Colour and Clarity of the Tarawera River
1991 – 2008

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Cover Photo: Tasman Pulp and Paper Mill and Tarawera River (2004) taken by Rob Donald.

Executive Summary

An assessment of colour and clarity trends in the Tarawera River was undertaken to update records from previous surveys and reports. As part of the field work a survey of light penetration in the Tarawera River was conducted in July/August 2007 and January/February 2008. Colour and clarity were assessed using existing compliance and regional monitoring data.

Colour in the Tarawera River is measured as the absorbance of filtered samples at 440nm and this data is then used to assess river state against the classification standards set in the Tarawera River Catchment Plan. The water colour at State Highway 30 (below the Tasman Mill treatment pond discharge) improved significantly between 1990 and 2000. From 2000 to 2007 colour has been variable but largely unchanged.

The Tasman Mill treatment pond discharge is in compliance with consent 02 4224 but the lower river does not meet the current classification standard for colour (applies from State Highway 30 down). The monitoring results show that this is because the river barely meets the classification standard at Onepu, upstream of the Tasman discharge. It is believed that this is due to other discharges, including the groundwater discharge of pulp mill effluent to the river from the rapid infiltration basins (RIB's) previously operated by the SCA tissue mill.

The Tarawera River between the Kawerau Bridge and the Onepu site (upstream of the Tasman discharge) is managed under the plan for aesthetic purposes and the classification standard requires that there be no decrease in visual clarity of more than 20%. The monitoring results show that this standard is also often not met. However, there may be future clarity improvements due to the cessation of discharges from the SCA tissue mill to the RIB's in May 2007.

Measurements of light penetration since 1993 have shown a consistent pattern of reduction downriver due to the industrial discharges. In 2007 a 66% decline in the euphotic depth (the depth at which 1% of the surface light occurs) was recorded between Kawerau Bridge and the lower river at Awakaponga (reduced from 5.8m to 2.0m). Between 1993 and 2007 light penetration in the lower river has improved by around 50%. The euphotic depth in these areas is now around 2.0m which means that submerged water plants or benthic algae could now grow throughout most of the river bed if substrates were suitable. Results also show seasonal trends in colour and clarity which need to be assessed when determining trends.

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Chapter 1: Introduction

1.1 Scope

This report presents survey results quantifying the water quality of the Tarawera River in terms of colour and clarity. It also forms part of the wider ongoing Tarawera River technical investigations, which have been conducted to provide data on impacts from industrial discharges to the lower river system. These studies provide environmental baseline and background information independent of any consent related monitoring requirements.

The goals of this study were:

(a) To update information on the colour and clarity of the Tarawera River; and

(b) Provide an assessment of temporal trends and whether the rules relating to colour and clarity set out in the Tarawera River Catchment Plan are being met.

1.2 Background

The Tarawera River is situated in the Eastern Bay of Plenty and flows from Lake Tarawera down to the sea at Matata. There have been concerns expressed for the water quality since the mid 1950's following the building of a pulp and paper mill which discharged industrial waste to the river just over 21 km from the sea. Pressure on the river increased as the mill was later expanded and another mill built, along with development of geothermal resources. Water quality declined to a very poor state in the late 1960's and on into the mid 1970's. Since then, industry began improving treatment of industrial wastes and mill processes to lessen the adverse environmental impacts on the rivers ecosystem. Despite improvements in water quality of the river, the perception held by many people up to the 1990's was that the river continued to be severely compromised.

With the introduction of the Resource Management Act in 1991, Environment Bay of Plenty became the agency primarily responsible for overseeing the continuation of river improvement. Extensive studies of the impacts of industrial pulp and paper mill wastewater, geothermal waste water, and sewage discharges on the ecology of the Tarawera River were conducted by Environment Bay of Plenty and the industrial users of the river in the early 1990's. Investigations provided technical information to assist with the development of a regional catchment plan to address public concerns and statutory requirements of the Resource Management Act. A summary covering a wide range of these research findings is presented in Donald (1994a, 1994b) and Bioresearches (1999).

One of the major concerns for the lower Tarawera River has always been colour. Since the early 1990's the Tarawera River has been continuously sign-posted by local residents as the "Black Drain". This label summed up the river's appearance and peoples strong concerns for its state. Water colour and clarity were key issues that were investigated and addressed under the "Regional Plan for the Tarawera River Catchment" (the Tarawera River Catchment Plan).

1.3 Colour and Clarity

Colour and clarity are important to people's perception of a water body. Clarity is also an important ecological parameter which can impact the health of a water body. Two of the most important optical processes responsible for colour and clarity of a water body are absorption and scattering. When a light beam travels through water some of the photons will be absorbed (absorption coefficient) while others will be scattered from the beam (scattering coefficient) which both add up to the beam attenuation coefficient. The beam attenuation coefficient can be easily measured as it is an inherent optical property and can be estimated from black disk measurements. However, in natural waters light penetration is often more complex due to suspended solids.

Colour of water is primarily determined in terms of hue and brightness. Hue depends on the wavelength distribution of the light backscattered from within the water. Clear pristine water appears blue due to red wavelengths being absorbed. Plankton absorbs blue light and hence gives a green hue to water. Brightness depends on the amount of light reflected back to the observer.

The high concentration and nature of dissolved organic compounds in pulp mill effluent make them highly light absorbing. This means that the brightness of the Tarawera River is very low and the hue (yellowish) is derived from a range of wavelengths. This results in very little light being reflected back giving the water a very dark colour appearance. The organic compounds in the mill effluent have some similarity to those of soil humic substances and the natural tannin stained waters of the South Island west coast streams.

In the Tarawera River Catchment Plan management of colour is achieved through the monitoring of absorption at 440 nm. The reason for the choice of 440 nm (blue light) is that absorption of light by chlorophyll-*a* peaks at this wave length. Thus measurements at this wavelength provide a measure of the degree of "competition" with aquatic plants for available light (MfE 1994). Clarity is also managed and protected with rules based on black disk measurement.

