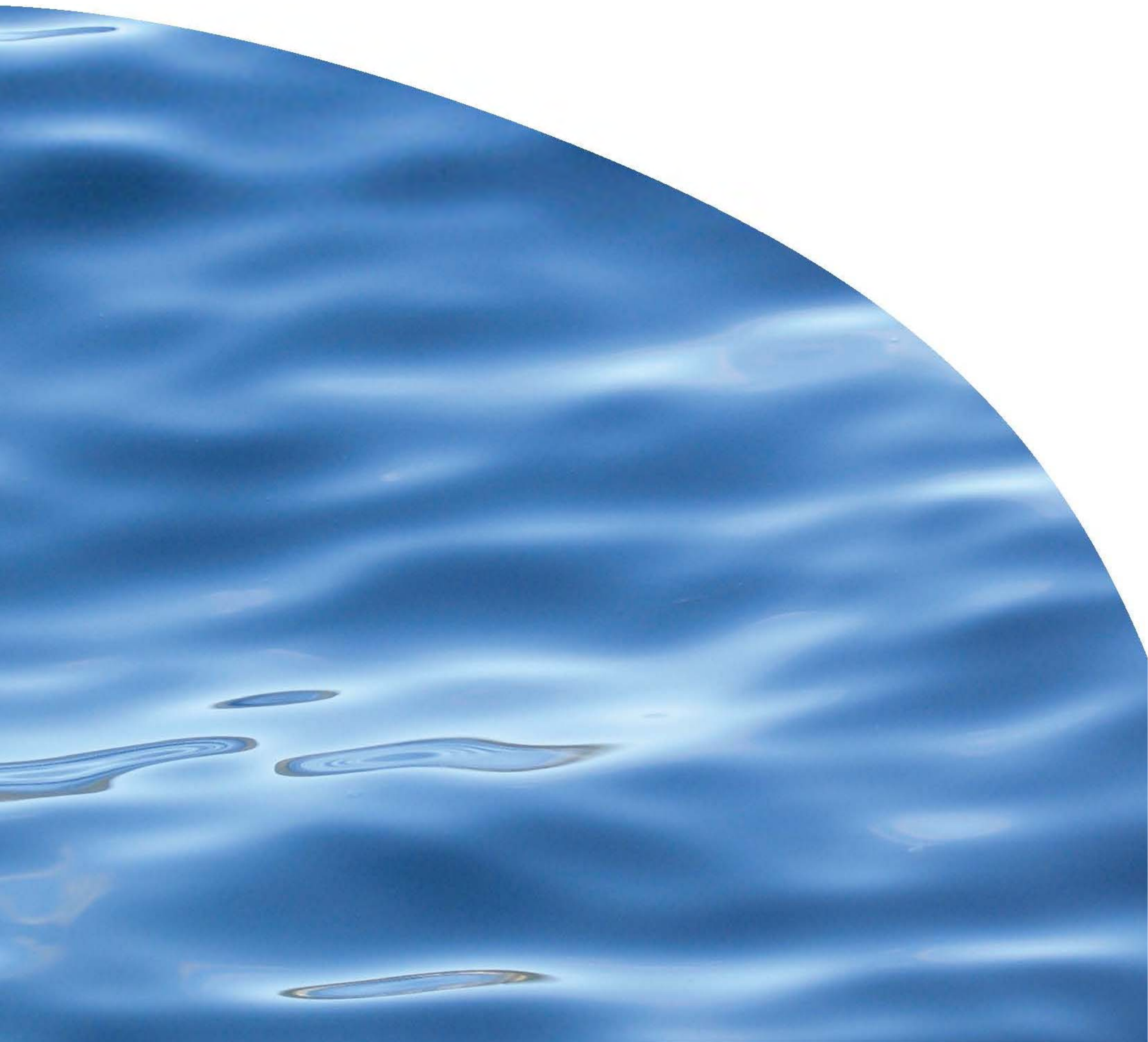
REPORT NO. 2371

THE IMPACT OF THE MAITAI DAM ON RIVER HEALTH RELATIVE TO OTHER CATCHMENT PRESSURES: A REVIEW



THE IMPACT OF THE MAITAI DAM ON RIVER HEALTH RELATIVE TO OTHER CATCHMENT PRESSURES: A REVIEW

CRAIG ALLEN, ROBIN HOLMES, KAREN SHEARER

Prepared for Nelson City Council

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

REVIEWED BY:
Joe Hay

APPROVED FOR RELEASE BY:
Rowan Strickland

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EXECUTIVE SUMMARY

The purpose of this report is to identify the most dominant anthropogenic influences on water and habitat quality within the Maitai River catchment. The influence of the Maitai Reservoir is considered relative to other catchment pressures.

Observations of river health in the Maitai catchment approximately align with modelled pressures derived from various anthropogenic influences, where land-use type is the main influence on river health.

Plantation forestry and urban stormwater runoff appear to be the dominant pressures facing the Maitai catchment. Forestry is the main land use in the mid-catchment. Macroinvertebrate community health indicators are sensitive to changes in nutrient and deposited fine-sediment levels. High levels of both of these contaminants have been associated with tributaries in parts of the catchment dominated by Forestry. Therefore, the observed declines in macroinvertebrate community indicators throughout the mid-catchment suggest that forestry works are negatively impacting upon stream biota downstream through increased fine-sediment and / or nutrient levels. Benthic cyanobacteria blooms may be an emerging issue due to increased input of nitrogen from forestry activities. Toxins produced by benthic cyanobacteria mats can restrict recreational activities.

The lower catchment, especially the lower tidal reach, is particularly degraded relative to the rest of the catchment in terms of macroinvertebrate community composition and contaminant loads in the sediments. Stormwater drains are the likely source of contaminants that bind to the Maitai River sediments. Concentrations of faecal indicator bacteria regularly exceed guideline values for swimming in parts of the lower Maitai. It seems likely that most of the faecal bacteria present in the water are derived from faults in the city's sewage system, though contamination from waterfowl is another potential source. There is evidence of a strong signal for human faecal markers in the Maitai River downstream from the Halifax Street footbridge.

Based on data assessed in this review, the impact of the Maitai Reservoir on the mid and lower Maitai River is likely to be comparatively minor when considered in the context of the magnitude and extent of other pressures facing the catchment. Habitat degradation in the lower catchment is largely attributable to forestry and urbanisation, more specifically, sediment and nutrient loading from Sharland and Groom Creeks, and nutrient and contaminant loading from various stormwater drains. Nutrients from the back-feed discharge may contribute to cumulative impacts within the catchment, but these are secondary to other land-use pressures.

However, three specific ecological issues that arise as a result of the Reservoir and may affect ecological values in the wider catchment are:

1. Concentrations of naturally occurring heavy metals (manganese, iron, nickel and chromium) are higher in the upper Maitai River than in the mid-catchment. There is a

low to moderate risk that this issue may be exacerbated by the discharge of anoxic water from the Maitai Reservoir.

2. The Reservoir spillway is the most significant fish passage obstacle within the Maitai River, restricting access for native fish (particularly longfin eel and koaro) and trout to habitat in the Maitai Reservoir and North Branch.
3. Water chemistry is altered below the Reservoir's back-feed discharge, especially during periods when anoxic reservoir water is discharged. Subtle changes in water chemistry can alter algal communities, potentially providing favourable conditions for undesirable species (*e.g.* toxic cyanobacteria).

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GLOSSARY

Abbreviation/unit	Definition	Type
ANZECC	Australia and New Zealand Environment and Conservation Council	Acronym
EPT	Ephemeroptera, Plecoptera, Trichoptera	Acronym
FENZ	The 'Freshwater Environments of New Zealand' geo-database	Acronym
FIB	Faecal indicator bacteria	Acronym
ha	Hectare	Abbreviation
ISQG–Low	Interim Sediment Quality Guideline–Low Trigger Value	Acronym
LCDB	Land Cover Database	Acronym
MALF	Mean Annual Low Flow	Acronym
MCI	Macroinvertebrate Community Index	Acronym
Median flow	The rate of discharge of a river for which there are equal numbers of greater and lesser flow occurrences	Definition
Minimum flow	The lowest permissible river discharge	Definition
MST	Microbial Source Tracking	Acronym
NCC	Nelson City Council	Acronym
NZFFD	New Zealand Freshwater Fish Database	Acronym
PAH	Polycyclic Aromatic Hydrocarbons	Acronym
QMCI	Quantitative Macroinvertebrate Community Index	Acronym
SOE	State of the Environment	Acronym
SQMCI	Semi-quantitative Macroinvertebrate Community Index	Acronym
SVOC	Semi-volatile Organic Compound	Acronym

1. INTRODUCTION

1.1. Purpose of this report

This review attempts to identify the most dominant anthropogenic influences on water and habitat quality within the Maitai River catchment, updating information presented in Crowe *et al*. (2004), 'The Current State of the Maitai River'. First we discuss anthropogenic pressures affecting the entire catchment. Then we attempt to place the effects of the Maitai Reservoir in the context of issues being faced in the wider catchment.

1.2. Overview of the Maitai River catchment

The Maitai River catchment covers 9,140 ha and can be broadly divided into three main sub-catchments based on land use: 'Upper', 'Middle' and 'Lower' (Figure 1). Various sites within these three sub-catchments have been used in the past for monitoring stream health in the Maitai River and its tributaries. For the purposes of this report the main tributaries are included within these three sub-catchments (*e.g.,* Groom Creek — middle; Sharland Creek — middle; and The Brook — lower).

1.2.1. Land use

Different types of land use are known to be associated with specific impacts on river ecosystems, so by considering land use (and changes in land use) within the Maitai River catchment we can build a picture of what pressures are likely to be influencing ecological parameters. In Sections 2 and 3 we consider these land-use pressures alongside historical river health indicators to help identify impacts both qualitatively and quantitatively.

Land use has been described in the Ministry for the Environment's '*Land Cover Database*' (LCDB), which assesses land use using satellite information collected in 1996/97, 2001/02, and 2007/08. These are commonly referred to as the LCDB1, LCDB2 and LCDB3 databases (respectively), and give a reliable assessment of changes in land use over this period. The LCDB3 was released in 2012, so is the most up-to-date land-use information available.

Figure 1 displays current land use in each of the three sub-catchments. Land use in the upper Maitai sub-catchment is dominated by native forest (95%). The middle Maitai sub-catchment is dominated by exotic forest (54%) and native forest (39%), with a small area of pastoral / agricultural land use (4%). The lower Maitai sub-catchment (which includes the Brook)[1] is dominated by native forest (60%), exotic

[1] The Brook enters the mainstem in the lower reaches of the Maitai, so water quality in the lower Brook has a significant influence at this point. Including the Brook when accounting for land use in the 'lower Maitai sub-

forest (15%), urban / built up areas (14%), and pastoral / agricultural land use (8%). In all three sub-catchments there has been no substantial change in land use since 1996.

