report

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Assessment of Effects of the Alliance Lorneville Wastewater Discharge on the Makarewa and Oreti Rivers and New River Estuary

Submitted to:
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1.0 Background

Alliance Group Limited (Alliance) is seeking to lodge applications for new resource consents to discharge treated wastewater (the discharge) from its Lorneville Plant (the Plant) to the Makarewa River in 2015. The discharge from the Plant includes wastewater from the slaughter, further processing, rendering and fellmongery operations along with human wastewater generated on site and from Wallacetown. Wastewater is treated onsite via physical, anaerobic and aerobic treatment systems followed by discharge to the Makarewa River (PDP 2014).

Work associated with the assessment of the current and possible future discharges on the Makarewa River, Oreti River and New River Estuary began in 2012. The work has included the following key assessments:

- Environmental data review and monitoring plan preparation (Freshwater Solutions 2013).
- Discharge and river water quality data analysis and assessment (Freshwater Solutions 2015a).
- Site specific receiving water ammonia criteria evaluation (Freshwater Solutions 2014, attached as Appendix 1).
- New River Estuary nutrient and sediment load estimates (Robertson and Steven 2013).
- Aquatic plant, benthic invertebrate and fish surveys in summer 2013, spring 2013 (off season) and summer 2014 (Freshwater Solutions 2015a).
- Mixing zone assessment in summer 2014 (Freshwater Solutions 2015b).

Freshwater Solutions (2015a) have provided a comprehensive description of the existing receiving environment including hydrology, water quality and ecology of the Makarewa River, lower Oreti River and New River Estuary, and have reviewed relevant sediment water quality and ecology data collected under the existing treated wastewater discharge consent (Discharge Permit 92195). The report included a description of the results of the summer 2010, summer 2013 and spring 2013 biological surveys (habitat, aquatic plant, benthic invertebrates and native fish) in the Makarewa River and characteristics of the discharge from long-term monitoring.

A review of the current ammonia concentrations, description of the ANZECC approach to ammonia trigger value derivation, review of the toxicological data for ammonia, ammonia trigger value derivation using ANZECC (2000) and USEPA (2013) and recommended ammonia limits for protecting aquatic species found in the Makarewa River downstream of the discharge is provided in Freshwater Solutions (2014) and attached as Appendix 1.

Robertson and Stevens (2013) described and assessed the nutrient loads entering the New River Estuary using the Catchment Land Use for Environmental Sustainability model (CLUES 10.1). The report summarised and presented the point and diffuse sources of total nitrogen (TN), total phosphorus (TP) and total suspended solids (TSS) to the estuary and estimated the Plant's contribution to the Makarewa River and New River Estuary.

Freshwater Solutions (2015b) presented and described the results of a mixing zone assessment based on a survey of the river in March 2014 at low river flow and during an outgoing and incoming tide using an Acoustic Doppler Current Profiler and global positioning system.

Coast and Catchment (2014) reviewed the extensive monitoring information for the New River Estuary in order to describe the current state of the estuary and to assess the effects of the current and future discharge from the Plant.

The following assessment of ecological and recreation effects is based on the work described above and other information sources relevant to the potential effects on river and estuarine environments that may result from the discharge of treated waste from meat processing plants and sewage treatment from small rural communities (in this case Wallacetown).

This report has been prepared jointly by Freshwater Solutions Ltd and Aquatic Environmental Service Ltd and is structured to provide an assessment of the actual and potential effects of the discharge from the Plant, identifies what standards and guidelines are required as targets and then assesses each of the effects of the current discharge quality against those standards and targets. The report then identifies what mitigation is required to meet those targets or guidelines.

2.0 Potential Ecological and Recreational Effects

Alliance discharges treated wastewater from the Plant and Wallacetown in to the Makarewa River some 4.4 km downstream of the Wallacetown-Lorneville Highway Bridge and 5 km upstream of the confluence between the Makarewa and Oreti Rivers. This confluence is approximately 14 km upstream of the New River Estuary (Figure 1).

As described in Freshwater Solutions (2015a), the Makarewa River drains a 991 km^2 catchment which has largely been developed and modified for agriculture. Thus by the time the river reaches the Alliance discharge it is already characterised by high levels of nitrogen and phosphorus, high bacteria levels, low visual clarity, and an invertebrate community indicative of ‘fair’ water quality. Data for the New River Estuary, a large shallow ‘tidal lagoon’ estuary, indicate that significant and increasingly larger parts of the estuary are seriously impacted by sediments and elevated nutrient levels, which are reflected in changes to the macroalgal community.

The discharge of treated wastewater from meat processing plants has a number of potential direct and indirect effects on the receiving waters. The Freshwater Solutions (2014a) report has identified increased nutrient levels, and in particular ammonia, total phosphorus and nitrogen, water clarity and presence of scums and foams, as potential effects from surveys and monitoring of receiving waters below the discharge. However such discharges also have the potential to change the physical properties of the water, microbial and biological communities as well as affecting recreational values.

Sampling sites referred to in this report are shown in Figure 1. Sites U1 and U2 and Bridge sites are well above the discharge and site U1 above the limit of the tidal influence. Site D2 is just above the discharge and potentially in the mixing zone at high tide. Site D1 is just below the discharge and in the mixing zone. The site labelled ‘200 m’ is actually approximately 350 m below the discharge and just beyond the mixing zone. The Boundary site is well outside the mixing zone.