Chapter 2: Location and methods

2.1 Location

2.1.1 Tarawera River

The Tarawera River flows from the high quality (oligotrophic) Lake Tarawera to the coast at Matata, a distance of 60 km. Mean flow measured at Awakaponga is ~26 m^3s^{-1} over the last 20 years with a catchment area at this point of 906 km^2 (McLarin & Stringfellow 1997). The lower Tarawera River system is shown in Figure 1 with the river mouth in close proximity to that of the Rangitaiki River.

Volcanism has a major influence on the water quality and habitat of the Tarawera River and its tributaries. The very active Okataina volcanic centre surrounds Lake Tarawera. Mt Tarawera itself last erupted in 1886 and covered the upper Tarawera River in 30-100 cm of ash as far as Mt Putauaki (Mt Edgecumbe).

Historically, the Tarawera River was connected to the Rangitaiki River (which partly flowed out through the same mouth to the west of Matata) and was flanked by extensive wetlands that covered much of the lower Rangitaiki Plains. In the 1910's most of the Tarawera River below State Highway 30 was straightened. This resulted in the river flowing faster, having a higher scouring action and contributed to a decline in the quality and quantity of fish habitat. In 1914, the Rangitaiki River was diverted directly out to sea and a new entrance to the Tarawera River was opened in 1917.

The flow regime is constant due to the combination of the lake reservoir and the highly permeable pumice soils reducing surface runoff. High volumes of sand and pumice are transported down the river resulting in the bed being mobile, particularly in the lower reaches. Most benthic organisms have trouble existing in this type of habitat.

A number of natural features and industrial discharges influence the water quality of the Tarawera River. Numerous geothermal features including warm springs influence the headwaters of the catchment. Substantial natural and industrial geothermal inflow also occurs around Kawerau. Until recently two pulp and paper mills discharged effluent to the Tarawera River near Kawerau. The SCA mill is a bleached sulphonated-chemithermomechanical (CTMP) pulp mill producing tissue, light weight paper grades and specialty papers. Paper machine wastewater is treated via a clarifier and up until 1999 had been discharged to the river but now goes to the Tasman aeration ponds. Pulp mill wastewater had been treated via an anaerobic treatment system taking sewage from the town of Kawerau in addition to mill effluent, and discharging (mean 6,000 -8,500 m^3 day^{-1}) to the river and rapid infiltration basins (Bruere 2003). The pulp mill was closed down in May 2007 and there is no longer a direct discharge to the river.

The Tasman mill produces bleached kraft (Carter Holt Harvey) and newsprint from mechanical pulp (Norske Skog). From April 1998 the kraft mill ceased using chlorine gas (elemental chlorine) in its bleaching process and changed to chlorine dioxide, the by-products of which are less harmful to aquatic ecosystems. Effluent treatment occurs in an aerated pond system with a residence time of 4-5 days and a mean discharge rate from July 2006 to June 2007 of 1.7 m^3/s.

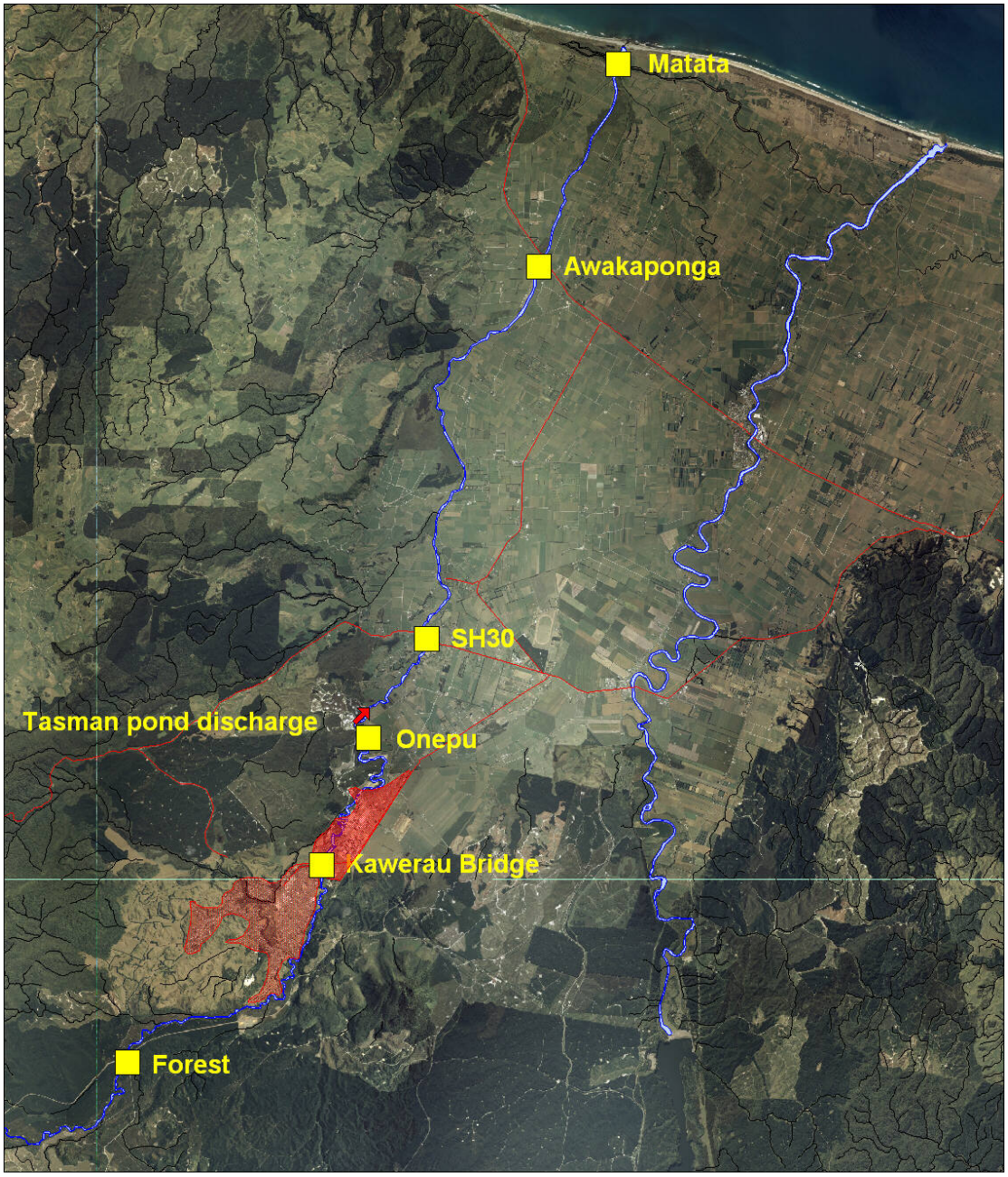

Figure 1 *Location of sampling sites and Tasman pond discharge on the Tarawera River.*