1.2.2. Modelled prediction of river health caused by Maitai catchment pressures

The ‘Freshwater Environments of New Zealand geo-database’ (FENZ) ‘River Pressure’ dataset can be used to predict the effect of spatial variations in human pressure on the health of the Maitai River. Model inputs include: satellite-based estimates of land cover, information on the distributions of mines and reservoirs, estimates of the extent of impervious cover based on topographic map data, modeled nitrogen inputs to rivers and streams, and the estimated distributions of introduced fish. Estimates of river health are combined into a single index, values for which vary from 0 (totally degraded) to 1 (pristine).

Figure 1 displays the FENZ predictions of human pressure on river health in the Maitai catchment. In general, waterways situated in native forest are predicted to have the highest estimates of river health (0.6–1). River health is predicted to decrease with distance downstream as various anthropogenic pressures come into effect, driven mainly by the dominate sub-catchment land use. This is particularly evident in areas dominated by plantation forestry. Streams in the North Branch of the upper Maitai sub-catchment are predicted to be under greater pressure than those in the South Branch, which reflects the influence of the Maitai Reservoir on fish passage (Figure 1).

Pressure from surface water allocation in the Maitai catchment is negligible, according to a GIS database that describes the extent of surface water allocation in New Zealand in 2011 (Clapcott 2011).

catchment’ may seem unusual, but we have tried to simplify the greater Maitai catchment and concentrate on river health within the mainstem.

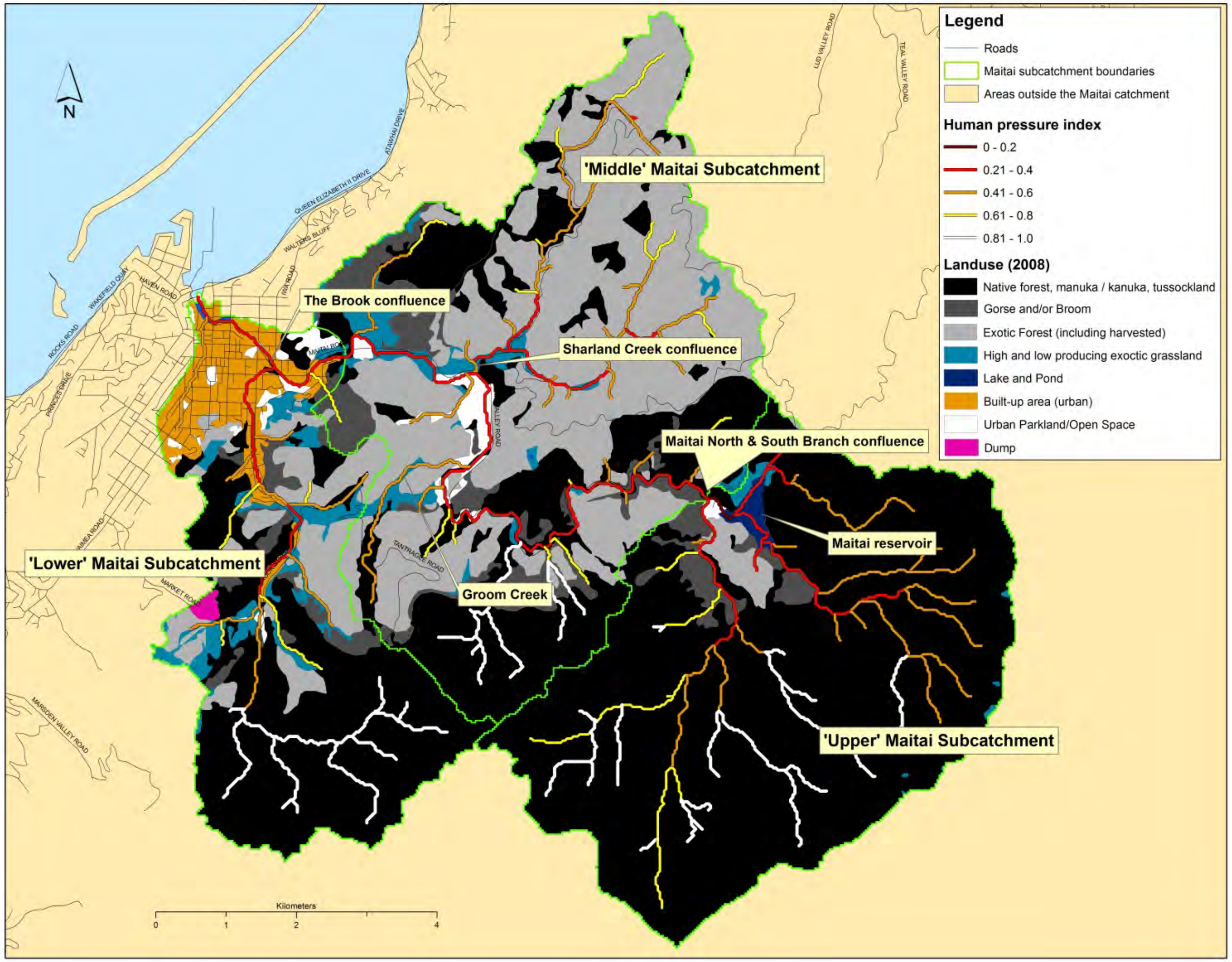

Figure 1. Land use in the Maitai River catchment: 'Upper', 'Middle' and 'Lower' sub-catchments (green boundaries) are stratified according to land-use type. Land-use influences the human pressure index for river health, where '0-0.2' is degraded due to greater pressure and '0.81-1' is pristine (Source: LCDB3, Ministry for the Environment 2012; and the FENZ geo-database 2010).

1.2.3. Observed impacts on river health

Freshwater classification

The condition of rivers in the Nelson region is assessed by Nelson City Council (NCC) every year using a scoring system that combines information on general habitat condition, water quality, sediment toxicity and invertebrate/periphyton community assessments. See Appendix 1 and Wilkinson (2007b) for a full description of NCC's Freshwater Classification system. The results of these assessments are publicly available through the NCC website.

Table 1 summarises the condition of the Maitai River as assessed in reports published in 2002, 2007, and 2013. River condition at the site representing the upper catchment is designated '*Excellent*' in all three reports[2]. This site is located on the South Branch of the Maitai, upstream from the influence of the Maitai Reservoir. Downstream, river condition varies mostly between '*Moderate*' and '*Degraded*'.

In 2013 the three major tributaries (Groom, Sharland and Brook) are mostly considered to be in a '*Moderate*' or '*Degraded*' state at their confluence with the Maitai River. The middle sub-catchment tributaries (Sharland and Groom creeks) have declined since 2007; whilst in the lower catchment The Brook (and mainstem Maitai) has shown some improvement.

River health environmental targets set out in NCC's 'Long Term Plan (2012-2022)' focus on improving these scores. The Council intends to improve river health in the region so that by 2025 there will be no streams below 'Class C'; and streams that are currently 'Class C' will be improved sufficiently to be reclassified as 'Class B' (Nelson City Council 2012a). The document also states an intention to increase the number of monitored swimming areas that meet swimming quality standards.

[2] This *'Excellent'* designation for the upper Maitai (South Branch) does not align with the indices predicted by the Human Pressures Index (Figure 1), which suggests that the streams are degraded (*i.e.,* 0.21-0.4). A possible explanation for this is that the satellite derived estimate of vegetation cover used in FENZ does not take account of the naturally occurring ultramafic geology in this area, which limits vegetation growth compared with more fertile soils elsewhere. FENZ is likely to have categorised this area as having been cleared of vegetation.

Table 1. Freshwater classifications for the Maitai River catchment (in order of catchment descent) (Wilkinson 2007; 2013 [draft]). Tributaries are shown in italics.

Sub-catchment	**Site location**	**2002 Classification (for period 2000-2002)** (Wilkinson 2007)	**2007 Classification (for period 2000-2007)** (Wilkinson 2007)	**2013 Classification (for period 2007-2012)** (Wilkinson 2013)
Upper	Maitai at South Branch Intake	'A' – Excellent	'A' – Excellent	'A' – Excellent
Middle	Maitai at Groom Road	'D' - Degraded	'C' – Moderate	'C' – Moderate
	Groom Creek at Maitai confluence	'C' – Moderate	'B' – Very good	'D' - Degraded
	Sharland Creek at Maitai confluence	'D' - Degraded	'C' – Moderate	'D' - Degraded
Lower	Maitai at Riverside	'C' – Moderate	'D' - Degraded	'C' – Moderate
	Brook at Manuka Street	'D' - Degraded	'D' - Degraded	'C' – Moderate

Note: Further description of classifications:
A: High conservation / ecological value
B: Generally healthy
C: Healthy but ailing
D: Highly disturbed, unhealthy
E: Severely degraded

Algal communities

Nuisance periphyton growths have been a feature of the Maitai River since at least the 1980s (Crowe *et al*. 2004) and possibly earlier (pers. comm. Paul Sheldon, Tasman District Council). These growths are usually associated with low-flow conditions. Based on available data it is not possible to determine if the incidence of nuisance algal growths has increased over time. However, increased algal growths have been noted downstream of the Maitai Reservoir back-feed discharge (Section 2.2).

Cyanobacteria may be an emerging issue in the catchment. Following the death of a dog due to cyanobacteria toxicity in the Maitai River in 2009, NCC now monitors cyanobacteria coverage at three sites in the 'middle' Maitai River. Since 2009 there have been no further reports of dog deaths and NCC erect warning signs seasonally (spring-summer-autumn) in the middle and lower Maitai as a precautionary measure.

Macroinvertebrates

A range of macroinvertebrate community indices are commonly used for assessing river health. These include % EPT taxa; MCI (Macroinvertebrate Community Index); SQMCI (Semi-Quantitative Macroinvertebrate Community Index); and QMCI (Quantitative Macroinvertebrate Community Index). These indices, based on the relative occurrence of pollution sensitive and pollution tolerant species, provide a value that indicates the level of nutrient enrichment and fine-sediment deposition at a sampling location (with higher values indicating more pristine environmental conditions, and lower values more degraded conditions). Indices are described in more detail in Appendix 2.

Macroinvertebrate communities have been monitored in the upper reaches of the Maitai since the early 1980s as part of consent monitoring for the Maitai Reservoir. This monitoring is described in more detail in Section 2. Recent analyses carried out to assess long-term changes in macroinvertebrate communities below the Reservoir found that there has been a statistically significant decreasing trend in %EPT, MCI and QMCI between 1989 and 2012, indicating that water quality has decreased below the Maitai Reservoir (Holmes 2012).

Despite this apparent decrease in water quality, macroinvertebrate data from below the Reservoir indicate that water quality is '*Good*' ('*with possible mild pollution*'), as interpreted by guidelines suggested by Stark and Maxted (2007) (see Table A2.1, Appendix 2).