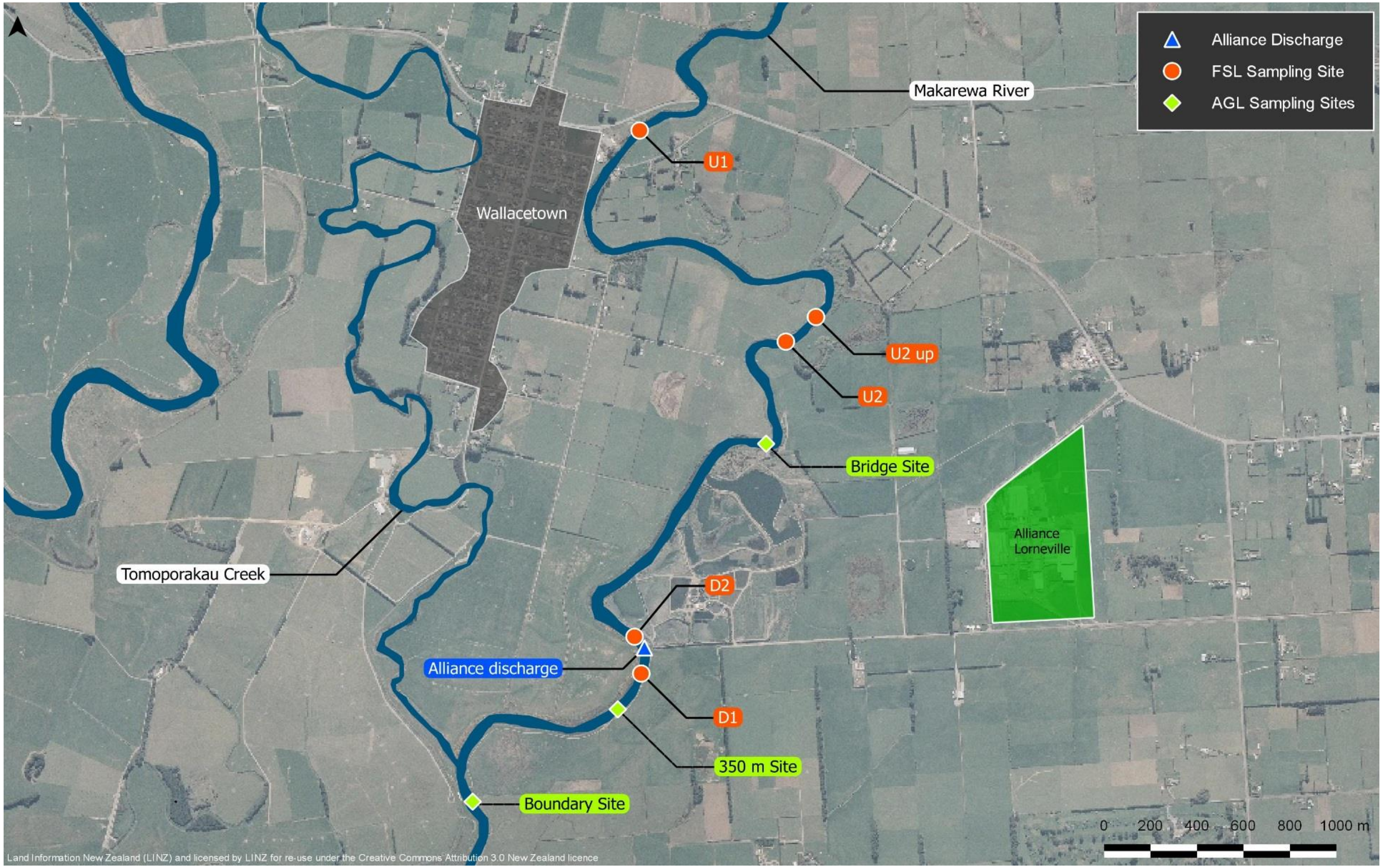

Figure 1: Lower Makarewa River, Oreti River and the New River Estuary and location of discharge and sampling sites.

The actual and potential effects of the discharge on the receiving environment that are assessed in this report are presented in Table 1 and include:

- Ammoniacal-N (Amm-N) toxicity.
- Increased nutrient concentrations.
- Increased bacteria concentrations.
- Reduced dissolved oxygen (DO) concentrations.
- Altered colour and clarity.
- Generation of foams and scums.
- Development of nuisance algal growths.
- Altered benthic invertebrate community.
- Altered fish community.
- Reduced cultural and recreational values.

The potential effects assessed in this report and summarised in Table 1 were identified through analysis of the available discharge and receiving environment data and through consultation with Alliance's project team, SRC and the stakeholders Technical Working Party (TWP).

Amm-N

Elevated Amm-N has the potential to be toxic to a range of aquatic organisms and can contribute significantly to nitrogen enrichment (Richardson 1997). Table 2 provides a summary of acute toxicity data for short-term experiments for a number of New Zealand species, including eels and other native fish, and a range of macroinvertebrates. The most sensitive species are invertebrates including the mayfly *Deleatidium*, the amphipod *Paracalliope fluviatilis*, the stonefly *Zelandobius furcillatus* and the clam *Sphaerium novaezelandiae*. In a recent paper, Clearwater et al. (2013) also provided results of acute toxicity tests with glochidia (early larval stage that is parasitic on a host fish) of the New Zealand freshwater mussel *Echyridella menziesii*, which showed they were relatively sensitive with a 48-hr NOEC (No Observed Effect Concentration) of 8–10 mg total Amm-N^{-1} (pH 7.8).

Freshwater Solutions (2014) provides chronic Amm-N levels for various species from a number of studies including the mayfly *Deleatidium* where No Observed Effects Concentration (NOEC) levels over a 29 day period were 1.3 mg/L (Hickey et al. 1999) and the clam *Sphaerium novaezelandiae*, which was more sensitive with a chronic level over 60 days of 0.57 mg/L (Hickey and Martin 1999). Thus the Amm-N concentrations in the discharge have the potential to cause adverse effects in the mixing zone and lower Makarewa River through chronic and acute toxicity, to adversely affect fish migration in the mixing zone and to contribute to nitrogen loadings in the lower Makarewa, lower Oreti and New River Estuary.

Nutrients

Dissolved nitrogen and phosphorus can cause nuisance algal growths in some rivers (MFE 2000) while total phosphorus (TP) and total nitrogen (TN) can result in eutrophication effects such as nuisance macrophyte and macroalgal growths in the lower reaches of rivers and in estuaries (NIWA 2007, NIWA 2012).

The nitrogen and phosphorus load in the discharge has the potential to contribute to adverse cumulative effects as a result of elevated background nutrient concentrations in the Makarewa River, the lower Oreti River and the New River Estuary. These effects are a result of the current level of nutrients in the discharge as well as the input of nutrients from the wider catchment which will impact on the lower Makarewa and Oreti Rivers (e.g., cyanobacteria blooms at the Wallacetown-Lorneville Highway Bridge) and the New River Estuary (e.g., macroalgae proliferations). The input of nutrients from the Plant includes treated human waste from Wallacetown and the Plant and the meat-processing wastewater from the Plant itself and will contribute to nutrient loads in the lower Makarewa, lower Oreti below the confluence with the Makarewa, and the New River Estuary.

Elevated sediment nutrient concentrations can lead to nuisance macrophyte growths that adversely affect aquatic biological communities through altering habitat and water quality (NIWA 2012). The elevated background water and sediment nutrient concentrations in the Makarewa River and the high concentrations of nitrogen and phosphorus in the discharge have the potential to cause nuisance plant growths. The nature of the habitat in the lower Makarewa River is largely fine gravels developing into fine muds and silts, which means that potential effects are on macrophyte and not periphyton growths. In the New River Estuary the potential effect is through macroalgae growth (e.g., sea lettuce).

Microbial

Bacteria have the potential to cause human health issues (MFE/MoH 2003) directly through contact recreation and indirectly through contamination of fish and shellfish. The background faecal indicator bacteria concentrations in the Makarewa River including the upper catchment, the lower Oreti River and the New River Estuary are elevated. There are no designated bathing areas in the lower Makarewa River but trout fishing, whitebaiting, eeling for cultural and commercial activities and game bird hunting do occur. New River Estuary is an important area for fishing and gathering of shellfish and contact recreation and as a consequence the high faecal indicator bacteria load in the discharge has the potential to adversely affect humans.

Dissolved Oxygen

Dissolved oxygen (DO) is critical to supporting healthy aquatic ecosystems with concentrations needing to be above 5 g/m^3 as a minimum over 7 days and above 4 g/m^3 as a one day minimum to avoid adverse effects (NIWA 2013). The discharge can occasionally contribute to low summertime DO concentrations below 5 g/m^3 in the lower Makarewa River that has the potential to have an adverse effect on aquatic biota.

Colour, Clarity, Foams and Scums

Wastewater discharges have the potential to have aesthetic effects by altering colour and clarity and generating foams and scums (MFE 1994). Although there is no public access or designated bathing areas in the Makarewa River downstream of the discharge the river is used by duck hunters and fishermen and their enjoyment of fishing and hunting could be reduced by the presence of a detectable change in colour and clarity and foams and scums.