Colour and dissolved oxygen are now considered the main issues in the lower river (Dell et al. 1996). The large increases in colour are predominately due to the discharge of Kraft mill effluent. Downstream of the discharge the appearance of the river changes from a blue-green colour to a dark brown. Aside from the aesthetic effects, this change has ecological consequences as it results in reduced light penetration and clarity, though improvements have occurred since 2000.

2.1.2 Sampling sites

Location of sampling sites for measurement of colour and clarity of the Tarawera River are shown in Figure 1. A non-impact site for light measurement was located above the Kawerau Township in the forest to avoid any possible urban run off or geothermal influences further down the river. The Kawerau Bridge (Boyce Park) site is the reference site used in earlier studies and the Tarawera River Catchment Plan. It is located upstream of the rapid infiltration basins and previous river discharge point for industrial effluent from the SCA mill and above a number of storm water and geothermal discharges.

The Onepu site is also a reference site for assessing clarity in the Tarawera River Catchment Plan. It is above the main Tasman aeration ponds discharge but below the geothermal and former SCA mill discharges.

The State Highway 30 site is another reference site which is downstream of all the industrial discharges to the river and is located at the bridge crossing. Awakaponga and Matata sites are not reference sites for the Tarawera River Catchment Plan. They are included to provide a clear picture of the river's state along its entire length.

2.2 Methods

2.2.1 Colour

Water samples collected in glass containers from monitoring sites were returned to the laboratory and passed through a 0.45 micron filter. Colour of the filtered sample was then measured by the absorption coefficient at 440nm on a spectrophotometer.

2.2.2 Visual clarity (Black Disk)

Visual clarity measurements were taken using a standard matte black disk. Measurements were taken in river using a mirror to view the horizontal distance over which the black disk can be viewed and a tape to measure the distance. Black disk measurements are independent of ambient lighting and yield a scientifically valid and reasonably accurate estimate of the beam attenuation coefficient (reduction in strength of a light beam).

2.2.3 Light penetration

Measurement of light (photosynthetically available radiation – PAR) in the Tarawera River was made using a Licor light meter with flat diffusing plate which records average down-welling light. The meter was attached to a pole marked with depth graduations. To record light at each site, profiles were taken with measurements taken at the surface (just below to exclude reflectance effect) and then at 0.2 m intervals until the bottom of the river or 1.2 m depth was reached. In taking the light readings care was taken to ensure that cloud cover remained as constant as possible and that the meter was not shaded by the pole or operator or any other underwater object. On each sampling occasion three profiles of light penetration were taken. Measurements were recorded for all sites on 23, 24, 31 July and 5 August 2007 except the forestry site which was sampled on 24 July and 5 August 2007 and then at all sites on eight days between 25 January and 13 February 2008.

The measurements from each profile were then used to calculate the vertical light extinction coefficient (Vlec) according to the formula;

Vlec = (ln L1) – (ln L2)/D2-D1, where D1 is depth 1, D2 is depth 2 and L is the corresponding light measurement.

Euphotic depth, which is the depth at which 1% of the surface light occurs and percent of surface light at 2.0 m were then derived using a reworking of the formula. The final values presented in the report for each variable are averages derived from the series of profiles taken for the winter or summer surveys. For each sampling occasion (day) at any given site, measurements are repeated three times to provide a more reliable set of values for the profile.

Sampling was conducted under base flow conditions although there had been some light rain on the preceding day for measurements taken on 24 and 31 July. On these two occasions it was noted that the river was marginally higher (around 5 cm). All sites except the forestry site have been sampled in previous years. River flows (Figure 2) in winter were below average and during summer (January/February) flows were around the five year low flow level.