Crowe *et al*. (2004) suggested that the quality of macroinvertebrate communities in the middle Maitai mainstem (including the motor camp) had declined since 1983, and that communities in the lower Maitai mainstem (around Branford Park) were poor in quality over the period 1983 to 2003. Macroinvertebrate data prior to 1980 is sparse.

Crowe *et al*. (2004) also noted that macroinvertebrate communities decreased in quality with distance down the mainstem, but could not determine the point at which the decline begins.

Trout fishery

Prior to the early 1980s the Maitai River supported a relatively abundant population of small trout and quite high numbers of medium-sized trout in the mid to lower reaches (Crowe *et al*. 2004). Electric-fishing surveys in the mainstem (undertaken since the 1980s) indicate that trout abundance has declined in recent years. This is particularly so in the upper reaches, where there has been an apparent declining trend in abundance since about 1992, with populations remaining depressed from 2002 (Figure 2) (Holmes 2012).

Similarly, drift-dive surveys carried out by Fish & Game NZ in the middle mainstem Maitai show a substantial decrease in trout abundance in the three surveys carried out since 1992 (Figure 3). Observations in the lower reaches in 2000 and 2010 indicate that there are still relatively high numbers of adult trout downstream of The Brook confluence (unpublished data, recieved from Lawson Davey, Fish & Game NZ, 20 June 2013).

Whilst trout continue to spawn in the Maitai River catchment, recent surveys show that substantially fewer juveniles have been found in tributaries that once provided "abundant spawning grounds" (Graynoth & Skrzynski 1974). Electric-fishing undertaken in Sharland Creek and Packers Creek (a tributary of Sharland Creek) found very low densities of juvenile trout (unpublished data, Fish & Game 2013) compared to that expected in a healthy spawning tributary (pers. comm. Neil Deans, Fish & Game NZ).

However, as pointed out by Holmes (2012), decadal variation in fish densities can be quite marked and differences between sampling occasions could be due to the influence of flow variation - primarily the frequency and magnitude of flood events, rather than some anthropogenic impact (Young *et al.* 2010). In addition to this, fish can migrate throughout a catchment and thus the population at any point in the river may be influenced by pressures elsewhere.

Fish abundance estimates are therefore less useful than macroinvertebrate indices when assessing river health at specific locations. Nevertheless, these fish monitoring results are included because they are consistent with the decline observed in the macroinvertebrate monitoring (Holmes 2012).

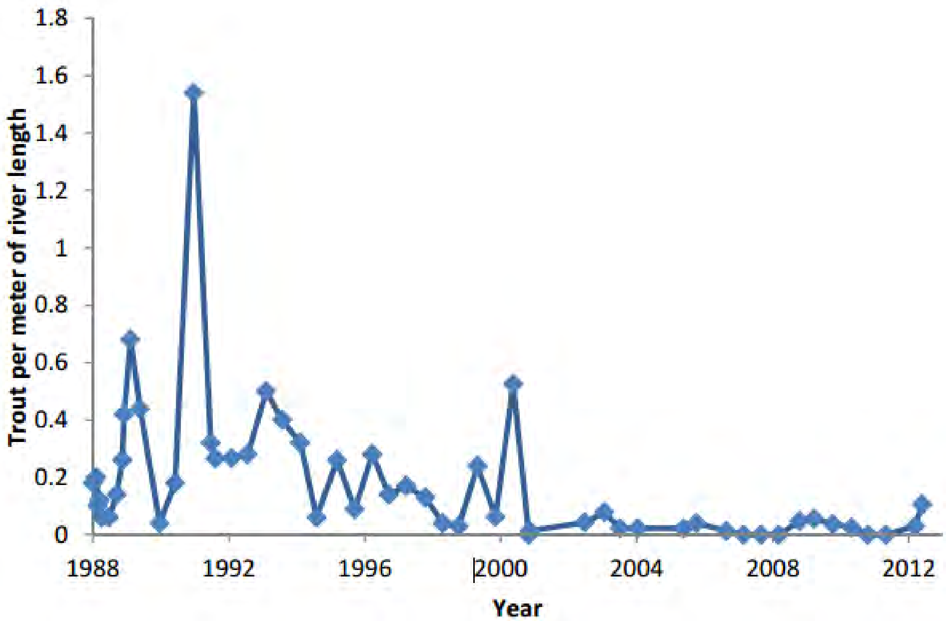

Figure 2. Trout abundance below the Maitai Reservoir (upper sub-catchment, mainstem Maitai River) calculated using electric-fishing data 1988–2012 (Holmes 2012).

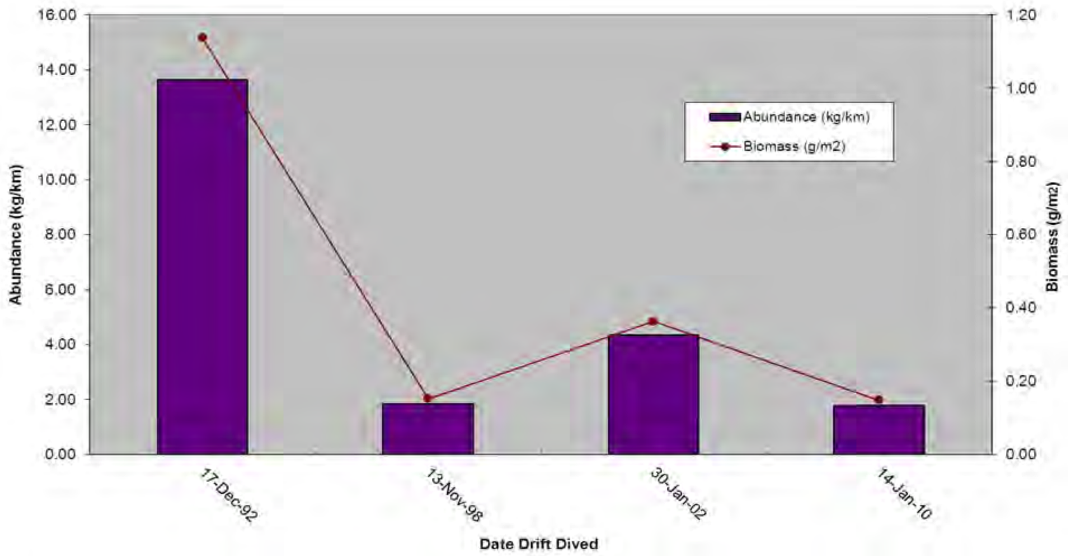

Figure 3. Trout abundance and biomass above Pole Ford Bridge (middle sub-catchment, mainstem Maitai River) during four drift-dive surveys carried out between 1992 and 2010 (unpublished data, recieved from Lawson Davey, Fish & Game NZ, 20 June 2013).

Native fish

Between 1965 and 2013, fourteen species of native fish have been identified in the Maitai River (New Zealand Freshwater Fish Database (NZFFD); Stark 2003) (Table 2).

Table 2. Native fish found in the Maitai River. Brackets indicate the number of fish found.

Common name	Scientific name	Reference
Longfin eel	*Anguilla dieffenbachii*	NZFFD (65)
Shortfin eel	*Anguilla australis*	NZFFD (5)
Common smelt	*Retropinna retropinna*	NZFFD (1)
Banded kokopu	*Galaxias fasciatus*	NZFFD (2)
Koaro	*Galaxias brevipinnis*	NZFFD (8)
Inanga	*Galaxias maculatus*	NZFFD (6)
Torrentfish	*Cheimarrichthys fosteri*	NZFFD (4)
Redfin bully	*Gobiomorphus huttoni*	NZFFD (14)
Common bully	*Gobiomorphus cotidianus*	NZFFD (7)
Giant bully	*Gobiomorphus gobioides*	NZFFD (1)
Bluegill bully	*Gobiomorphus hubbsi*	Stark (2003) (1)
Upland bully	*Gobiomorphus breviceps*	NZFFD (24)
Yelloweye mullet	*Aldrichetta forsteri*	NZFFD (1)
Estuarine triplefin	*Grahamina* sp.	NZFFD (2)

For the most part, data on native fish in the Maitai River have been collected in a sporadic and unsystematic manner. Consequently, it is not possible to draw robust conclusions on the current and past status of native fish within the Maitai catchment.

Long-term data from electric-fishing surveys carried out in the upper reaches of the Maitai, below the Maitai Reservoir, indicate that the number of longfin eels have decreased markedly since 1988 (Figure 4) (Holmes 2012). Numbers have declined from a peak in the mid-1990s and have remained depressed since about 2004. Longfin eel have a conservation status of '*At risk: Declining*' (Allibone *et al*. 2009). There is no way to determine if this apparent decline noted in the upper river is typical of native fish populations in the rest of the catchment.

As noted for trout, estimates of abundance of native fish should be interpreted with caution; however, the declining trend for eels is very similar to that observed with macroinvertebrate indices and trout abundance.

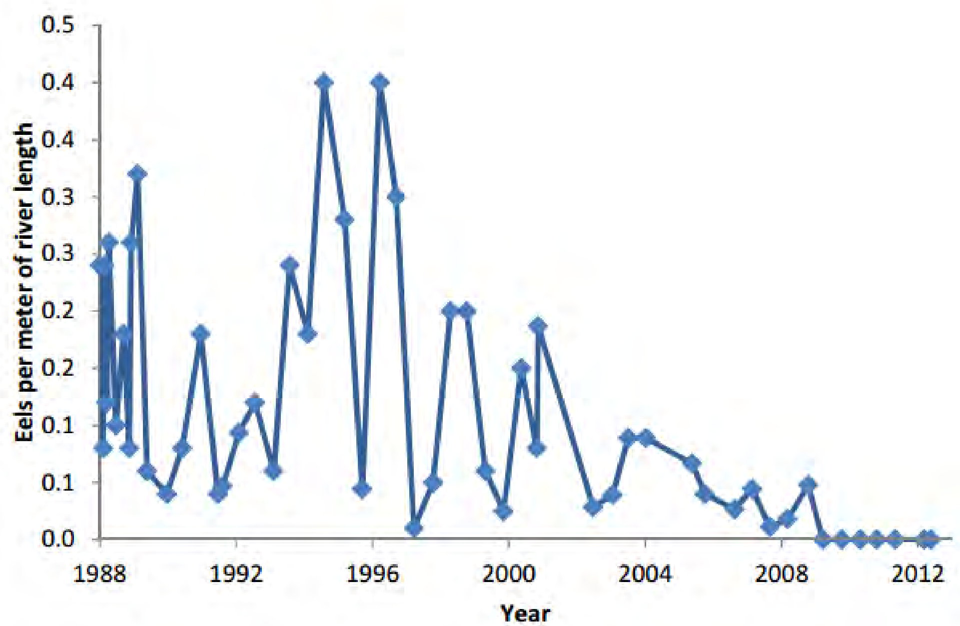

Figure 4. Longfin eel abundance below the Maitai Reservoir (upper sub-catchment, mainstem Maitai River) calculated using electric-fishing data 1988–2012 (Holmes 2012).