Nuisance Algal Growths

Nuisance algal growths include sewage fungus (MFE 1992), periphyton (MFE 2000) and macrophtyes (NIWA 2012). Its soft bed, slow flowing, macrophyte dominated and tidal nature means that the lower Makarewa River and lower Oreti River are depositional environments, and along with the New River Estuary, they reflect the cumulative pressures of land use and drainage throughout the Makarewa and Oreti River catchments. The soft bed and tidal nature is not suited to supporting periphyton growths. The discharge has low concentrations of Biochemical Oxygen Demand (BOD) needed to sustain sewage fungus and the discharge does not cause sewage fungus growths. The discharge location and elevated nutrient concentrations in the discharge and receiving environment have the potential to elevate water and sediment nutrient levels, with the sediment levels in particular potentially leading to the proliferation of macrophytes that in turn can alter pH and DO levels and affect habitat for a range of aquatic biota (NIWA 2012).

Benthic Invertebrate Community

The benthic macroinvertebrate community (snails, bivalves, chironomid larvae, worms, caddisflies, and occasionally mayflies) in the lower Makarewa River reflects the location, land use and modification throughout the catchment. The soft bed and tidal nature of the receiving environment is not suited to water and habitat sensitive taxa (e.g., the mayfly *Deleatidium*) and thus reduces the overall sensitivity of the invertebrate community to water quality effects associated with the discharge. Despite this the invertebrate community is an important component of the lower river ecosystem and there is potential for the discharge to result in adverse effects in the lower Makarewa River indirectly through altered habitat (e.g., increasing macrophyte cover) or directly through toxicity (e.g., Amm-N effects). Available habitat for a number of macroinvertebrate taxa will be reduced or they will not be present due to the tidal nature of the lower river, irrespective of the discharge.

Fish

The lower Makarewa River supports significant shortfin eel and common bully populations and provides seasonal adult habitat and feeding areas for inanga, brown trout and black flounder. The discharge has the potential to have direct effects (e.g., through Amm-N toxicity) on fish diversity and abundance within the mixing zone and the lower Makarewa River downstream of the discharge and indirect effects through altered habitat (e.g., macrophyte growths) and altered food sources (e.g., benthic invertebrate community composition) in the mixing zone, lower Makarewa River and New River Estuary. The lower Makarewa River is a migratory pathway for a range of whitebait species including inanga, banded kokopu, giant kokopu and koaro. The Amm-N concentrations within the discharge have the potential to affect fish migration within the mixing zone during the early part of the processing season (October-December) when upstream migration of some species such as inanga and kokopu is occurring.

Recreational Use and Value

The lower Makarewa is used for a range of activities with the main ones being whitebaiting and game bird hunting. New River Estuary is an important area for non-contact (walking, fishing, bird watching, picnicking etc.) and contact recreation (boating, water skiing, and bathing) and as a consequence the high faecal indicator bacteria load in the discharge has the potential to adversely affect humans. The discharge has the potential to contribute to the cumulative negative effects of the wider catchment on the recreational values of these waterways by altering water quality and biological communities.

Table 1: Summary of potential adverse effects associated with the discharge.

Potential effect	Mixing zone	Lower Makarewa River	Lower Oreti River	New River Estuary	Time
Amm-N toxicity	Y	Y	N	N	Discharge period
Increase nutrients	Y	Y	Y	Y	Discharge period for DRP and DIN, Year round for TP and TN
Increase faecal bacteria	Y	Y	Y	Y	Discharge period
Reduce dissolved oxygen	Y	Y	N	N	Discharge period
Alter colour and clarity	Y	Y	N	N	Discharge period
Cause conspicuous foams and scums	Y	N	N	N	Discharge period
Elevate sediment nutrients	Y	Y	Y	Y	Year round
Nuisance algae and plant growths	Y	Y	Y	Y	Year round
Reduce benthic invertebrate community health	Y	Y	N	Y	Year round
Reduce fish abundance and diversity	Y	Y	N	Y	Year round
Barrier to fish migration	Y	N	N	N	Discharge period
Reduce recreational use	Y	Y	Y	Y	Year round

Table 2: Selected Amm-N acute toxicity data for New Zealand resident species.

Species	LOEC (mg/L)	NOEC (mg/L)	Reference
Anguilla australis (shortfin eel)	156	91	Richardson (1997)
Deleatidium spp. (mayfly)	34	7.1	Hickey and Vickers (1994)
Galaxias fasciatus (banded kokopu)	53, 13	31,10	Richardson (1997)
Galaxias maculatus (inanga)	98	75	Richardson (1997)
Gobiomorphus cotidianus (common bully)	57	41	Richardson (1997)
Gobiomorphus huttoni (redfin bully)	24	16	Richardson (1997)
Lumbriculus variegatus (Oligochaeta)	14	6.5	Hickey and Vickers (1994)
Paracalliope fluviatilis (amphipod)	14[a]	3.7[b]	Hickey and Vickers (1994)
Paratya curvirostris (shrimp)	- 74, 19	16 43, 13	Hickey and Vickers (1994) Richardson (1997)
Potamopyrgus antipodarum (snail)	24, 8.7	14, 5.7	Hickey and Vickers (1994)
Pycnocentria evecta (caddis)	31	9.2	Hickey and Vickers (1994)
Retropinna retropinna (common smelt)	82, 13	41, 9.5	Richardson (1997)
Sphaerium novaezelandiae (clam)	12	6.5	Hickey and Vickers (1994)
Zephlebia dentate (mayfly)	-	1.0	Hickey and Vickers (1994)
Zelandobius furcillatus (stonefly)	-	2.8[b]	Hickey and Vickers (1994)

Note: LOEC = Lowest Observable Effects Concentration, NOEC = No Observable Effects Concentration, LOEC data are 96-hr LC50 or EC50 unless stated, NOEC data are 96-hr LC10 or EC10 unless stated. Data adjusted to pH 8 and 20ºC, [a]48-hr EC50, [b]48-hr EC10.

3.0 Receiving Environment Quality

The water quality and biological communities in the receiving environment prior to and following the proposed wastewater treatment upgrade were assessed against the standards and targets presented in Table 3 and Table 5. The targets set out in Table 3 and Table 5 have been selected after a careful evaluation of the receiving environment, the effects of the discharge and following consultation with the working party. The rationale for the selection of each of the water quality and biological attributes is presented below.

Temperature

River temperature is a key potential stressor of biological communities with water temperatures greater than 24°C shown to be stressful to a range of invertebrate taxa and fish species. At temperatures around 24–27°C some sensitive invertebrates, particularly some insects, would be severely stressed and some fish eliminated if such temperatures persisted (Olsen et al. 2012, NIWA 2013). The Makarewa River has very little channel shading from riparian vegetation and water temperature has the potential to reach levels that are harmful to aquatic life. However, there is a low risk of the discharge adversely affecting river water temperature given the nature of the discharge. The river temperature guideline used for determining if there is a likely effect on biota in the receiving waters is a <3°C change from upstream and with 23°C being the maximum temperature. This limit is commonly used, and is protective of most aquatic organisms (NIWA 2013). No river temperature limit is set in the recently released National Policy Statement for Freshwater Management (NPS-FM, MFE 2014).

pH

pH is an important factor in determining Amm-N toxicity risk (Richardson 1997). No limit is presently set for pH in the recently released National Policy Statement for Freshwater Management (NPS-FM, MFE 2014). The Southland Regional Water Plan (SRWP) has a limit of 6.5–9.0 and has been selected as the target for the receiving environment.