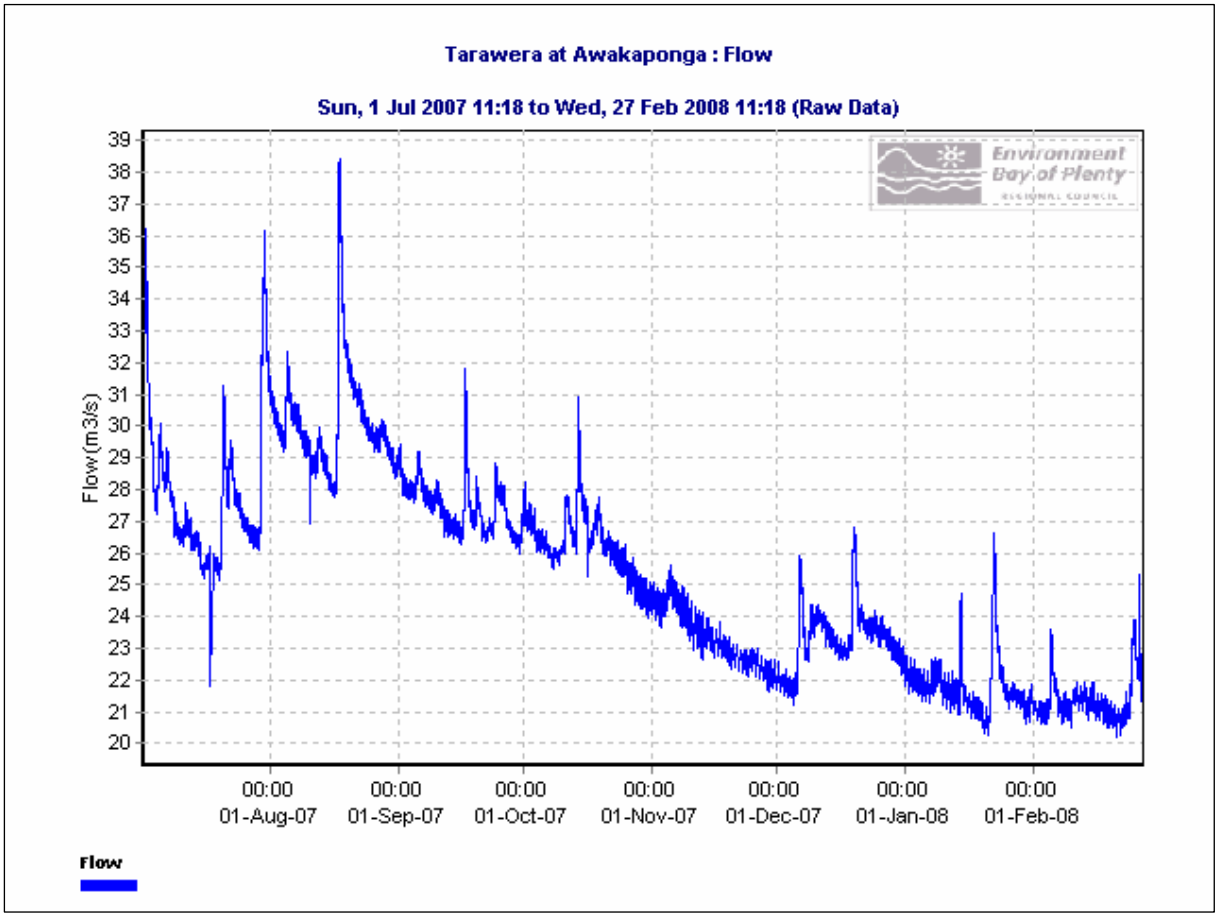

Figure 2 *Flow of Tarawera River over the period of the winter (07) and summer (08) surveys for light and clarity.*

Chapter 3: Results

3.1 Colour

In Figure 3 below the full length of monitoring data for the absorption coefficient at 440 nm from the Kawerau Bridge (Boyce Park) and State Highway 30 sites (below all the industrial discharges) is shown. There has clearly been a marked improvement in colour downstream of the industrial discharges since the 1990's. At the Kawerau Bridge site there has also been a significant increase (p = 0.001) in colour during the same period.

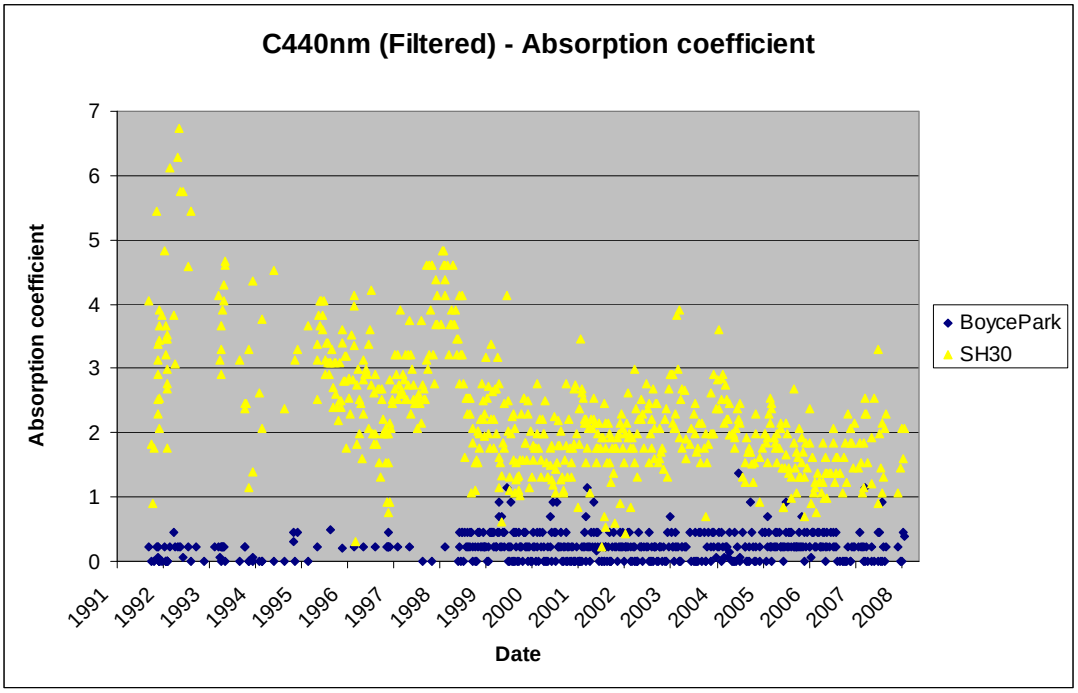

Figure 3 *Absorption coefficient of filtered Tarawera River water samples measured at 440 nm.*

In Figure 4 below, the colour monitoring data collected from 2002 to 2007 for the Kawerau Bridge, Onepu and State Highway 30 sites on the Tarawera River have been plotted. The graph includes the six month moving average for each site and the Tarawera River Catchment Plan standards from 1 January 2001 (red line) and 30 December 2005 (blue line). Since the reporting of the last colour data up to December 2003, there has been an improvement with the absorption coefficient at 440 nm declining at both the Onepu and State Highway 30 sites up to around the end of 2005. From 2006 onwards the absorption coefficient has steadily increased back up to levels seen through 2002/2004.