1.2.4. Predicted verses observed river health

Observations of river health for the Maitai catchment (Section 1.2.3) generally follow those predicted by the FENZ geo-database (Section 1.2.2). River health appears largely driven by land-use type and generally declines with distance downstream: a pattern that is most likely due to pressures induced by plantation forestry, at least in the middle sub-catchment. River health in the lower sub-catchment will also be influenced by urban pressures.

Sections 2 and 3 discuss specific impacts of the Reservoir and other land-use pressures in more detail.

2. IMPACTS OF THE MAITAI RESERVOIR ON MAITAI RIVER HEALTH

The Maitai Dam, built on the North Branch of the Maitai River in 1987, is 36 m high and retains a reservoir that covers an area of 32 hectares. Water is abstracted from the South Branch of the Maitai (see 'South Branch intake', Figure 5), and then replaced by an equivalent or greater volume of water from the Reservoir ('back-feed discharge', (Figure 5). Abstracted water is then filtered and treated to provide potable water for Nelson. Ecological pressures brought about as a consequence of this facility can be split into three groups: abstraction, discharge, and fish passage.

Figure 5. Diagram of the Maitai Water Supply Scheme showing the water supply intake (labelled 'South Branch intake') and back-feed discharge. Also shown are the locations of the bi–annual biomonitoring sites (Holmes 2012). Not to scale.

2.1. Abstraction

Following the construction of the Reservoir there has been no significant change to the frequency of small floods (4–10 m^3/s), compared to both natural flows and a pre-reservoir abstraction regime (Hewitt & Kemp 2004). In addition, the flow regime associated with the Reservoir has a beneficial effect during extreme low-flow events in the Maitai, by augmenting natural flow (Hayes 2003; Hewitt & Kemp 2004). However, Hayes (2003) notes that both the present (abstracted) and natural mean annual low flows (MALFs) in the Maitai are insufficient to maintain optimal trout habitat, but suggests that factors other than habitat availability may also be limiting the trout population.

Hayes (2003) discusses two flow-related factors that are likely to have brought about a reduction in food supply for fish and hence a likely reduction in the condition and / or abundance of trout and drift feeding native fish. First, the NCC water abstraction has a negative effect on the spatial availability of macroinvertebrate habitat in the Maitai, reducing it by approximately 14%[3]. Second, macroinvertebrate habitat is available for a lesser amount of time than it was with the natural flow regime, because flows of the magnitude of the pre-dam median flow are now equaled or exceeded 11% less of the time than they were previously. The effects of reduced food supply on fish will depend on population density. Abundance of both trout and native fish appear very low in the upper Maitai River (Holmes 2012). Therefore, although carrying capacity may be reduced as a result of abstraction, a reduction in food production as result of abstraction seems unlikely to be limiting fish populations to their present densities. Other factors that may be limiting fish populations in the catchment are discussed later in this report.

2.2. Discharge

Consent monitoring of macroinvertebrate communities at 'Site B', below the back-feed discharge (Figure 5), between 1989 and 2012 shows a statistically significant decreasing trend in macroinvertebrate scores, which indicates a decline in water quality over this period (Holmes 2012). Macroinvertebrate indices from a control site immediately upstream show no decline, which indicates that water and / or habitat quality is higher upstream, although monitoring has only been undertaken at this site since 2008. Therefore, the operation of the back-feed discharge is the most plausible explanation for the observed differences between the two sites. In the past five years, macroinvertebrate monitoring indicates that water quality at the 'Control site', is '*Excellent*' (Stark & Maxted 2007), whereas at 'Site B', below the back-feed discharge, water is of *'Good'* quality (*i.e. 'with possible mild pollution'*). The results from the 'Control site' are mirrored by those from NCC's water quality monitoring site 'Maitai at

[3] At the median flow, when compared with the natural flow regime.

South Branch Intake', which is also upstream of the back-feed discharge and had an *'Excellent'* water quality grade (Table 1).

Similarly, following long periods of stable flow, there is evidence of a higher coverage of periphyton at 'Site B' than at the 'Control site'. On one occasion, potentially toxic cyanobacteria mat cover was considerably higher at the downstream site (Holmes 2010; Holmes & Kelly 2012). Since the two sites have similar physical characteristics and hydrological histories, the findings imply that the cause is water introduced from the back-feed discharge. The back-feed may be encouraging the growth of algae by increasing nutrients, altering the nitrogen to phosphate ratio or introducing micronutrients (iron and manganese) to the South Branch (Holmes 2010). It is not currently possible to determine the downstream extent of the apparent influence of the back-feed on algal growths. However, work planned by NCC in 2014 will address this.

Anoxic water

Since the construction of the Maitai Reservoir, there has been a consistent pattern of mid- to late-summer thermal stratification in the Reservoir. Stratification is the process by which lakes and reservoirs develop separate layers: the epilimnion (surface layer), thermocline (temperature/density gradient) and hypolimnion (bottom layer). Anoxic conditions can occur in the hypolimnion once it is isolated from the surface by the thermocline. The reservoir water that is discharged to the South Branch from the backfeed is usually extracted from the lowest intake (referred to as 'scour'). Consequently, water drawn from the base of the Reservoir that is discharged into the Maitai South Branch has very low dissolved oxygen levels during summer. However, sufficient aeration occurs over the discharge-weir to re-oxygenate the water within a short distance. Biannual dissolved oxygen spot measurements taken since 1980 at Site B (50 m downstream of the back-feed) consistently exceed ANZECC (1992) guidelines for the protection of aquatic life (*i.e*. >80% saturation).

Trace metals

The geology of the upper Maitai is such that there are naturally high levels of trace metal contaminants such as manganese, iron, nickel and chromium. Routine monitoring of dissolved metal concentrations show that metal (iron and manganese) levels are elevated in the hypolimnion of the Reservoir during stratification in the warmer months (Table 3). However, concentrations of iron and manganese are usually close to or below the ANZECC guideline values for the protection of aquatic life (1 mg/L for both these metals).

Table 3. A comparison of mean, minimum and maximum recorded concentrations (mg/L) of iron and manganese from monthly spot samples taken from the Maitai Reservoir deep water intake (intake three, below the summer thermocline) for the period January–May and June–December from 2000 to 2012.

		Mean	Minimum	Maximum
January–May	Iron	0.2	0.0	1.0
	Manganese	0.2	0.2	1.7
		Mean	**Minimum**	**Maximum**
June–December	Iron	0.1	0.0	0.5
	Manganese	0.2	0.0	0.5

Water drawn from the Reservoir is currently taken from near its base to aid compliance with water temperature conditions in the discharge consent. When this water enters the Maitai South Branch at the back-feed discharge, any metals will oxidise and settle out onto the stream bed and disperse downstream with flow. Compliance monitoring at Site B has shown that occasionally water with elevated concentrations of manganese is discharged into the Maitai River from the Reservoir (Holmes 2010), although metal levels in the discharge have been low in recent years (Holmes 2012).

A 2012 study found very high concentrations of nickel and chromium in sediments from the Maitai at a site approximately six kilometres below the Maitai Reservoir, with reduced concentrations downstream (Sneddon & Elvines 2012). Whilst nickel and chromium toxicity was not covered in the report, concentrations were well above those recommended in ANZECC (2000) guidelines for freshwater quality[4]. As with, manganese and iron, anoxic conditions in the Reservoir may be contributing to this problem by speciating metals from the Reservoir sediments and discharging them via the back-feed. Alternatively, these metals may have been deposited in the catchment purely though natural erosion processes.

Water temperature

The modified temperature regime (due to the back-feed) of the South Branch generally falls within the optimal range for trout growth, and a growth model has predicted that the temperature regime enhances growth (Crowe *et al.* 2004). Trout sampled in 1982 and 1996 were found to be growing at the maximum rate (based on unlimited invertebrate food) at least for the first two years of life.

Wilkinson (2007b) found that water temperature in parts of the lower Brook, the middle Maitai (upstream from Sharland Creek and downstream from Blackhole Reserve), and the lower Maitai (at Riverside Pool) exceeded the guideline value for

[4] Nickel concentrations measured 250 mg/kg, *c.f.* Australia and New Zealand Environment and Conservation Council — Interim Sediment Quality Guideline-Low Trigger Value (ANZECC ISQG-Low) recommendation of 80 mg/kg; Chromium concentrations measured 540 mg/kg, *c.f.* ‘ANZECC ISQG-Low’ recommendation of 21 mg/kg and ‘ANZECC ISQG-High’ recommendation of 52 mg/kg.

thermal stress in brown trout and *Deleatidium* on a regular basis. Following the release of this report, NCC undertook considerable riparian planting along sections of the Maitai reserves to improve shading (pers. comm. Paul Fisher 10 July 2013).

2.3. Fish passage

The Maitai Dam represents a possible obstacle for the upstream passage of native and non–native fish in the Maitai North Branch. Most native fish are diadromous (*i.e.* require access to and from the sea to complete their life-cycle). If diadromous fish above the Reservoir cannot complete their life-cycle they will eventually disappear from this part of the catchment, although some could theoretically form landlocked populations above the dam. Based on recent sampling undertaken in 2013, Kelly and Shearer (in press) suggest that passage for longfin eels and koaro may be impeded by the spillway.

3. IMPACTS OF CATCHMENT PRESSURES ON MAITAI RIVER HEALTH

3.1. Plantation forestry

The negative effects of plantation forestry (*e.g.* increased erosion and risk of landsliding) can cause substantial damage to stream ecosystems, particularly in the first six years following harvest (Philips *et al*. 2012). Wilkinson (2007c) summarised the general effects of forest felling on water quality (Appendix 3), comparing clear-felled plantation forest with mature plantation forest and un-forested land. The major water quality impacts of forest harvest include an increase in sediment loading, increased nutrient loading, and increased water temperature.

Fine sediment carried in runoff from bare land and road infrastructure can cause excessive sediment loading in streams. However, slope failure of forest roads have been shown to be one of the main causes of sediment erosion from areas undergoing forest felling, and can contribute one or two orders of magnitude more sediment than runoff from road surfaces (Collins 2004), although the propensity for landslides is likely to vary with local geology. The process of excessive sediment loading, known as 'siltation', is problematic for stream ecosystems because it reduces habitat for fish (including spawning habitat) and invertebrates. Changes in the invertebrate community can lead to reduced food for fish, and fish are less able to identify food in more turbid water, thereby further reducing food availability.

Siltation may be related to the decline of the Maitai trout fishery (Hayes 2003), particularly in the middle sub-catchment where the dominant land use is plantation forest (54%). As discussed by Wilkinson (2007c), NCC water quality monitoring data from Sharland Creek shows that turbidity and suspended solids are substantially elevated following rainfall, relative to that in the Maitai mainstem. Sharland and Packers creeks once had high densities of juvenile trout, and were thought to provide excellent spawning and juvenile rearing habitat (Section 1.2.3). Siltation due to plantation forestry is one plausible explanation for the apparent decline in juvenile trout densities, given that 77% of the Sharland catchment is in plantation forestry[5].