Dissolved Oxygen

Dissolved oxygen is essential to a wide range of aquatic organisms (NIWA 2013). Low DO can reduce benthic invertebrate community diversity and abundance and cause fish stress leading to mortality (NIWA 2013). Eels and common bully show little response to low DO concentrations and have lethal thresholds of <1 g/m^3 while other species show less tolerance.

The NPS (MFE 2014) is a comprehensive and recent evaluation of DO effects that has recognised the merits in setting DO concentration limits as opposed to saturation limits and for this reason it has been adopted for setting the target DO state for the lower Makarewa River instead of the SRC water plan DO limits. Dissolved oxygen can fluctuate widely in lowland rivers draining agricultural catchments in response to a range of factors including river temperature, photosynthesis and respiration by aquatic plants, and ground and surface water interactions. The lower Makarewa River is highly modified and the current consent limit of 6 g/m^3 is conservative. Recent work as part of the development of attribute states and limits has identified a 1-day minimum threshold to avoid acute levels for sensitive species and longer term 7 day minimum levels to avoid significant chronic impacts levels (MFE 2014). Considering the invertebrate and fish community present in the lower Makarewa River, which is composed of more water quality and habitat tolerant species, the NPS-FM (MFE 2014) bottom lines for DO are considered appropriate. Despite this a DO target of ≥ 6 g/m^3 (96% of samples) and > 5 g/m^3 on all occasions has been selected for assessing the effects of the discharge.

Clarity and Colour

Water clarity affects aesthetic values and aquatic biological communities (MFE 1994). Rowe and Dean (1998) reported that banded kokopu avoided waters with >20–25 NTU. Inanga and smelt are less sensitive to turbidity and can tolerate levels less than 160 NTU (Rowe et al. 2002). Total suspended solids (TSS), turbidity and visual clarity measured by black disc sighting distance are not always well correlated. The discharge and river TSS and river clarity (by clarity tube) is currently monitored by Alliance. Turbidity has been monitored in the 2014 – 2015 processing season.

The lower Makarewa River upstream of the discharge does not meet the black disc visual sighting distance of >1.6 m for waterways that are managed for contact recreation (MFE 1994) but the lower Makarewa River is not managed for contact recreation. The current consent clarity limit of <20% change between upstream and downstream appears to have been selected from MFE guidelines (MFE 1994), which states that 'for class A waters (where visual clarity is an important characteristic of the water body): the visual clarity should not be changed by more than 20%'. MFE (1994) states that 'for other waters: The visual clarity should not be changed by more than 33–50% depending on the site conditions'. The RMA Section 107 also states that a discharge permit should not be granted if there is 'any conspicuous change in the colour or visual clarity'. Water clarity in the upper Makarewa River catchment is low and as a result of this and the reduced sensitivity of lowland rivers draining agricultural catchments to changes in clarity a <33% change has been selected as the appropriate clarity guideline for assessing the effects of the discharge.

Foams and Scums

Conspicuous foams and scums can reduce the aesthetic values and human enjoyment of waterways (MFE 1994). The RMA Section 107 requires that a discharge cannot be permitted, if after reasonable mixing, there is 'production of any conspicuous oil, or grease films, scums or foams of floatable or suspended materials'. Algal scums and foams are often associated with oxidation ponds such as those at the Plant. The recreational use of the Makarewa River within and immediately beyond the mixing zone is thought to be very limited as a result of a lack of access over private land. Because of a low level of recreational use the receiving environment within and immediately downstream of the mixing zone has been assessed as insensitive to the generation of foams and scums. The proposed target for foams and scums is therefore 'no conspicuous foams and scums beyond the mixing zone (site at 350 m)'.

Amm-N

Amm-N can have acute toxic effects on aquatic biota (e.g., Richardson 1997, Hickey and Vickers 1994) as well as chronic toxic effects. Regional councils are required to impose limits on Amm-N that reflect or are better than the attribute states or bottom line. NPS (MFE 2014) Amm-N bottom line has been selected along with the Amm-N limits derived by Freshwater Solutions (2014) for assessing the effects of the discharge (see Appendix 1 for full discussion of Amm-N related potential and actual effects). There is also currently uncertainty about the way the NPS (MFE 2014) limits should be applied (e.g., monthly, weekly, how to deal with diurnal change). Our understanding is that the NPS limits are designed to be applied to Freshwater Management Units and may not be directly applicable to assessing the effects of individual point source discharges. However it is recommended that outside the mixing zone, levels should at least meet the bottom line for the NPS-FM.

Applicability of an ammonia standard is discussed in the next section.

NO_3-N

Nitrate can be toxic to aquatic life and cause significant adverse effects (Hickey and Martin 2009). Nitrate levels over 30 mg/L can result in inhibited growth, affect immune systems and cause stress in a range of aquatic species. The lower Makarewa River receives significant NO_3-N inputs from the surrounding catchment and is in a highly modified state but nitrate levels are still well below the limits that would cause nitrate toxicity. For this reason values for between Bands B and C for the NPS attribute state have been adopted for assessing the effects of the discharge in the lower Makarewa River beyond the mixing zone. It should be noted that these attribute states were developed to prevent toxicity rather than addressing nutrient loads to freshwaters. Nitrate can be a major component of nutrient load to estuaries and is readily taken up by algae. Thus an additional target state of a ≥10% improvement in nitrate concentrations, as identified as a policy in the Southland Regional Water Plan, has also been adopted here.

DIN, DRP, TN and TP

The MFE (2000) nutrient guidelines for controlling periphyton growths cannot be applied to the soft-bottomed tidally influenced section of the lower Makarewa River (NIWA 2007). The Southland Regional Water Plan (SRWP) does not include any limits for DIN and DRP but states as a policy that there is a requirement to improve degraded lowland rivers by reducing nitrate and phosphorus by ≥10% before January 2020. This standard has been used for assessing the effects of the discharge. Given the rapid rate of decline in the health of the New River Estuary, achieving a higher level of catchment wide nutrient reduction would likely benefit the estuary. Although nitrogen is generally considered the most common limiting nutrient in estuaries, co-limitation can occur (Larned et al. 2011) thus both nutrients need to be considered in assessing nutrient loadings. It is also possible that nutrient concentrations may be at saturation level and so it is uncertain what the state of nutrient limitation is at present in the estuary.

NIWA (2007) states that natural soft-bottomed streams may not require nutrient criteria for reducing algal growths, but that if streams flow into estuaries where eutrophication (nutrient enrichment) could occur, then nutrient criteria may be required. Given the declining state of the New River Estuary it is apparent that catchment wide controls are likely to be required to arrest the current decline in quality and to seek to improve the current quality.

Robertson and Stevens (2013) estimated that the TN load to the New River Estuary from the catchment would need to decrease by between 69–84% compared with present loadings to reach the ‘moderate state’. It has been estimated that the discharge contributes 53% of the total TN load and 68% of the total TP load to the lower Makarewa River (Robertson and Stevens 2013) but the discharge currently contributes only approximately 4% of the total TN load to the New River Estuary. As a consequence, reducing the TN load from the discharge will improve estuary health, but on its own, is very unlikely to result in an observed or tangible improvement in the state of the New River Estuary (Coast and Catchment 2014).