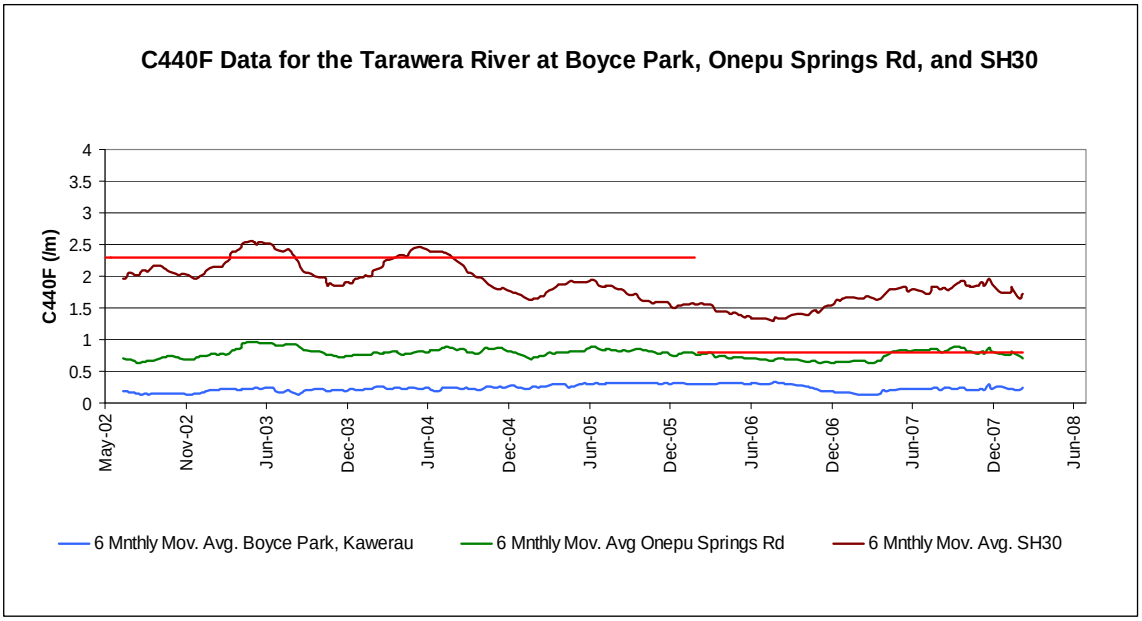

Figure 4 *Absorption coefficients of filtered samples measured at 440 nm from the Tarawera River at Kawerau Bridge, Onepu and State Highway 30 with six month moving averages. Straight line represents the classification standard.*

The State Highway 30 six month moving average for colour data exceeds the Tarawera River Catchment Plan classification of 0.8 which applies from 2006 onwards for the lower river. This limit does not apply to the river above the Tasman pond outfall, although as seen in Figure 4, colour in the river measured at Onepu is often in excess of it.

3.2 Visual Clarity

Figure 5 below provides a plot of the Black Disk clarity measured at Kawerau Bridge (Boyce Park) and at Onepu. In both the Kawerau Bridge and Onepu data there is a statistically significant decrease (prob = 0.000) in clarity over time up until August 2007. The mean Black Disk clarity at the Kawerau and Onepu sites between 1998 and 2002 was 1.97 m and 1.41 m and between 2004 and August 2007 it was1.54 m and 1.04 m respectively. Since August 2007 up until February 2008, both sites showed significant upwards trend in clarity. Variability in clarity appears to have a strong seasonal component and results show a high degree of consistency between the sites. Onepu has consistently recorded lower Black Disk clarity than the Kawerau Bridge site.

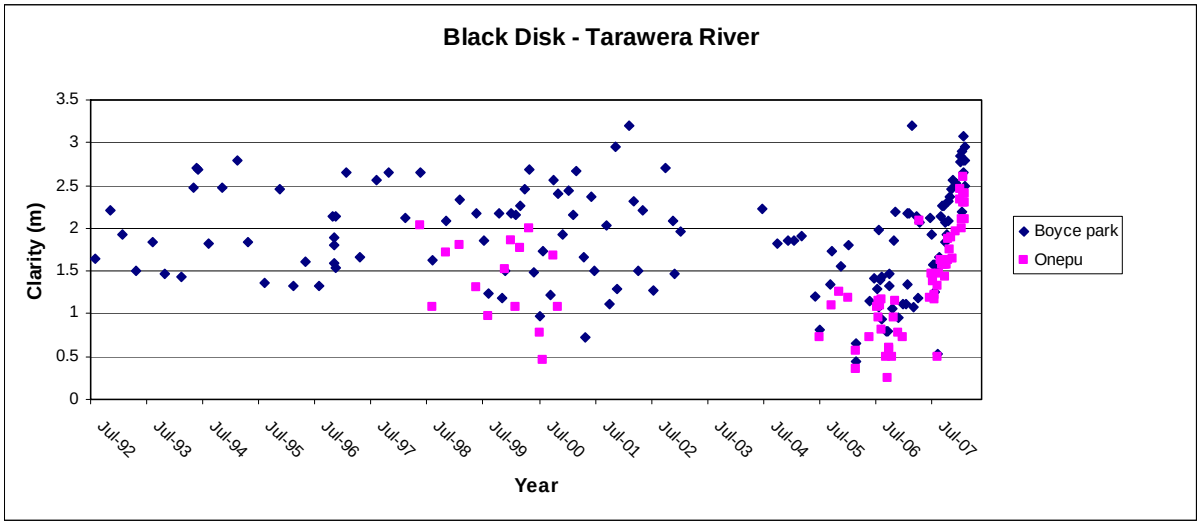

Figure 5 *Black disk measurements from Kawerau Bridge (Boyce Park) and Onepu in the Tarawera River from 1992 to 2007.*