The response of native fish populations in the Maitai River (and tributaries) to increases in fine-sediment loading from forestry is not known. However, like trout, they are vulnerable to habitat loss due to increased siltation.

The harvest of plantation forest can also affect water quality by increasing nitrogen and, to a lesser degree, phosphorus levels (Payn & Clinton 2005). Wilkinson (2007c)

[5] Another possible explanation is that juvenile densities are lower today because there are simply less trout around in the mainstem to spawn.

discusses the mechanisms of nutrient leaching following the harvest of plantation forestry, explaining that nitrogen concentrations are highest in winter / spring and that nutrient concentrations will be elevated for a period of five to six years after the completion of harvest.

Crowe and Young (2005) investigated the likely causes of particularly high nitrate concentrations in Sharland Creek. Whilst no single source was identified, possible sources included inputs from extensive tracts of recently logged / young exotic forest and inputs from underlying bedrock. In 2012, NCC stream monitoring in Sharland and Groom creeks showed elevated nitrate concentrations following recent harvest, which contributed to the 'Degraded' state of these middle sub-catchment tributaries (Nelson City Council 2012c).

Water quality in catchments where there is a high proportion of forestry will vary according to the schedule of forest harvesting operations and earthworks, such is the case with monitoring data from Sharland and Groom creeks (Table 1). According to the LCDB land-use database (Section 1.2.1), there was a substantial increase in 'Harvested forest' in the Maitai middle sub-catchment between 1997 and 2002, when around 14% of the total land area (25% of the plantation forestry) in the sub-catchment was harvested. This may explain the degraded state of stream health within the middle sub-catchment over this period (Table 1), and also coincides with the apparent declines in fish numbers in the upper catchment. A better understanding of this potential issue could be gained by comparing forest harvest plans over this period with NCC's quarter annual water quality monitoring data.

Wilkinson (2007c) notes that despite elevated nutrient concentrations and poor water clarity in Sharland Creek, macroinvertebrate community data indicate that water quality is *'Good'*. However, the most recent NCC river and stream health report for Sharland and Groom creeks states that aquatic animal and plant communities are in *'Moderate'* condition (Nelson City Council 2012c). Furthermore, the NCC water quality monitoring is carried out quarter-annually and mostly during low-flow conditions, so will not reflect the true impact of land-use activities (pers. comm. Paul Fisher, Nelson City Council, 10 July 2013).

Crowe and Young (2005) concluded that "Maitai River nitrate concentrations were consistently higher downstream of Sharland Creek, and nitrate loads from Sharland Creek were at least double those coming from the entire Maitai catchment upstream, resulting in dramatic increases in loads downstream. The high turbidity / poor clarity water entering the Maitai River from Sharland Creek reduced water clarity in the Maitai River and are also likely to have increased loads of fine sediment in the substrate downstream, particularly at high flow." However, forestry impacts may be exacerbated by nitrogen and sediment inputs from cattle observed grazing in and around the stream bed of the lower Sharland catchment. This is discussed further in Section 3.2.

Wilkinson (2013) recommends a mapping investigation of felled areas to quantify the nitrogen output per hectare per year, as well as a desktop review of existing water quality data with reference to current scientific literature on the impacts of plantation forestry on nutrient loading in streams.

Forestry operations in the Maitai catchment are managed by Hancock Forest Management (NZ) Ltd. When asked to comment on current sediment control practices in the Maitai catchment, Hancock Forest Management said that they comply with the conditions set out in their resource consent[6], as well as current industry standards described in the New Zealand Forest Road Engineering Manual (and the associated 'Operators Guide'). They also have their own 'Environmental Management System' that stipulates specific 'Environmental Standards' for forest operations including harvesting, engineering, waterway crossings *etc.* Hancock typically uses sediment traps; stormwater diversions (such as fluming) to move runoff away from erodible areas; and road construction well away from waterways, wherever possible. Silt fences are used on occasion to control sediment, but are thought not typically required in the Maitai catchment due to the stable geology and typical distance of operations from waterways (pers. comm., Sally Strang, Health, Safety and Environment Manager at Hancock Forest Management, August 2013).

3.2. Agriculture and stock grazing

Nutrient enrichment and fine-sediment input from pastoral land use can encourage periphyton growth and cause invertebrate communities to be dominated by pollution tolerant species (*i.e.* those species that score poorly in the MCI). As shown in Section 1.2.1, 'High and low producing exotic grassland', which is usually associated with pastoral land use, is minimal within the Maitai catchment (upper sub-catchment = 0%; middle sub-catchment = 4%; lower sub-catchment = 8%). Whilst nutrient enrichment from pastoral land use is unlikely to be a problem in the upper Maitai sub-catchment, it may contribute to nutrient enrichment and microbial bacteria contamination in the middle and lower sub-catchments, particularly in the lower part of Sharland Creek and tributaries to the Brook (see Figure 1).

3.3. Barriers to fish passage: weirs, fords, and culverts

Fish passage with respect to the Maitai Dam is discussed in Section 2.3. Other than the Reservoir, Fish & Game (NZ) are currently of the opinion that fish passage is not a major issue in the Maitai River (pers. comm. Neil Deans, Fish & Game NZ). However, two potential barriers to fish passage were noted, including the ford at Almond Tree Flat, which crosses the mainstem approximately 1 km downstream from the confluence with Sharland Creek; and a culvert on Packers Creek, which is a major

[6] Resource consent number RM075428

tributary of Sharland Creek. There is a tendency for passageway blockage at both of these sites due to sediment build up, which is known to the respective land managers (NCC and Hancock Forest Management), and efforts are made to mitigate the issue by way of regular maintenance (pers. comm. Neil Deans, Fish & Game NZ).

A 2004 memo written by NCC staff member Debra Bradshaw[7] lists and prioritises proposed fish passage enhancement projects in Nelson rivers. The only entry for the Maitai mainstem is for Almond Tree Ford, for which restoration work was later carried out under the supervision of Rowan Strickland (Cawthron Institute)[8].

Whilst Almond Tree Ford was noted as the only barrier on the Maitai mainstem, Bradshaw's memo mentions one more site within the Maitai catchment, located on the lower Brook. Ongoing work to restore fish passage in the Brook has been underway since 2010, and is mentioned in NCC's latest 'Long Term Plan' document, which allocates $566,000 between 2012 and 2022 to carry out remedial work in the Brook Street channel (Nelson City Council 2012a).

3.4. Urbanisation

Stormwater discharges are the main source of urban pollution entering the Maitai River. Channelisation of the river and / or flood protection works have also affected the river through changes to the flow and increased sediment input.

Crowe *et al*. (2004) highlighted three effects of urbanisation in the lower reaches of the Maitai River:

- Stormwater discharges were possibly affecting water quality (bacterial contamination, nutrients) in the lower reaches of The Brook and Matai River.
- High levels of sediment contaminants occurred in the lower reach of the Maitai River (just before it enters Nelson Haven), at concentrations likely to cause adverse ecological effects. In the main stem upstream of The Brook confluence, sediment contaminants (metals and polycyclic aromatic hydrocarbons) occurred in low or undetectable concentrations.
- Sediments from the mid and lower reaches of The Brook were considered moderately contaminated with polycyclic aromatic hydrocarbons (PAH) (Crowe *et al*. 2004).

Since Crowe *et al*. (2004) was published, the Brook Valley has experienced the greatest expansion in residential housing, compared to other parts of the Maitai

[7] NCC memo, dated 16 March 2004, file reference RM0600-02.
[8] Although as mentioned above, both this ford and the ford at the bottom of Packers Creek remain an intermittent barrier to fish passage whenever sediment builds up above them.

catchment. Little is known about the ecological impact of housing development in this area (and the lower Maitai River), but a limited amount of NCC monitoring undertaken since 2007 indicates that "residential development in the upper middle reaches of the Brook has not caused a deterioration in stream health" (Wilkinson 2013).

3.4.1. Storm water discharge and urban pollution

Since 2004, a considerable amount of work has been done in the Maitai catchment to assess water quality in urban stormwater outfalls; river sediment contamination; and issues with faecal contamination in the lower Maitai.

Water quality of stormwater discharged into the Maitai

Stormwater discharges can detrimentally change stream health through the introduction of contaminants such as nutrients, bacteria, heavy metals, oil, grease and fuel compounds.

In Nelson, three 'representative' stormwater discharges that enter the lower Maitai River are monitored. These monitoring sites are the Collingwood Street drain, Bronte Street discharge and Buxton Square car park discharge (Sneddon & Barter 2004, Sneddon & Johnston 2011, Sneddon 2012, 2013). The most recent monitoring of these sites was undertaken in 2012. For a description of the sites see Appendix 4.

The results from surveys undertaken in 2010 and 2012 (and for the Bronte Street site 2004) are presented in Appendix 5. Sneddon (2012) concludes that water quality at the Bronte Street and Buxton Square car park sites was generally better in 2012 than in previous surveys, and that stormwater from the Collingwood Street site was poorer in 2012 than in 2010. The Collingwood Street outfall featured higher levels of faecal coliforms than the other sites.

Despite the apparent improvement at the Bronte Street and Buxton Square car park sites, copper and zinc exceeded NCC Class D standards at all three monitoring sites in 2012, as did the concentration of lead at the Collingwood Street site. Nutrients (dissolved inorganic nitrogen and total nitrogen) exceeded NCC Class D standards at all sites in 2012. Dissolved reactive phosphorus exceeded standards at the Bronte and Collingwood Street sites (Appendix 5).

These drains will contribute to the water contaminants observed in the lower the Maitai River. However, Sneddon (2012) suggests it would be unrealistic to compare them with water quality guidelines that are designed for streams. Sneddon (2012) cautioned that while the NCC water quality standards provide a context for stormwater quality, they do not account for the dilution of the discharge in the receiving stream. Factors by which individual stormwater samples must be diluted with pure water to meet Nelson water quality Class D are provided in Sneddon (2012).

Sneddon (2012) pointed out that a multitude of confounding variables contributes to high variability in stormwater samples. Continued monitoring will provide a temporal record of quality across survey years, and an emerging picture of the status of Nelson stormwater and the specific parameters of concern.

River sediment contamination

Water quality samples can provide information on the water quality of a stream or river at a point in time. However, often contaminants can bind to river sediment (*e.g.* heavy metals, PAHs), and as such sediment samples provide a broader picture of the accumulation of toxins in a river system over time.

Metals

As discussed in Section 2.2, Sneddon & Elvines (2012) reported that very high concentrations of chromium and nickel found in sediments from the Maitai River (6 km downstream from the dam), were present in reduced concentrations with distance downstream. They considered the concentration to be indicative of a strong, naturally-occurring (geological) source in the upper catchments and suggested that there are relatively insignificant inputs in the lower reaches.