The SRWP does not include any limits for TP but does state as a policy that there is a requirement to improve water quality in lowland rivers and thus by inference the loadings reaching degraded estuaries by ≥10% reduction in phosphorus before January 2020. This is the target used to assess the effects of the discharge on the New River Estuary.

Biochemical Oxygen Demand

Concentrations of soluble BOD >2 g/m^3 can result in sewage fungus (MFE 1992) and a receiving environment limit of <2 g/m^3 has therefore been used for assessing the effects of the discharge.

Table 3: Receiving environment quality prior to wastewater treatment upgrade.

Parameter	Target	Reference
Temperature	not increase >3°C above upstream	RMA, Alliance Consent (Class D Standards)
	not increase >3°C when ambient ≤16°C	SRWP (2013)
	not increase >1°C when ambient >16°C	SRWP (2013)
	not >23°C	SRWP (2013)
	not >24°C	NOF (NIWA 2013)
pH	6.0–9.0	NOF (NIWA 2013), Alliance Consent (Class D Standards)
	6.5–9.0	SRWP (2013)
DO	≥6 g/m^3 (96% of samples) and shall not on any occasion be less than 5 g/m^3	Alliance Consent
	Summer 7-day mean minimum ≥5 g/m^3	NOF (NIWA 2013), NPS (MFE 2014) - Bottom line
	Summer 1-day mean minimum ≥4 g/m^3	NOF (NIWA 2013), NPS (MFE 2014)- Bottom line
	7-day mean ≥6.5 g/m^3	NOF (NIWA 2013)
	>80%	SRWP (2013)
Clarity	not >20% change from upstream	Alliance Consent
	not >33% % change in water clarity tube reading from upstream	MFE (1994)
Foams and scums	No conspicuous foams or scums beyond 350 m	RMA, Alliance Consent and SRWP (2013)
	No conspicuous foams or scums beyond the boundary site	This report
Amm-N	As per table 4	
	≤0.90 g/m^3 (at pH 8.0)	SRWP (2013), ANZECC (2000)
	≤1.9 g/m^3 (at pH 8.0, 20°C)[a]	USEPA (2013)
	Annual median <1.3 g/m^3 (at pH 8.0 and temperature 20°C) Annual maximum <2.2 g/m^3 (at pH 8.0 and temperature 20°C)	NPS (MFE 2014) - Bottom line
	Annual median <1.9 g/m^3 (at pH 8.0 and temperature 20°C) Annual 95%-ile <2.4 g/m^3 (at pH 8.0 and temperature 20°C)	Freshwater Solutions (2014)
NO_3-N	Annual median <2.4 g/m^3 95th percentile <3.5 g/m^3	NPS (MFE 2014) - Band B/C
Nitrate and Phosphorus	≥10% reduction in rivers before January 2020	SRWP (2013)
BOD-soluble	<2 g/m^3	MFE (1992)
FC	<1,000 cfu/100mL	SRWP (2013)
E. coli	<1,000 bacteria/100mL	NPS (MFE 2014) - Bottom line

Table 4: Proposed maximum total ammonia nitrogen concentrations prior to the wastewater treatment upgrade.

	Temperature (°C)						
pH	**0**	**5**	**10**	**15**	**20**	**25**	**30**
6.5	29.0	26.0	25.0	25.0	24.0	16.4	11.8
6.75	26.0	25.0	23.0	22.0	22.0	15.3	10.9
7.0	23.0	21.0	21.0	20.0	18.9	13.5	9.5
7.25	19.0	18.0	16.0	16.2	15.8	11.0	7.8
7.5	14.3	13.4	12.7	12.2	12.0	8.4	6.0
7.75	10.0	9.4	9.0	8.6	8.5	5.9	4.3
8.0	6.6	6.2	5.8	5.7	5.6	4.0	2.9
8.25	3.7	3.5	3.4	3.3	3.2	2.3	1.72
8.5	2.1	2.0	1.89	1.89	1.89	1.41	1.05
8.75	1.21	1.15	1.12	1.13	1.16	0.88	0.68
9.0	0.71	0.68	0.68	0.71	0.75	0.59	0.48

Table 5: Receiving environment quality following wastewater treatment upgrade.

Parameter	Target	Reference
Temperature	not increase >3°C above upstream	RMA, Alliance Consent (Class D Standards)
	not increase >3°C when ambient ≤16°C	SRWP (2013)
	not increase >1°C when ambient >16°C	SRWP (2013)
	not >23°C	SRWP (2013)
	not >24°C	NOF (NIWA 2013)
pH	6.0–9.0	NOF (NIWA 2013), Alliance Consent (Class D Standards)
	6.5–9.0	SRWP (2013)
DO	≥6 g/m^3 (96% of samples) and shall not on any occasion be less than 5g/m^3	Alliance Consent
	Summer 7-day mean minimum ≥5 g/m^3	NOF (NIWA 2013), NPS (MFE 2014) - Bottom line
	Summer 1-day mean minimum ≥4 g/m^3	NOF (NIWA 2013), NPS (MFE 2014)- Bottom line
	7-day mean ≥6.5 g/m^3	NOF (NIWA 2013)
	>80%	SRWP (2013)
Clarity	not >20% change from upstream	Alliance Consent
	not >33% % change in water clarity tube reading from upstream	MFE (1994)
Foams and scums	No conspicuous foams or scums	RMA, Alliance Consent and SRWP (2013)
	No conspicuous foams or scums beyond the boundary site	This report
Amm-N	As per table 6	
	≤0.90 g/m^3 (at pH 8.0)	SRWP (2013), ANZECC (2000)
	≤1.9 g/m^3 (at pH 8.0, 20°C)[a]	USEPA (2013)
	Annual median <1.3 g/m^3 (at pH 8.0 and temperature 20°C) Annual maximum <2.2 g/m^3 (at pH 8.0 and temperature 20°C)	NPS (MFE 2014) - Bottom line
	Annual median <1.9 g/m^3 (at pH 8.0 and temperature 20°C) Annual 95%-ile <2.4 g/m^3 (at pH 8.0 and temperature 20°C)	Freshwater Solutions (2014)
NO_3-N	Annual median <2.4 g/m^3 95th percentile <3.5 g/m^3	NPS (MFE 2014) - Band B/C
Nitrate and Phosphorus	≥10% reduction in rivers before January 2020	SRWP (2013)
BOD-soluble	<2 g/m^3	MFE (1992)
FC	<1,000 cfu/100mL	SRWP (2013)
E. coli	<1,000 bacteria/100mL	NPS (MFE 2014) - Bottom line

Table 6: Proposed maximum total ammonia nitrogen concentrations following the wastewater treatment upgrade.

pH	Total Ammonia Concentration g/m^3		
	30 day Rolling Average and Annual Median (1.9 g/m^3 @pH 8.0)	4 day Rolling Average Maximum (4.75 g/m^3 @pH 8.0)	Annual 95th % ile (2.4 g/m^3 @pH 8.0)
6.5	5.2	13.0	6.6
6.6	5.1	12.8	6.5
6.7	5.0	12.6	6.3
6.8	4.9	12.3	6.2
6.9	4.8	11.9	6.0
7.0	4.6	11.5	5.8
7.1	4.4	11.1	5.6
7.2	4.2	10.5	5.3
7.3	4.0	9.9	5.0
7.4	3.7	9.2	4.7
7.5	3.4	8.5	4.3
7.6	3.1	7.8	3.9
7.7	2.8	7.0	3.5
7.8	2.5	6.2	3.1
7.9	2.2	5.5	2.8
8.0	1.9	4.7	2.4
8.1	1.6	4.1	2.1
8.2	1.4	3.5	1.8
8.3	1.2	3.0	1.5
8.4	1.0	2.5	1.3
8.5	0.8	2.1	1.1
8.6	0.7	1.8	0.9
8.7	0.6	1.5	0.8
8.8	0.5	1.3	0.7
8.9	0.4	1.1	0.6
9.0	0.4	0.9	0.5

