' activity, even though under the two alternative flow regimes the mass discharge of contaminants (and therefore presumably the in-stream effects) would be identical. The implication is that a short duration dairy pond discharge of low dilution will have only a negligible effect beyond the standard mixing zone; but this hypothesis was not tested, and a 'controlled' activity provision requires a high degree of certainty and robustness. Thus, the current Plan's provision of 1:100 'at all times' for a controlled activity is conservative but considered appropriate in the level of protection it affords.

The biological survey showed that the stretch of stream studied, located towards the head waters of a lowland stream, was nevertheless of very high ecological quality. This is of significance when considering the value and place of first-order streams in the overall environment of the region. The effects of riparian vegetation are considered especially apparent from the good bio-monitoring results at several of the sites, confirming the valuable contribution of riparian vegetation to enhancing in-stream ecosystems.

Typically, MCI values in ringplain streams decline with increasing distance from their source, due to diffuse and point source discharges and changes in stream morphology and riparian shading. For a stream of the sort in this study, a typical rate of decline is considered to be 1-2 MCI units per kilometre (*pers comm* C Fowles). For the stream in question, there was actually an increase from Site 1 to Site 5 (102 increasing to 105), with significantly higher values at the site with the greatest degree of riparian shade, when a decline of 1.5-3 MCI units would have been expected in the distance between Sites 1 and 5. With marginal (insignificant) declines between Sites 1 and 5 in a couple of physicochemical water quality parameters, and other parameters consistent between the two sites, other environmental factors such as riparian planting must be playing a role in the increase in ecological condition observed below the discharge.

It was found that the removal of ammonia (including the mechanism of transformation to nitrate) occurs at a very significant rate (43-95%) within 120 metres of the discharge point, even under conditions of very low dilution (high in-stream concentration). The removal of nitrate proceeded at a lower rate, with continuing

removal of nitrate evident between Site 2b (120 metres below discharge) and Site 4 (450 metres below discharge), and further removal between Site 4 and Site 5 (1.55 kilometres below the discharge point). At Site 5, nitrate levels were the same as at the upstream site, Site 1, during periods of discharge (i.e. the nitrate was fully assimilated by this point), and after discharge ceased, nitrate levels at Site 5 were lower than at Site 1.

High nitrate levels were found throughout the stream in April, after the pond discharge had long since ceased, following a prolonged period of heavy rain. It appears this nitrate was driven by high groundwater tables. This is consistent with other Council data that shows high nitrate concentrations to be a wet weather/winter event in Taranaki, rather than a summer issue when the potential for the proliferation of undesirable aquatic growths is at its highest.

It was found that the removal of biochemical oxygen demand (a measure of the organic content) occurs at a very significant rate (33-77%) within 120 metres of the discharge point, even under conditions of very low dilution (high in-stream concentration). Even given that the discharge was higher than typical in BOD, at this downstream site all results except one met the Council's criterion for the permitted effects of a 'controlled' activity on in-stream BOD. Further reductions, to background concentrations, occurred by Site 4. That is, by 450 metres below the discharge point the BOD from the pond discharge was fully assimilated.

Because of high variability in indicators of bacteriological contamination such as counts of faecal coliforms, caution needs to be applied to the interpretation of the study's data. However, at the first downstream site (120 metres), faecal coliform removal was found to be between 0 and 100%- the lowest removal rate apparently being at the lowest dilution rate and in the morning, and high removal rates at greater dilution and in the afternoon. On most occasions while discharge was occurring, the counts of faecal coliforms were actually lower at the downstream site than the upstream site.

It was found that the removal of reactive dissolved phosphorus (a nutrient that can cause undesirable growths in higher concentrations) occurs at a very significant rate (84-100%) within 120 metres of the discharge point, even under conditions of very low dilution (high in-stream concentration). It was also found that even upstream of the discharge point DRP and TP always exceeded the ANZECC guideline for the maximum DRP and TP to avoid undesirable growths, yet the ecological quality of the stream's ecosystems was found to be very high. The rate of removal of total phosphorus was lower than for DRP; this is not surprising given that a proportion of TP is present in insoluble form, and is therefore less readily available. At 120 metres, removal of TP lay in the range 19-69%; at Site 4 a further 20% was generally removed during the period when discharge was still continuing. Further reduction of TP and DRP occurred through to Site 5, 1.55 kilometres below the discharge point. Once discharge ceased, sites 4 and 5 were very similar to the upstream site i.e. levels of TP and DRP were stable throughout the stream.

Overall, there was effective attenuation within 120 metres for ammonia and DRP, significant attenuation within 120 metres and effective attenuation within 450 metres for BOD and faecal coliforms, and effective attenuation within 1.55 kilometres for TP and nitrate. This suggests that if consideration of cumulative effects is to be given

effect to via explicit provisions within Council policies, then these provisions could apply where there are multiple discharges occurring within a distance that is less than those indicated above. This study indicates that a distance of 450 metres or somewhat less than this, is the most appropriate, as the more readily reactive contaminants are assimilated within this distance.