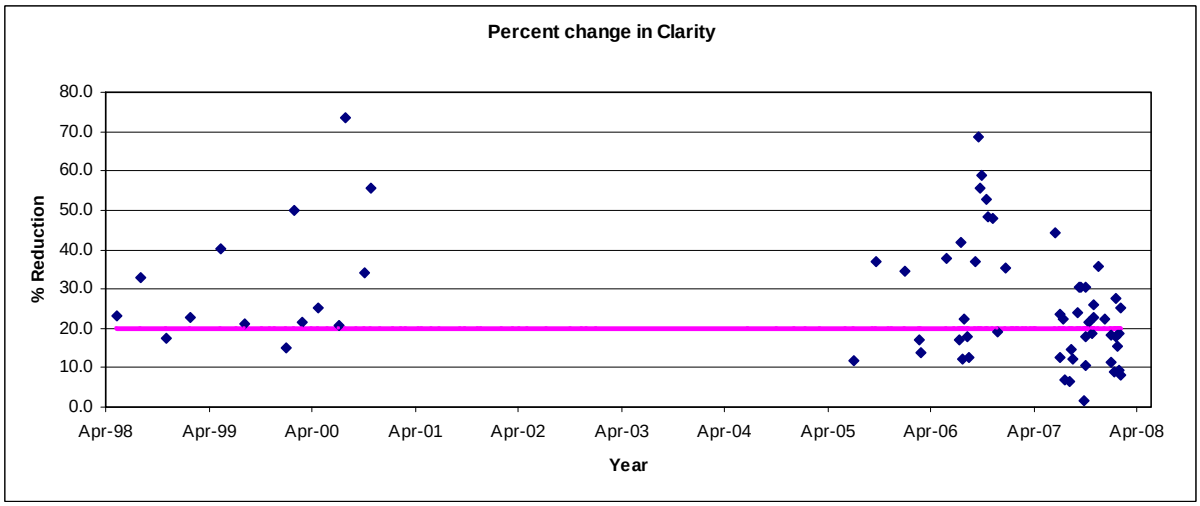

Figure 6 *Percent change (reduction) in Black Disk visibility between the Kawerau Bridge and Onepu sites in the Tarawera River between 1998 and 2007.*

In Figure 6 the percentage reduction in clarity between the Kawerau Bridge and Onepu sites is shown. A statistical analysis of the percentage change in Black Disk clarity over time shows that there has been no change between 1998 and 2008.

3.3 Light penetration

Results of light measurements in the Tarawera River are presented in Table 1 and Figure 7 below. Results are compared to previous surveys to allow an assessment of change over time. Looking at the amount of change in the euphotic depth at each site from 1993 to 2008, the Forest and Kawerau sites indicate better light penetration in the 2003 and 2008 surveys which were taken in summer. For these two sites the high variability between sampling periods may simply reflect seasonal/climatic influence. All other sites have shown a more consistent trend over the same period with Onepu showing a 78% improvement, State Highway 30 50%, Awakaponga 90% and Matata 76%. The improvement in light penetration between 2003 and 2008 is statistically significant for the Onepu, Awakaponga and Matata sites.

The State Highway 30 site has improved between 1993 and 2003 but shows no further change up to February 2008.

Changes between sites down the river have been very consistent for each of the four surveys. The addition of the Forestry site (10km upstream from Kawerau Bridge) provides a reference site above all the possible urban and farming influences. The monitoring shows an average 15% reduction in euphotic depth between the Forestry and Kawerau Bridge sites. As mentioned above clarity has varied between surveys at this site and it appears that clarity is higher in summer.

Table 1 Mean percentage of surface light at 2.0 m depth and the euphotic depth at sites on the Tarawera River in 1993, 2003, 2007 and 2008.

Site	% surface light @ 2.0m				Euphotic depth (m)			
	1993	2003	2007	2008	1993	2003	2007	2008
Forest	-	37.5	27.3	34.0	-	9.4	7.1	8.7
Kawerau	16.9	33.1	20.2	30.6	5.26	8.4	5.8	7.9
Onepu	4.3	8.7	10.5	15.7	2.8	3.8	4.1	5.0
State Highway 30	0.3	0.9	1.5	1.7	1.34	1.9	2.1	2.0
Awakaponga	0.2	1.3	1	3.0	1.35	2.1	2	2.6
Matata	0.4	0.7	1.9	3.6	1.53	1.86	2.3	2.7

Figure 7 below shows the same sets of light penetration survey data graphically. The top graph shows the percent of surface light present at 2.0 m depth at each of the sampling sites. The euphotic depth at each of the sampling sites shown in the bottom graph is the depth at which light from the surface will be reduced down to 1%. This is the light levels required by aquatic plants (macrophytes) and algae for photosynthesis to sustain them.

In the 2007 and 2008 surveys, all sites below State Highway 30 recorded euphotic depths of 2.0 m or more. As significant areas of the Tarawera River bed are around this depth, it would be possible for plants and algae to establish and grow there now. However, much of the river bed is highly mobile pumice and sand which will be one of the limiting factors to plants or algae trying to grow.