Faecal Coliforms and *E. coli*

Faecal coliforms and *E. coli* are indicators of human health risk associated with contact recreation (MfE/MoH 2003). The tidally influenced section of the Makarewa River is not regarded as having any bathing areas and because of its low water clarity, steep river banks, poor water quality and lack of public access it is very unlikely to be considered by the public in its present state as a suitable area for bathing. However the lower Makarewa River is used for a range of recreational purposes (Freshwater Solutions 2015a) and for that reason the SRWP FC limit of <1,000 cfu/100 mL (now analysed and reported as cfu) and the NPS (MFE 2014) *E. coli* bottom line <1,000 bacteria/100 mL have been selected for establishing the long-term target microbiological state in the Makarewa River.

Periphyton

As outlined above there is no applicable periphyton cover and biomass standard or guideline for soft bed rivers like the tidally influenced section of the lower Makarewa River (i.e., a depositional environment dominated by macrophytes). On the basis that the habitat is not suitable for periphyton, no periphyton limit has been used in determining the target quality of the receiving environment against which the effects have been assessed.

Macrophytes

New Zealand has not yet set macrophyte cover or biomass guidelines or recommended water column or sediment nutrient limits for controlling nuisance macrophyte growths (MFE 2012). NIWA (2007) stated that macrophytes in lowland streams are generally not limited by water column nutrient supply but more commonly by sediment nutrients, and in particular, nitrogen supply. NIWA (2012) recommended provisional guidelines for macrophyte cover (Table 7) and these could be adopted for assessing the effects of the discharge. Macrophytes provide important habitat for a range of invertebrates and fish species and with the mix of species and % cover they are not assessed as reaching nuisance levels at present. At this stage it is considered important to monitor macrophyte cover and composition but not appropriate to set targets.

Benthic Invertebrates (MCI, SQMCI, QMCI)

The NPS (MFE 2014) does not include standards for benthic invertebrates. The SRWP (2013) sets lowland river Macroinvertebrate Community Index (MCI) and Semi Quantitative Macroinvertebrate Community Index (SQMCI) scores of >80 and >3.5 respectively. However the MCI and Quantitative Macroinvertebrate Community Index (QMCI) are not well suited to the tidal section of the lower Makarewa River and are generally not applied to tidally influenced or non-wadeable rivers (Stark and Maxted 2007 report to MFE). The study design adopted for this assessment involved the selective sampling of gravel and cobble substrates using a Surber sampler. This design and sampling method was selected to control for habitat variables as much as possible and to ensure the collection of standardised quantitative samples across all the sampling sites. For these reasons hard bottom MCI and QMCI scores were used along with other indices and community composition data, to assess the effects of the discharge. SQMCI is a semi quantitative method while QMCI is a quantitative method suited for use in upstream downstream type assessments. The MCI and QMCI have been used in this assessment of effects of the discharge as they describe the type of community present, but for the reasons outlined above, no target state for the receiving environment has been set (Table 7).

Fish

The NPS (MFE 2014) does not include specific standards for fish. The NPS (MFE 2014) and the SRWP (2013) do however set a range of water quality targets aimed at protecting fish. In addition, the SRWP (2013) and RMA sets 'avoiding rendering fish unsuitable for human consumption' as a target for lowland rivers and this has been set as the target state for the receiving environment and assessing the effects of the discharge. There are also important implications of discharging human waste into freshwaters and how mahinga kai is viewed in those waters. This issue will be dealt with separately in another report.

Table 7: Selected lowland water body biological standards.

Parameter	Standard/Guideline	Reference
Periphyton	No applicable standard or guideline for soft bed rivers	-
Macrophytes	≤50% surface cover (aesthetics and recreation) ≤50% channel volume/cross sectional area (ecological condition, flow conveyance, recreation)	NIWA (2012) NIWA (2012)
MCI	>80 - but not applicable to tidally influenced, non-wadable rivers	SRWP (2013)
SQMCI	>3.5 - but not applicable to tidally influenced, non-wadable rivers	SRWP (2013)
QMCI	4.0 - but not applicable to tidally influenced, non-wadable rivers	This report
Fish	Shall not render unsuitable for human consumption	RMA, SRWP (2013)

Note: Standards shaded in light blue are those selected for setting the target state for the receiving environment and assessing the effects.

4.0 The Effects of the Current Discharge

4.1 Water and Sediment Quality

Makarewa and Oreti Rivers

The following assessment of effects is based on data reported in Freshwater Solutions (2015a) and the results of a Whole Effluent Toxicity Test (WETT) undertaken by Alliance in 2002.

Whole Effluent Toxicity Test Results

NIWA (2002) has reported the results of Lorneville Pond 6 effluent WET (whole effluent toxicity) testing with green algae (*Selenastrum capricornutum*), water flea (*Ceriodaphnia dubia*) and rainbow trout (*Oncorhynchus mykiss*). NIWA reported threshold effect concentrations (TECs) and test endpoints for those species as follows:

- Green algae: 4.4% effluent (72-hour, cell growth)
- Water flea: 8.8% effluent (48-hour, survival)
- Rainbow trout: 17.7% effluent (96-hour, survival)

Based on the discharge record and Makarewa River flow (at Counsell Road) between December 2001 and June 2014 the median river dilution resulted in 3.1% effluent, and the maximum river dilution resulted in 12.8% effluent. Hence, whereas the rainbow trout TEC was not exceeded at any time, the green algae and water flea TECs were exceeded 37%

and 5.3% of the time, respectively. When assessed versus the test duration, the green algae (72-hour) and water flea (48-hour) TECs were exceeded 25% and 2.2% of the time, respectively. Hence, the WET testing indicates there is potential for growth inhibition of green algae, however as NIWA states in their report ‘care must be taken when extrapolating results for protection of organisms in a particular receiving water’. This is due to diverse reasons, such as ion imbalance (SETAC, 2004), use of non-standard and variable procedures (Burton et al. 1996), and failure to report raw data, including that for the control.

Other Water Quality Effects

There is no apparent effect of the discharge on temperature in the Makarewa River, which was only very occasionally >3°C at the 350 m Site compared with the upstream Bridge Site. The maximum temperature recorded since 2001 was 21.5°C. A marginal increase in pH downstream of the discharge is apparent, but the data record indicates that on no occasion was the downstream pH outside the Class D Standard’s pH range (6.0–9.0). The slight increase in pH downstream is unlikely to have any direct effect on aquatic biota.

The discharge results in a slight increase in Makarewa River conductivity at the 350 m Site, with the increase also evident at the Boundary Site. There is no consent requirement relating to conductivity and the increase in conductivity is unlikely to have any effect on aquatic biota.