While heavy metal concentrations in sediments from the lower Maitai River did not exceed the strictest ANZECC (2000) quality criteria (*i.e.* Interim Sediment Quality Guideline-Low Trigger Value (ISQG-Low) in the latest (2012) survey, the criteria for lead, zinc and copper have been breached in previous sampling occasions (2006 and 2010).

Metals concentrations in sediments from The Brook have been consistently below ISQG-Low guideline but approached the trigger level for zinc in the lower Brook in the 2006 and 2010 surveys. To date, the record suggests clear contamination by lead and zinc in the mid and downstream Brook sites for all but the 2012 survey. Sneddon and Elvines (2012) suggest that the increasing concentrations of lead and zinc downstream in the Brook Stream catchment indicated in the 2006 and 2010 surveys may have been from traffic sources (and also potentially galvanised roofing for zinc).

Polycyclic aromatic hydrocarbons (PAHs)

Significant anthropogenic sources of PAHs to the environment include fuel combustion, automobiles, spillage of petroleum products, and waste incinerators. Polycyclic aromatic hydrocarbons — especially high molecular weight PAHs — are relatively stable in soils and sediments and degrade less readily than many other organic compounds.

Sneddon and Elvines (2012) reported the PAHs in the Brook have been below the ISQG-Low guideline in the 2006, 2010 and 2012 surveys. However, in the lower Matai River (below the Brook confluence) PAH levels in the sediment have exceeded the ISQG-Low guideline on all occasions. Sneddon and Elvines (2012) suggested that it is likely to be a mix of wood fires and vehicle emissions that contribute to the PAH contamination of the rivers sediments, although elevated levels in winter are most likely due to an increase in the use of wood fires. They further suggested that an apparent decrease in PAH concentrations in the lower Maitai over time was possibly attributable to general decreases in emissions from log burners and open fires in Nelson, although comparisons of their results with previous surveys was confounded by differences in the seasonal timing of the surveys.

Overall, if the ANZECC (2000) sediment quality criteria “Interim Sediment Quality Guideline-Low Trigger Value” (ISQG-Low) are accepted as a benchmark for possible ecological effects, the PAH levels in the lower Maitai are still a concern.

Faecal contamination

In addition to apparent faecal contamination in the Collingwood Street stormwater outfall noted by Sneddon (2012), high concentrations of faecal indicator bacteria (FIB) have been the subject of several other studies.

A NCC health warning has been in place since 2007 warning against swimming in the lower Maitai (at Collingwood Street Bridge) because of frequently high concentrations of FIB found in routine monitoring (Nelson City Council 2011; 2012b; 2013). The monitoring, undertaken as part of summer swimming water quality surveys, consistently shows much lower FIB concentrations 1 km upstream at the ‘Girlies Hole’ swimming spot.

Sinton (2007) and Kirs (2008) investigated what was described as a ‘chronic problem’ of faecal contamination in the lower Maitai. Sampling sites in the lower Maitai included Girlies Hole, Domett Bridge (the footbridge at the end of Hardy Street), Normanby Bridge (also known as the Bridge Street bridge), Shakespeare Walk, Collingwood Street Bridge and Trafalgar Street Bridge. Kirs (2008)[9] found strong signals of human faecal markers in all samples collected downstream from the Halifax Street footbridge. Also, ruminant and / or possum faecal markers were found at all the sites below Normanby Bridge, though no such tests were carried out with samples taken upstream of this point. While land runoff was probably the major source of animal-associated faecal contamination, leaking sewage collection systems or cross-connections that impact the groundwater or stormwater systems were likely the major source of human-associated faecal contamination in the Maitai River (Kirs 2008). Stormwater outfalls can transfer contamination to the river, as well as provide a sunlight-protected environment for faecal indicator bacteria to survive and potentially replicate. Stormwater runoff at the Trafalgar Street Bridge site had concentrations of indicator bacteria similar to raw sewage (Kirs 2008). Alex Miller, NCC utilities investigator, notes that storm / wastewater infrastructure in urban areas surrounding the lower Maitai River were originally served by a combined sewer system that

[9] Sampling was carried out in December 2007, so after 2006 NCC sewer line remedial works in the area.

discharged to the river. "*The most likely source of contamination is from older foul sewer lines that have not been separated from the stormwater system and this is subject to continued investigation. The converse is also true, where stormwater is directed to the wastewater reticulation, causing overflows from manholes, [which is subsequently] collected (by way of overland flow) by nearby stormwater intakes (roadside sumps etc.)*"(pers. comm., Alex Miller, NCC utilities investigator, August 2013).

Neither Sinton (2007) nor Kirs (2008) looked specifically at the outfall from Queens Gardens that flows into the Maitai River at Bridge Street. Presumably, this drain would contain high levels of FBI derived from the duck pond in Queens Gardens. Kirs did not test for the presence of faecal indicators specific to birds.

3.4.2. Channelisation and flood protection works

Crowe *et al*. (2004) highlighted two main features of channelisation and flood protection works in relation to the Maitai River:

- Channelisation as a result of river control works appears to have decreased the sinuosity of the lower river. This probably has reduced cover for fish and increased water velocity, meaning that floods are more likely to impact fish populations (Hayes 2003).
- Natural (*e.g.* waterfalls and cascades) and human-made (*e.g.* dams, weirs, bridge aprons and culverts) structures can limit the distribution of native fish.

Other than the fish passage restoration work discussed in Section 3.3, there have been no significant changes in the Maitai River in relation to channelisation or flood protection works (to the authors knowledge) beyond what already existed leading up to the Crowe *et al*. (2004) report.

3.5. Recreation

The Maitai River is close to Nelson and the surrounding area offers a variety of recreational activities to the public. These are concentrated in the parks and reserves in the middle / lower sub-catchment and include activities such as swimming, river-side picnicking, camping and dog exercising. Some degree of impact on water quality (particularly faecal contamination) can be expected from such activities. Estimating the extent of this is very difficult, but it is likely to be much less significant than the impacts from urban environments (Section 3.4). Recreational motor-cross riding in forestry areas may be exacerbating sedimentation by abrasion / rutting of roads and tracks, though the relative impact of this is also difficult to quantify.

4. OVERVIEW AND DISCUSSION

4.1. Summary

Table 4 summarises the possible negative impacts that Maitai River catchment activities can have on river health.

Table 4. Possible impacts of catchment activities on river ecology within the Maitai River catchment.

Catchment activity	Examples	Possible negative impact
Maitai Dam water storage and water supply management	Abstraction / water storage	• Reduced habitat for invertebrates which will cause a reduction in food supply for fish, and hence a possible reduction in the condition and or size of fish populations. (Hayes 2003)
	Discharge of water from dam	• Water discharged into the Maitai River from the Reservoir over the summer months is anoxic, and may alter water chemistry downstream and contain contaminants such as manganese, nickel and chromium. • There has been a decline in water quality and an increase in algae growth directly below the dam back-feed discharge. • Whilst manganese, nickel and chromium are naturally occurring, the current dam operating regime may increase their concentration at the point of discharge into the Maitai River. • Micronutrients present in the Reservoir (*e.g.* manganese and iron) may be causing increased algae growth below the back-feed discharge.
	Reduced fish passage	• The Reservoir spillway may impede access for diadromous fish to areas upstream, specifically longfin eels and koaro. • The backfeed discharge acts as an attractant flow for migratory species, but is ultimately a dead end. Fish gathered in the pool adjacent to the discharge may be more susceptible to predation by birds.
Plantation forestry	Harvesting operations and earthworks related to plantation forestry	• Increased sedimentation and reduced water clarity (loss of fish habitat and spawning habitat; loss of invertebrate habitat; reduction in quality and quantity of food for fish and invertebrates) • Increased nutrient loading in streams during harvest may cause increased growth of algae and may also stimulate cyanobacteria growth
Agriculture and stock grazing	Stock access to channel or riparian area	• Decreased water quality (bacterial contamination, nutrient and chemical inputs, sedimentation from bank erosion (see above) • limited spatial impacts only relevant to the mid - lower Maitai sub-catchment (8% of land use)

Catchment activity	Examples	Possible negative impact
Barriers to fish passage	Maitai Dam, Almond Tree ford, Packers Creek ford, concrete fords and culverts	• Maitai mainstem: no significant barriers downstream from the Maitai Reservoir, other than occasional temporary blockage of fords • The lower Brook: Reduced passage for trout and native fish (NCC addresses this in the 'Long Term Plan' (2012-2022).
Urbanisation	Storm water discharge and urban pollution	• Urban stormwater outfalls deposit a variety of contaminants into the river in the lower reaches (nutrients, bacteria, heavy metals, oil, grease and fuel compounds from roads). • Regularly high concentrations of faecal indicator bacteria in the lower Maitai is 'chronic problem' for recreational water quality in the lower river (Sinton 2007)
	Channelisation and flood protection works	• Reduced fish habitat and fish passage • Reduced cover for fish and increased water velocity (floods are more likely to impact fish populations) • Probably also reduced habitat for invertebrates with resulting reduction in feeding opportunity for fish.
Recreation	Swimming, walking, picnicking, camping angling *etc.*	• Decreased water quality (bacterial contamination) • Pollution via the decay of litter such as plastic bags / bottles, food waste etc.

4.2. Dominant stressors / pressures

Based on the information provided in this review it is our view that forestry and urban stormwater runoff are the dominant pressures facing the Maitai catchment.

Forestry is the dominant land use in the mid-catchment. Diffuse inputs of sediment and nutrients, generated from forestry activities, are collected by the two main mid-catchment tributaries (Sharland and Groom creeks) and transported to the mid-lower Maitai River. The MCI is a measure of the macroinvertebrate community response to sediment and nutrient pollution. Therefore, the observed declines in MCI scores throughout the mid-catchment indicate that fine-sediment and / or nutrient levels are increasing and are negatively impacting upon stream biota. High levels of both of these contaminants have been repeatedly associated with the tributaries issuing from the areas of the sub-catchment dominated by forestry.

The lower catchment, especially the lower tidal reach, is particularly degraded relative to the rest of the catchment, both in terms of macroinvertebrate community composition and contaminant loads in the sediments. Stormwater drains are the likely source of contaminants that bind to the river sediments. However, with the exception of the high levels of microbial contaminants, the stormwater discharges that drain into the Maitai River are largely typical of urban drains in New Zealand (pers comm. Ross

Sneddon, July 8 2013). National urban stormwater quality datasets would provide a basis for comparison, *e.g.* NIWA's 'Urban Runoff Quality Information System'.

Concentrations of faecal indicator bacteria regularly exceed guideline values for swimming in the lower Maitai. There is only a relatively minor amount of farming in the catchment. Therefore, it seems likely that most of the faecal bacteria present in the river are derived from faults in the city's sewage system and / or waterfowl.