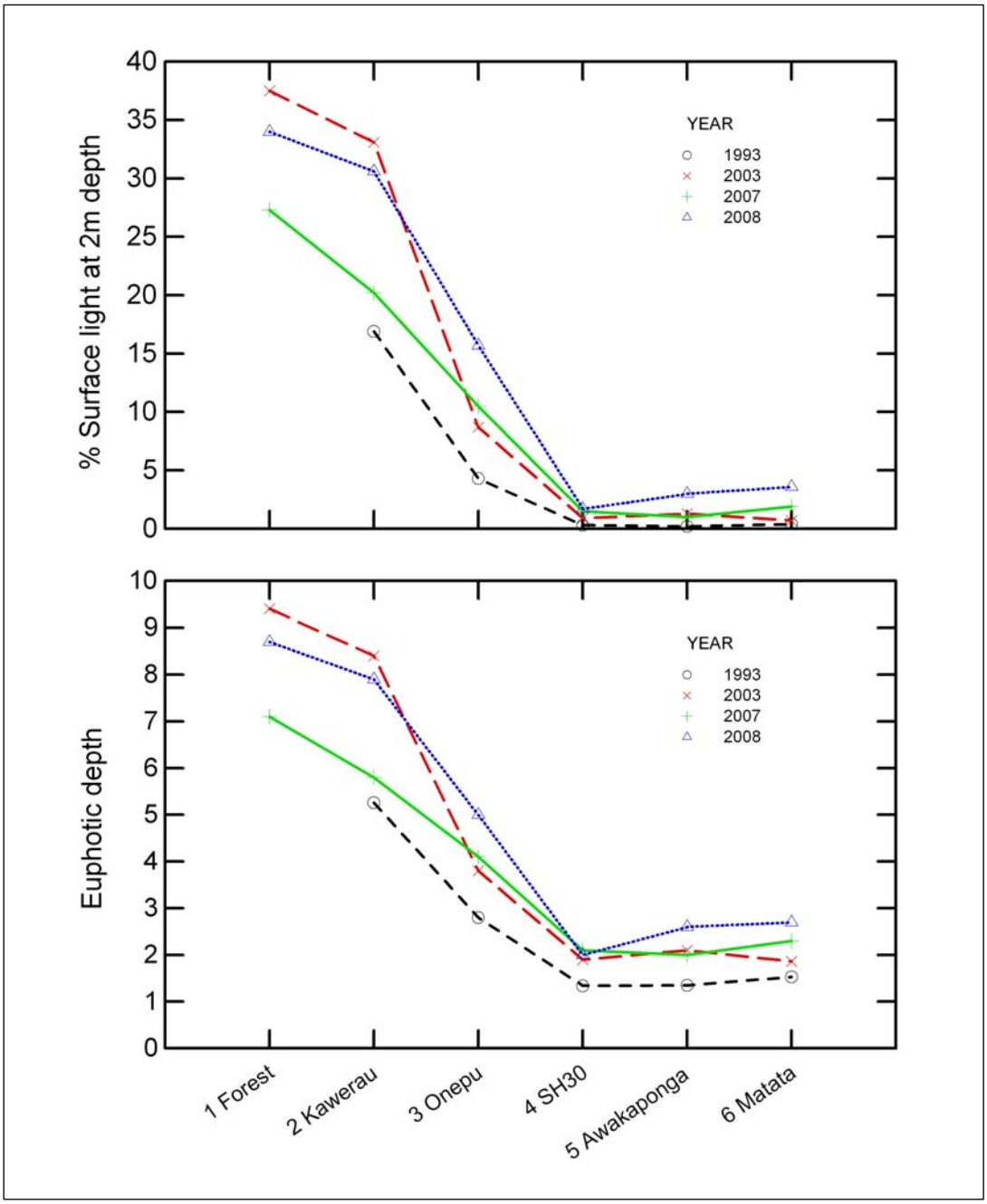

Figure 7 *Percentage of surface light at 2 m depth and the Euphotic depth at sites along the Tarawera River for surveys in 1993, 2003, 2007 and 2008.*

Chapter 4: Discussion and summary

4.1 Guidelines for the protection of aquatic life

In a review of the New Zealand water quality guidelines and the requirements of the RMA, MfE (1992) concluded that protection of visual clarity would usually also protect aquatic life, colour and light penetration. Guidelines for protecting Class A waters (managed for aesthetic purposes) against conspicuous changes in visual clarity require "the visual clarity not to be changed by more than 20%, for other waters (including AE – aquatic ecosystems) it should not change by more than 33-50%". This will generally provide sufficient protection for visually feeding fish and wading birds etc. However it is also recognised that the strongly light absorbing qualities of some pulp and paper mill discharges may not sit within this general guideline and may cause impacts by reducing the amount of light available for photosynthesis.

MfE set a guideline for protection against significant adverse effects on aquatic life as;

"In waters shallower than half the euphotic depth, the lighting at the bed should not be changed by more than 20%, or, in waters deeper than half the euphotic depth, the euphotic depth should not be changed by more than 10%".

Depth of the Tarawera River at Kawerau (maximum depth around 2 m) is less than half the euphotic depth so the less restrictive 20% change guideline should be used. The percentage change in surface light at a depth of 2 m from the Kawerau Bridge site to Onepu is around 48%, well above the 20% change guideline. Between the Kawerau and State Highway 30 sites the reduction is around 93%.

As shown in the 2007 survey results there is a marked reduction in light penetration in the Tarawera River between the Forestry site which is ten kilometres above the Kawerau Bridge site and the urban area. The percent change at 2.0 m depth is 26% which is a greater degree of change than the guideline. Over this small stretch of river it is not clear exactly what contributes to the reduction in light in relatively dry conditions, although there are some geothermal inputs. Between the Kawerau Bridge and Onepu sites, in addition to more geothermal inputs, there are a number of other minor discharges including ground seepage from the rapid infiltration basins. Over this stretch of river the percent change is 48%. Between Onepu and State Highway 30 which receives the treatment ponds discharge, the percent change at 2.0 m depth is 86%.

4.2 Tarawera River Catchment Plan

The Tarawera River Catchment Plan requires that, below the Tasman pond outfall, colour as measured by the absorption coefficient of a 0.45 micron filtered sample at 440 nm shall not exceed:

Up to 31 December 2000	3.8
From 1 January 2001	2.3
From 30 December 2005	0.8

This represents light levels at 2.0 m depth which are 0.036%, 0.204% and 1.828% of surface light respectively. The first two stages of this classification (prior to 30 December 2005) give little improvement in the percentage of light reaching the bed of the lower Tarawera River. The final colour limit of 0.8 does result in a significant improvement although it stills allows a 90% reduction in light at 2.0 m depth compared to the Kawerau Bridge site. The colour limit of 0.8 also equates to an expected euphotic depth of 2.56 m.

As measured in the 2007/08 surveys of light penetration, the euphotic depth is 2.0-2.1m at State Highway 30 (below the Tasman pond discharge). This is still less than what is now required by the equivalent colour absorption values in the Tarawera River Catchment Plan. The light surveys effectively provide an alternative direct measure of light penetration which is complimentary to the colour and clarity standards used in the plan.

Over the next year further improvement in colour is possible. As previously mentioned the SCA pulp mill was still operating up until May 2007 with effluent discharged to the rapid infiltration basins. Although it only takes a week or two on average for water movement through to the river from these basins, it is likely that it will take considerably longer for colour to be totally flushed through due to the very porous pumice soils.