Dissolved oxygen concentrations in the Makarewa River have consistently been above the Class D Standard and NPS (MFE 2014) 7-day mean minimum bottom line (5 g/m^3) at all sites monitored. The occasions when the reported DO was below 5 g/m^3 were infrequent and short-term, and have not been ecologically significant. Recent guidance for New Zealand freshwaters in the NPS (NPS 2014) is based on the report ‘National Objectives Framework – Temperature, Dissolved Oxygen and pH’ (NIWA 2013), which notes a 1-day threshold of 4 g/m^3 ‘should provide reasonable protection for most organisms for most of the time, while allowing for occasional, short duration low dissolved oxygen excursions’. In addition, BOD concentrations at all Makarewa River Sites were low and not expected to affect DO concentrations.

There is a consistent decrease in clarity of the Makarewa River downstream of the discharge compared with the upstream site. Decreased clarity as a result of increases in TSS can impact on physiological and feeding processes for invertebrates and fish and reduce benthic algal production through light attenuation. However, at the median TSS load (580 kg/day) and median Makarewa River flows at the 350 m Site (7.65 m^3/s) the contribution from the discharge TSS to the Makarewa River amounts to <1 g/m^3, which is considered unlikely to result in a significant reduction in clarity or any effect on aquatic biota. An analysis of TSS loads discharged to the Makarewa River at low flows (4 m^3/s) indicates a median increase of TSS downstream of the discharge of 3.4 g/m^3, which is close to the analytical detection limit (2.5 g/m^3) and, as such, barely distinguishable by the human eye. It is considered the reduction in clarity that is observed is most likely attributed to the presence of algae in the discharge and is very unlikely to cause adverse effects.

Alliance has no consent condition for nitrate-nitrogen but the NPS annual median bottom line for nitrate-nitrogen, which is based on toxicity to aquatic biota, is 6.9 g/m^3 and for Band B/C is <2.4 g/m^3 (NPS 2014). Based on the Makarewa River data the highest annual median level was 1.3 g/m^3 (Freshwater Solutions 2014a), thus there is little potential for nitrate-nitrogen toxicity to affect aquatic biota upstream or downstream of the discharge.

The effect of the discharge on Amm-N concentrations downstream is presented in Figure 2. The increase in Amm-N concentrations that results from the discharge has the potential to affect aquatic biota. The Amm-N concentrations at the 350 m Site have been assessed versus the Amm-N limits presented in Table 3 and Table 4 and the percentage of the time the Amm-N limits are met, according to the particular limit requirements (e.g., in some cases absolute limits, others annual medians), is summarised as follows:

- Alliance consent: 99%.
- SRWP (2013)/ANZECC (2000): 30%.
- USEPA (2013) without mussels: 81%.

These limits may not all be relevant to New Zealand species or to those found in the Makarewa River, and in particular the habitats and associated communities found in the lower Makarewa River. Table 2 presented acute toxicity data for selected aquatic species native to New Zealand. Although the Alliance consent limit may be met most of the time (99% between 2003 and 2014), based on the data from December 2001 to June 2014, the Amm-N in the Makarewa River downstream of the discharge has the potential to be greater than the reported No Observable Effects Concentrations (NOECs) (pH and temperature adjusted) for several of our native species including *Deleatidium* (mayfly), Sphaeriidae (fingernail clam) and *Zelandobius furcillatus* (stonefly) (Table 2). The bottom line for the annual median in the latest NPS (MFE 2014), which was developed to protect 80% of species from chronic toxicity and only impact on the more sensitive species, is 1.3 mg/L compared with the present consent limit of 5.6 mg/L which is an acute level. However, the NPS limits were developed for Freshwater Management Unit rather than point source discharges.

As noted in the descriptive report (Freshwater Solutions 2015a), the discharge contains alkali and alkaline earth metals that are associated with meat processing wastes, and aluminium used in the wastewater treatment system. The concentrations in the discharge are not sufficient to result in effects on the receiving environment outside the mixing zone when these levels were compared with ANZECC (2000) guidelines. The only potential exception is aluminium, which is about 1.4 mg/L in the discharge and thus could be higher than in the guidelines (27 µg/L) below the mixing zone, depending on the dilution. Aluminium is toxic to a range of aquatic organisms at low concentrations in laboratory experiments, however in natural waters other compounds and processes markedly reduce its toxicity to a level where no effects are observed. Thus, there are a number of questions around its application and at the levels that may be encountered in the Makarewa River it would not be expected to cause a toxicity effect because of the dilution.

The New Zealand guideline for water colour (MFE 1994) states that Class A waters should not be changed by more than five points on the Munsell scale. For other waters the change should not be more than 10 points. The water colour at the 350 m Site and Boundary Site was identical to the Bridge Site on most occasions when determined in March and April 2014. On the two occasions the colour differed at the 350 m Site compared with the upstream Bridge Site, the Munsell scale difference was 2.5 points. Based on this evidence, the discharge is not causing a conspicuous change in water colour of the Makarewa River.

The current discharge does contribute to the presence of some foams and scums on occasions, at least within the mixing zone (200 m) and a small distance downstream (Freshwater Solutions 2014a). It should be noted that foams and scums have also been observed when no discharge is occurring.

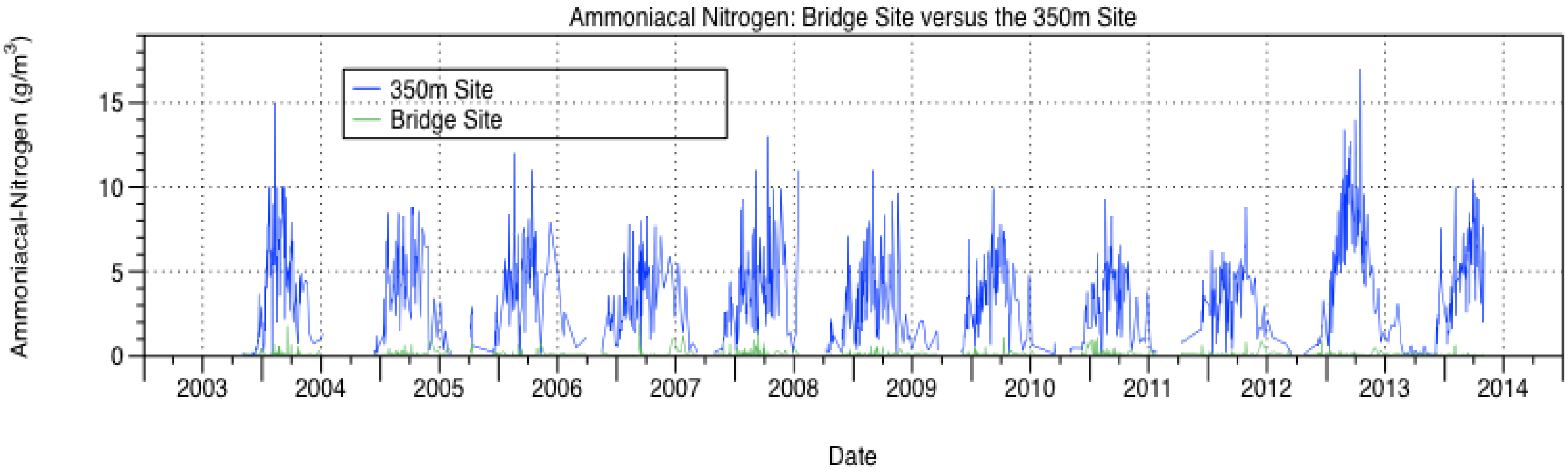

Figure 2: Amm-N concentration at the Bridge and 350 m Site between December 2003 and June 2014.