Benthic cyanobacteria blooms may be an emerging issue. Toxins produced by benthic cyanobacteria mats can restrict recreational activities. The blooms that are occasionally observed in mid Maitai catchment are likely to be a response to cumulative nutrient loading from forestry. Cyanobacteria coverage is now regularly monitored at three sites in the 'middle' Maitai River. Nelson City Council erects warning signs in the middle and lower Maitai during summer as a precautionary measure. Nutrients and micronutrients present in the back-feed discharge from the Maitai Reservoir may also be contributing to the cumulative nutrient loading in the Matai River.

4.3. The effect of the Maitai Reservoir relative to other stressors / pressures facing the catchment

The Maitai Reservoir appears to have negative impacts on stream biota immediately downstream of the back-feed discharge. These impacts are caused by the discharge of anoxic water from the reservoir hypolimnion during mid to late summer. NCC has implemented a plan to quantify and address these issues over the next three years.

It is not possible to accurately assess the extent of the Reservoir's influence because little is known about the state of the segment of river immediately below the Reservoir discharge. This knowledge gap will be addressed by NCC with work planned in 2014. However, based on data assessed by this review, the impact of the Maitai Reservoir on the mid and lower Maitai River is likely to be minor when considered in context with the magnitude and extent of other pressures facing the catchment. Habitat degradation in the lower catchment is largely attributable to forestry and urbanisation, more specifically, sediment and nutrient loading from Sharland and Groom creeks, and nutrient and contaminant loading from various stormwater drains from urbanised areas downstream. There are however, three specific ecological issues which arise as a result of the Reservoir that may affect ecological values in the wider catchment:

1. Naturally occurring nickel and chromium levels are higher in the mid Maitai River than lower in the catchment (Sneddon & Elvines 2012). The anoxic conditions in the Reservoir may be contributing to this problem by speciating metals from the Reservoir sediments and discharging them via the back-feed. Alternatively, these

metals may have been deposited in the upper catchment purely though natural erosion processes.

2. The Reservoir spillway is the most significant fish passage obstacle within the Maitai River. Kelly and Shearer (2013) suggest that the spillway may restrict eels and koaro from utilising habitat in the Reservoir and North Branch of the Maitai River, thus reducing the potential population size of these species in the catchment. If fish passage issues are to be addressed in the Maitai catchment, the reservoir spillway would be a good place to focus resources.
3. Water quality is reduced below the back-feed discharge, especially during periods when anoxic reservoir water is discharged. The limited spot water quality data available for this location suggests that relevant ANZECC (2000) guidelines for the protection of aquatic life are not exceeded. However, even subtle changes in water chemistry can alter algal communities, potentially providing favourable conditions for undesirable species. An increase in mat-forming cyanobacteria has been noted below the discharge (relative to an upstream control site) on one occasion during routine monitoring (Olsen 2010). We consider that the back-feed discharge, as it is currently operated, presents a low to moderate risk of contributing to the apparent increasing occurrence of benthic cyanobacteria mats throughout the river. Biological surveys below the Maitai Reservoir, that include assessments of the algal communities, are planned for 2014 and will investigate this risk further.

4.4. Catchment values

NCC's 'Long Term Plan (2012–2022)' focuses on improving Nelson's waterways with regard to swimming water quality standards and 'ecosystem health' as measured by NCC's own river health classifications system. Our recommendations (Section 5) are specifically related to these performance measures.

Ecological values are implicit within NCC's river health classifications system; however, specific performance measures and targets associated with freshwater values such as native fish habitat or fishery values are not included in the long term plan. A framework for identifying and setting management limits and targets for freshwater values is provided in the Ministry for the Environment document 'Freshwater reform: 2013 and beyond' (Ministry for the Environment 2013). In a report for Auckland Council, Berkett *et al*. (2013) provides direction on how to undertake catchment management using a collaborative governance approach, in line with the recent central government recommendations.

5. RECOMMENDATIONS

5.1. Improving the Maitai River for swimming

Concentrations of faecal indicator bacteria found in the stormwater outfall on Collingwood Street were substantially higher than those found in water from two other stormwater outfall sites (in the order of 95 to 140 times) (Sneddon 2012) (Section 3.4). Similarly, Kirs (2008) found strong signals of human faecal markers in all samples collected downstream from the Halifax Street footbridge. Further investigation to identify the cause of contamination from this source could be considered a priority to identify opportunities to reduce faecal bacteria loading. Refer also to recommendations made by Kirs (2008).

Some faecal bacteria may originate from livestock within the middle and lower sub-catchments of the Maitai River. We recommend ground surveys to determine if appropriate stock exclusion fencing is in place throughout the catchment, including the major tributary's (*e.g.* Sharland and Groom creeks and The Brook). Fencing should be erected in areas where stock is known to have access to the stream, such as in the lower Sharland Creek.

Cyanobacteria growth is enhanced by nutrient enrichment. Furthermore, toxic mat-forming cyanobacteria are likely to be nitrogen limited (Wood & Young 2012). The majority of nutrient loading in the Maitai River is likely be from diffuse inputs associated with forestry and point-source loading associated with stormwater discharges. In addition, changes to water chemistry associated with the Maitai Reservoir back-feed discharge may favour mat-forming cyanobacteria. Cyanobacteria blooms affect swimming areas upstream of major stormwater influences; therefore, mitigation efforts should focus on reducing diffuse nutrient loading from forestry activities and the back-feed discharge from the Maitai Reservoir.

5.2. Improving ecosystem health

We have identified that fine sediment associated with forestry activity in the mid-catchment may be degrading ecosystem health in the mid and lower Maitai River. With this in mind, we suggest including sediment assessment protocols into the NCC River health monitoring programme as a minimum step to further monitor this issue. Specifically, the 'in-stream visual % cover' and 'suspended inorganic sediment quorer' protocols, as described in Clapcott *et al*. (2011) ought to be used. More intensive investigations into fine-sediment loading in the catchment should be considered (*e.g.* continuous turbidity monitoring in forested and reference sites).

Significant resources have been devoted to identifying point source contaminant discharges in the Maitai River. However, less is known about the diffuse sediment and nutrient input from forestry activities in the mid-catchment. Spatial habitat mapping and ground surveys could identify areas of the catchment where remedial actions, such as installing wider riparian buffers or sediment traps, could reduce fine-sediment loading in the Maitai River and tributaries.

Nickel and chromium levels in stream sediments appear elevated six kilometres below the Maitai Reservoir (Sneddon & Elvines 2012). Identifying the source of these contaminants could involve compiling existing sediment sample data, together with additional sampling if required, to determine if these contaminants are ubiquitous through the upper catchment or originate from the Reservoir.

Recommendations relating to the operation of the Maitai Reservoir can be found in Holmes and Kelly (2012) and Kelly and Shearer (2013).

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8. APPENDICES

Appendix 1. Freshwater Classifications for Nelson (Wilkinson 2007).

Class A: EXCELLENT - Natural State Ecosystems (High conservation/ecological value).
Effectively unmodified or other high value ecosystems, typically (but not always) occurring in conservation reserves or in remote, inaccessible, or restricted access locations. The ecological integrity of high conservation/ecological value systems is regarded as intact.
Uses and Values: Water uses which require, or water which is managed for, the highest possible natural water quality (pristine). Provides for flow and fauna, cultural and Tangata Whenua values.

Class B: VERY GOOD - Slightly disturbed ecosystems (generally healthy).
Ecosystems in which aquatic biological diversity may have been adversely affected by a relatively small but measurable degree of human activity. The biological communities remain in a healthy condition and ecosystem integrity is largely retained. Typically freshwater systems would have slightly to moderately cleared catchments and/or reasonably intact riparian vegetation. These systems could include rural streams where there is no significant contamination from grazing (restricted stock access) or forestry, or urban streams with intact or extensive riparian planting and/or esplanade reserves.
Uses and Values: This class includes water managed for values and uses requiring high quality water. Uses and values include aquatic ecosystems and fisheries, water bodies having significant cultural and spiritual values, aquaculture, shellfish and mahinga kai for human consumption, flow and fauna, Tangata Whenua values, human drinking water or contact recreation.

Class C: MODERATE - Moderately disturbed ecosystems (healthy but ailing).
Aquatic biological diversity has been moderately affected by human activity. The biological communities are under some stress from disturbance of their natural habitat. Typical Class C ecosystems would have cleared catchments with only sporadic riparian vegetation. These systems could include rural streams which receive some contamination from grazing (limited stock access) or forestry, or urban streams with limited building setbacks and only limited riparian vegetation.
Use and Values: Includes water managed for uses which require moderately high quality water, such as irrigation and stock water and general water use. Would also provide for limited contact, and non-contact recreation and aesthetic values where the visual characteristics of the water (clarity, colour and hue) are not compromised. May retain some spiritual and Tangata Whenua values.

Class D: DEGRADED – Highly disturbed ecosystems (unhealthy).
Highly degraded ecosystems of lower ecological value. Examples of highly disturbed systems would be urban streams receiving high volumes of road and stormwater contamination with no or little riparian protection, or rural streams which are contaminated by unrestricted stock access.
Uses and Values: Water quality which is suitable only for abstraction where quality is not an issue and contains few instream values, Tangata Whenua values or ecological values.

Class E: VERY DEGRADED - Severely degraded ecosystems.
Severely degraded ecosystems with few or no ecological values. Urban examples would include streams with historical industrial discharges and cumulative sediment contamination, or which have been highly modified or channelised to the extent that natural habitat is no longer retained. Rural streams might be subject to high intensity and frequent contamination from agriculture or land use activities, such as discharge of untreated effluent and uncontained large-scale sedimentation.
Uses and Values: Instream values are severely depleted and water is generally unsuitable for any use. Few values (*e.g.* Tangata Whenua values).

Appendix 2. Macroinvertebrate indices and their interpretation.

Tax richness / Number of taxa: This is simply the number of different kinds (*i.e.* taxa) pf animals present. Sometimes a taxon is resolved down to the species level (*e.g. Oxyethira albiceps*), but it may be taken only to the genera level (*e.g. Deleatidium* sp.) or even higher taxanomic level (*e.g. Oligochaeta*), depending on the practicality of identification.

% EPT taxa: The EPT taxa index is based on the number of kinds of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera) found in a sample. These kinds of freshwater insects are generally intolerant of pollution.

MCI (Macroinvertebrate Community Index: MCI values are calculated according to the method of Stark (1985, 1993a, 1998a). The MCI relies on prior allocation of scores (between 1 and 10) to different kinds of freshwater macroinvertebrates based on their tolerance to pollution. Macroinvertebrates that are characteristic of unpolluted conditions and/or coarse stony substrates score more highly than those found predominantly in polluted conditions or amongst fine organic sediments. In theory, MCI values can range between 200 (when all taxa present score 10 points each) and 0 (when no taxa are present) but, in practise, it is rare to find MCI values greater than 150. Only extremely polluted or sandy and/or muddy sites score under 50.