For the stretch of river between the Kawerau Bridge and the Tasman Pond outfall, the Tarawera River Catchment Plan has a rule to protect the visual clarity based on Black Disk which states; "…no decrease in visual clarity of more than 20%". This is equivalent to the MfE guideline for protection of aesthetic qualities and above that considered necessary to protect ecological values. Monitoring data shows that this limit is frequently exceeded. Taking all the measurements for 2007 (n=14) the average percentage change is 18.8%. Even with further clarity improvements in this part of the Tarawera River, it is likely that on the basis of an absolute limit, the rule is always going to be exceeded at times. Consideration could be given to rewriting this rule in terms of a percentile or moving average.

Results from the clarity and colour surveys have also highlighted seasonal variations which make interpretation of results more complex. It is also likely that climatic variations will also influence the colour and clarity measurements in the river to some degree. These influences need to be considered when assessing trends. The recent 2007/08 light readings have been done under lower than average river flows so the measurements could be better in the upper river, but worse below the Tasman pond discharge as a result. The Tasman pond discharge had also previously shown seasonal variation in colour load, but this has now changed. To assess possible future improvements at Onepu and the lower river another winter survey should be conducted in 2008 and seasonality assessed.

4.3 Consent for colour discharge to river

Consent 02 4224 allows the Tasman Pulp and Paper Mill to discharge treated waste water into the Tarawera River from the treatment ponds. Section 7.3 of the consent contains conditions relating to the amount of colour that can be discharged and defines a timetable over which the mill is required to meet lower limits. Initially under the consent the 30 day moving average limit for colour was 80 tonne/day (in terms of equivalent platinum cobalt units). This limit reduced to 70t/d on 1 January 2004 and 31 t/d on 1 January 2006. Compliance data for colour is graphed in Figure 8 below and shows that compliance with the consent limits has been met. The amount of colour discharged from the treatment ponds has decreased substantially over the period 1998 to 2007.

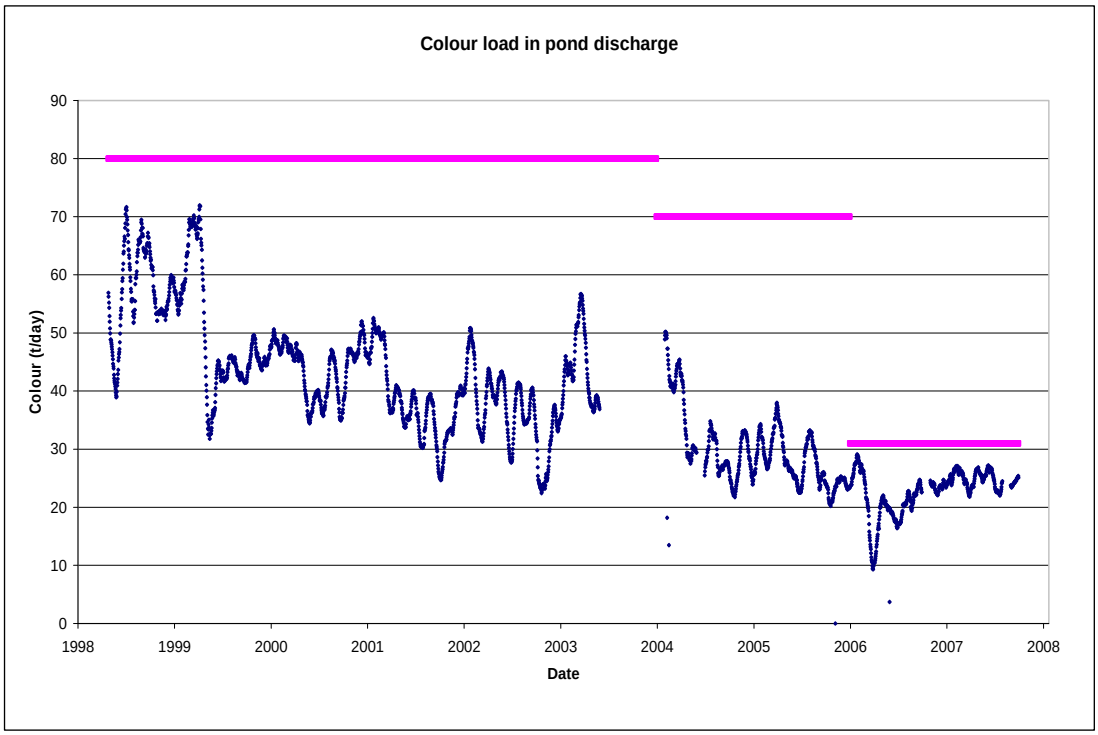

Figure 8 *Colour load (tonnes/day) discharged from the Tasman treatment ponds into the Tarawera River with consent limits shown.*

Although the Tasman Pulp and Paper Mill is achieving compliance against the consent limit for colour discharge to the river, the classification standard for colour set in the Tarawera River Catchment plan is not being met.

4.4 Summary

The current industrial discharges to the lower Tarawera River have been shown to have a significant impact in terms of colour and light penetration (euphotic depth). This in turn can affect the diversity and abundance of aquatic macrophytes and microflora. However, since 1998 colour and light penetration have improved in the lower river due to reductions in the colour discharged from the Tasman Mill.

The consent conditions restricting colour input to the river should achieve the objectives of the Regional Plan for the Tarawera River Catchment. However, monitoring shows that even though the Tasman Mill is complying with its discharge limits, it is not sufficient to meet the plan classification. In addition the colour standards laid out in the plan represent a reduction of surface light that is less than the MfE guidelines established for the protection of aquatic life. The percentage change in water clarity between the Kawerau Bridge and Onepu sites (upstream of the Tasman mill discharge) still exceeds on occasion the 20% standard given in the plan. It is possible that further improvement may occur over time as remaining colour is flushed from the rapid infiltration basins.

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