SQMCI (Semi-Quantitative Macroinvertebrate Community Index): Unlike the MCI, which only uses presence-absence data, the SQMCI incorporates relative abundances into an index calculation. SQMCI values, therefore, reflect the abundance and types of macroinvertebrates found at a site. Although the MCI, SQMCI and QMCI (see below) were developed to assess organic pollution in stony-bottomed streams, they have proven useful in other stream types for assessing habitat quality and environmental health.

QMCI (Quantitative Macroinvertebrate Community Index): The QMCI, like the SQMCI, reflects the abundance and types of macroinvertebrates found at a site. However, the QMCI incorporates the scores of the each taxon in the community in a unique way: each taxon's score is weighted by its abundance (as calculated by its percentage contribution to the total community), so that the overall index value is weighted towards the scores of the dominant taxa. Values range from0 to 10 (although, in practise, it is rare to find QMCI values less than 2.00 or greater than 8.00), and are directly comparable to SQMCI.

MCI, SQMCI and QMCI scores from hard-bottomed streams can be interpreted using the ranges described in Table A2.1.

Table A2.1. Interpretation of the Macroinvertebrate Community Index (MCI) and Quantitative Macroinvertebrate Community Index (QMCI) scores in stony streams with respect to water quality and/or pollution levels. Adapted from Stark & Maxted (2007).

Water quality	MCI	SQMCI / QMCI
Excellent (clean water)	> 120	> 6
Good (possible mild pollution)	100–119	5-5.9
Fair (probable moderate pollution)	80–99	4–4.9
Poor (probable severe pollution)	< 80	< 4

Appendix 3 List of generalised variations in catchment and ecosystem functioning associated with un-forested, forested and clear-felled land (from Wilkinson 2007c).

	Water / moisture balance **Un-forested catchment**	**Mature conifer stand**	**Clear-fell responses**
Atmosphere/catchment surface boundary (includes vegetation cover)	Low capture of cloud/mist Low evapotranspiration	Enhanced capture of cloud/mist water Enhanced evapotranspiration	Reduced cloud/mist capture Negligible evapotranspiration (initially)
Catchment surface / stream boundary (surface and sub-surface)	Reduced moisture retention in vegetation cover Reduced soil moisture Dry hydro-phobic soil surface Rapid onset of bypass flow	Enhanced moisture retention in vegetation cover Elevated soil moisture Infiltration and storage enhanced	Reduced moisture retention Changed soil moisture Rapid runoff mechanisms enhanced
Riparian/Instream effects	Reduced baseflow Flashier runoff response	Less flashy response Extended baseflow recession	Response becomes more flashy Baseflow recession shortened

	Physical environment **Un-forested catchment**	**Mature conifer stand**	**Clear-fell responses**
Atmosphere/catchment surface boundary (includes vegetation cover)	Enhanced air temperature High solar radiation Low humidity	Reduced air temperature and solar radiation (within canopy) Enhanced humidity	Amplitude of air temperature variation increases Loss of shading Lower humidity
Catchment surface/stream boundary (surface and sub-surface)	Soil surface heating	Soil cooler	Soil warming
Riparian/Instream effects	Minimal shading of stream Greater amplitude of temperature variation	Stream shading Stream temperature buffered (less variable)	Loss of shading Amplitude of temperature variation increases (within and between seasons)

	Hydro-chemical/nutrient behaviour **Un-forested catchment**	**Mature conifer stand**	**Clear-fell responses**
Atmosphere/catchment surface boundary (includes vegetation cover)	Low capture of aerosol	Enhanced capture of aerosol; marine salts, base cations and acidic anions (if present)	Salt capture eliminated
Catchment surface/stream boundary (surface and sub-surface)		Enhanced salt delivery to stream	Release of N, P, K from decaying slash
Riparian/Instream effects		Elevated conductivity	Conductivity declines Temporary enrichment of stream from slash leachates

	Sediment response **Un-forested catchment**	**Mature conifer stand**	**Clear-fell responses**
Atmosphere/catchment surface boundary (includes vegetation cover)	Negligible effects	Possible capture of dust	Loss of dust capture
Catchment surface/stream boundary (surface and sub-surface)	Dependent on land use	Access road erosion minimal	Access road erosion, some off-track ground disturbance
Riparian/Instream effects			Enhanced turbidity, elevated clay/silt/sand settlement and redistribution within channel

	Biotic characteristics **Un-forested catchment**	**Mature conifer stand**	**Clear-fell responses**
Atmosphere / catchment surface boundary (includes vegetation cover)	Access for night-roosting water fowl	Reduced avian fauna diversity	Reduced avian fauna diversity
Catchment surface/stream boundary (surface and sub-surface)		Impoverished soil biological diversity	
Riparian / In-stream effects		Improved in-stream invertebrate fauna Reduced spawning of natives	Reduced spawning of natives

	Amenity / Aesthetic / Human well-being / Community considerations **Un-forested catchment**	**Mature conifer stand**	**Clear-fell responses**
Land / viewscape	Bare/open look	Unvarying viewscape	War-zone appearance
Experience on the ground	Views Harsh open environment Biologically impoverished	Enclosed environment Poor off-track accessibility Biologically impoverished	Chaotic unwelcoming terrain
Downstream issues	Dependent on land use	Clear streamwater	Loss of clarity and algal growth
Financial / economic	Local income generation	Static investment	Local jobs and expenditure Central/corporate profit from forest products

	Climate and global perspectives		
	Un-forested catchment	**Mature conifer stand**	**Clear-fell responses**
Atmosphere / catchment surface boundary (includes vegetation cover)	High albedo Low moisture storage Enhanced air temperature?	Moderation of thermal and moisture environment	Increase in albedo Loss of moisture storage
Catchment surface/stream boundary (surface and sub-surface)	Minimal carbon storage	Carbon locked-up in bio-mass Minimal continuing carbon uptake Carbon held in soil and litter organic matter	Soil drying and respiration of CO_2

Appendix 4. Description of the three stormwater monitoring sites that discharge into the The Brook or lower Maitai River. Descriptions were adapted from Sneddon (2012).

Collingwood Street

The Collingwood Street drain is a discharge typical of commercial/residential areas in an urban setting, it comprises busy urban road surfaces but has a lower overall proportion in commercial land uses, the remainder being largely old residential. All of the catchment is developed (resulting in a relatively high proportion of impervious surface). Total catchment area is on the order of 16.5 ha and approximately 60% of this is under commercial land use Sneddon (2012).

Bronte Street

The Bronte Street discharge is sourced from in one of the older residential areas in Nelson, with many of the houses dating from the early 1900s. The catchment has a total area of 16 ha and features relatively little undeveloped land. Impervious surfaces make up 34% of the total area with nearly half of this as roof surfaces. Pervious surfaces are mostly characterised by well-established vegetation and mature trees. Gradients are variable but relatively steep in its less-developed southern portion. It drains to the lower Brook Stream through a perched outfall (Sneddon 2012).

Buxton Square carpark

Finally the discharge from Buxton Square collected in a catch pit before going into the stormwater system and into the River. Buxton car park occupies flat land bordered by commercial buildings fronting onto Hardy, Trafalgar, Bridge and Collingwood Streets. The area of the car park is approximately 1.3 ha and the catchment surfaces are effectively 100% impermeable. The sample collection point was one of the catch pits at the western end of the car park and, since only flow draining directly into the catch pit from adjacent surfaces was sampled (as opposed to piped flow into the sump), the grab sample effectively represented run-off from a sub-catchment of less than 0.3 ha, comprising only the bitumen and other pavement surfaces of the southwest quadrant of the car park (Sneddon 2012).

Appendix 5. Analysis results for first-flush stormwater grab samples in 2012 (first hour of run-off) compared to historical records for the same sites and Nelson Water Quality Classes (Nelson Resource Management Plan, Appendices 28.5-28.6). Values in bold font show exceedance of Class D standards. Values are not listed for Semi-Volatile Organic Compounds (SVOC) since no SVOC analyte has been above the analytical detection limit for any sample from these catchments. Table reproduced from Sneddon (2012).

	Bronte (Old residential)			Buxton car park		Collingwood (commercial)		Nelson WQ Stds	
Survey year	**2012**	**2010**	**2004** [a]	**2012**	**2010**	**2012**	**2010**	**Class C**	**Class D**
Indicator bacteria (cfu/100 mL)									
Enterococci	940	1000	7600	170	2400	600	4000	-	-
Faecal coliforms	583	2000	16000	740	2800	8.3×10^4	9000	400 [b]	-
Escherichia coli	583	2000	-	740	2800	6.9×10^4	9000	500 [c]	-
Physico-chemical parameters (mg/L)									
pH	7.7	7.6		7.5	**5.8**	7.2	**6.2**	6.5 – 8.5	6.5 – 9.0
Biochemical Oxygen Demand	8	20	32	11	81	31	29	-	-
Total suspended solids	22	22	90	56	62	30	88	-	-
Fixed suspended solids	14	4		33	22	15	48	-	-
Volatile suspended solids	8	18		22	40	16	40	-	-
Oil and Grease	13	5	<3	8	<3	<4	<3		
Nutrients (mg/L)									
Dissolved inorganic nitrogen	**0.89**	**1.3**	**0.58**	**0.64**	**4.0**	**2.3**	**1.8**	0.295 [d]	0.350 [d]
Nitrite-N + Nitrate-N	0.65			0.40		2.2		-	-
Total Ammoniacal Nitrogen	0.23			0.24		0.105		-	-
Total Kjeldahl Nitrogen	1.49			1.24		2.0		-	-
Total Nitrogen	**2.1**	**2.9**	**4.0**	**1.63**	**13**	**4.3**	**5.0**	0.250 [d]	0.337 [d]
Dissolved Reactive Phosphorus	**0.152**	**0.4**	**0.32**	0.006	**0.14**	**2.4**	**0.21**	0.026 [d]	0.030 [d]
Metals (mg/L)									
Cadmium	<0.00005	<0.0005	<0.0005	0.00006	<0.0005	0.00016	<0.0005	0.0004	0.0008
Chromium	0.0019	0.004	0.004	0.0024	0.014	0.0029	0.006	-	-
Copper	**0.022**	**0.040**	**0.047**	**0.019**	**0.13**	**0.029**	**0.060**	0.0018	0.0025
Lead	0.0070	0.009	**0.019**	0.0077	**0.018**	**0.011**	**0.014**	0.0056	0.0094
Nickel	0.0019	0.0022	0.0062	0.0044	**0.035**	0.0032	0.0056	0.013	0.017
Zinc	**0.19**	**0.15**	**0.284**	**0.14**	**1.7**	**0.74**	**1.5**	0.015	0.031

a. Sample in 2004 was a flow-weighted composite as opposed to the first-flush grab samples collected in subsequent years.
b. No greater than 20% of monthly samples.
c. Limit for monthly running median.
d. Mean monthly concentrations of dissolved inorganic nitrogen and dissolved reactive phosphorus measured in streams and rivers under low-flow conditions. Total nitrogen in lakes and reservoirs.