Although the effects of the current level of foams and scums could be assessed as potentially minor because of the lack of access and limited recreational use of the lower Makarewa River, it is a requirement under the RMA and will thus need to be addressed as part of any future upgrade to the wastewater treatment system.

The current discharge does result in elevated sediment nutrient concentrations in the vicinity of the discharge that may contribute to macrophyte growths.

The impact of microbial contaminants in the current discharge is variable, with some occasions when the level of faecal coliforms is higher below the discharge than upstream and other times when it is lower than upstream. The median annual levels of FC between 2001 and 2014 at the Bridge and 350 m Site downstream were 1,500 and 1,300 MPN/100 mL (cfu since 2005) respectively (Freshwater Solutions 2014a), which would breach the guidelines and standards but is because of contamination from the upper catchment and not just the discharge. However there were occasions when levels were higher downstream of the discharge (e.g., annual medians were higher at the 350 m Site than Bridge Site for 6 of the last 13 years, annual maximums were higher 5 times in the last 13 years). *E.coli* has only been measured since 2012 in the Makarewa River, with annual median levels of 280–750 cfu/100 mL at the 350 m Site. Medians were lower at the 350 m Site compared with Bridge Site in 2012/2013 but have been higher since then.

New River Estuary

Non-point or diffuse discharges to the New River Estuary, in particular from agricultural land-use, are estimated to contribute over 99% of the TSS load. The relative contribution of the existing discharge to sedimentation in the estuary is therefore considered to be insignificant. It should also be noted that most of the TSS in the discharge is likely to be organic material.

Environmental monitoring and assessments have found that, apart from nickel, the concentrations of key metal contaminants in estuary sediments are below guideline values. Nickel concentrations exceed low level sediment quality guidelines within the Oreti and Waihopai River mouths, with stormwater sources thought to be the most likely cause. The existing discharge is unlikely to have any significant influence on metal contaminants in New River Estuary and is thus not considered to be a key issue.

Routine water quality monitoring is not carried out in the estuary but benthic invertebrate monitoring indicates that parts of the estuary are severely affected by nutrient inputs. Nutrients are necessary to sustain the plant (algae) growth that forms the foundation of the food chain. Slight increases in nutrients can increase ecosystem diversity and productivity but high nutrient concentrations are detrimental and can potentially lead to nuisance phytoplankton and macroalgae blooms, reduced water quality and toxic effects. The key concern is considered to be the effects of nitrogen, which is the most common limiting nutrient in estuarine and coastal ecosystems. Phosphorus is generally of minor concern in coastal ecosystems where it does not tend to be the dominant limiting nutrient but can be a co-limiting nutrient. Nitrogen is the nutrient of most concern for the New River Estuary (Robertson and Stevens 2012a).

Nuisance macroalgae cover is most extensive in the Waihopai Arm, at Bushy Point and in Daffodil Bay, which is close to the mouth of the Oreti River where significant and worsening problems are being caused by rotting macroalgae and poorly oxygenated, sulfide rich sediments. In Daffodil Bay, macroalgae growth is limiting the natural removal of mud by reducing wave induced re-suspension, and as a consequence, sediments are becoming deeper, softer, and muddier in that area. Rotting macroalgae is releasing organic matter and nutrients into the sediments, reducing oxygenation and fuelling the growth of sulfide bacteria on the surface of the sediment. This is indicative of toxic conditions in which few animals can survive. In the Waihopai Arm, Stevens and Robertson (2012a) indicate that sediment conditions were so degraded that even the nuisance macroalgae were dying off due to over-enrichment. Underlying sediments at Bushy Point were still mostly sandy and relatively well oxygenated in 2012, but deposition of muds over an area of around 27 ha, was providing an early warning of deteriorating conditions.

The existing discharge is estimated to contribute around 4% of the total nitrogen load to New River Estuary. Other nitrogen sources including: diffuse runoff (mainly from rural land uses); municipal wastewater treatment plants; and, other meat processing and rendering plants were estimated to contribute the remaining 96% of the nitrogen load. Diffuse sources provided the greatest input, and were estimated to account for around 81% of the total load, with point sources (including the discharge) providing 19% of the load (Coast and Catchment 2014).

4.2 Aquatic Plants

Makarewa and Oreti Rivers

Low periphyton growths were observed in 2010 and may occur occasionally within the downstream mixing zone (Freshwater Solutions 2015a,b) but the discharge does not result in significant periphyton growths in the lower river due to the lack of suitable habitat (stable cobbles, shallow clear water and higher water velocities).

The range in water level and poor background water clarity limits macrophyte growth in the Makarewa River because of light attenuation. Despite this, there is some evidence nutrient concentrations in the discharge elevate sediment nutrient concentrations (N and P) and indicate that the discharge may contribute to the stimulation of macrophyte growths. There is a reduction in median concentration of TN at the Boundary Site compared with the 350 m Site but median TON and Org-N concentrations are similar at both sites. The slight reduction in median TP concentrations (0.17 g/m^3) that was also observed between the 350 m Site and the Boundary Site is mostly comprised of a reduction in DRP (median reduction = 0.13 g/m^3). Sediment nutrient concentrations are also lower at the Boundary Site compared with the 350 m Site, although direct comparisons are confounded by markedly different sediment textures between the sites. Hence, it is considered the reduction in Amm-N and DRP observed at the Boundary Site in the water and sediments compared with the 350 m Site is probably due to uptake by macrophtyes, most likely directly from the sediments.

New River Estuary

Most of New River Estuary is well flushed and largely remains free of nuisance macroalgae but around 10.6% of it is covered with high to very high percentages of nuisance macroalgae. The dominant macroalgae are the red alga *Gracilaria chilensis* and the green alga *Ulva intestinalis*. Both species are known to respond positively to elevated nutrient concentrations.

Nuisance macroalgae cover is most extensive in the Waihopai Arm, at Bushy Point and in Daffodil Bay (near the mouth of the Oreti River), where significant and worsening problems are being caused by rotting macroalgae and poorly oxygenated, sulfide rich sediments (see water and sediment quality). In 2012, around 8% of the estuary was classified as having gross eutrophic conditions due to the combination of high sediment mud content, shallow redox potential discontinuity (RPD) depths, elevated nutrient and organic concentrations, the displacement of invertebrates sensitive to organic enrichment, and high macroalgal growth (>50% cover). A trend of worsening conditions since 2001 was also noted.

Seagrass cover has also decreased by around 41% since 2001, with greatest losses occurring in the Waihopai Arm (Stevens and Robertson 2012). Stevens and Robertson (2012) note that gross eutrophic conditions should not be present in estuaries like the New River Estuary, which have short water residence times, and they conclude that this is a clear signal that the assimilative capacity of the estuary is being exceeded. The existing discharge may have a minor effect on stimulating macroalgal growth in New River Estuary.

4.3 Benthic Macroinvertebrates

Makarewa and Oreti Rivers

The discharge has the potential to adversely affect macroinvertebrates, reducing the diversity and abundance of species and altering community composition either directly through ammonia toxicity and impacts on their physiology and feeding processes due to changes in DO or temperature, or indirectly through impacts on their food sources such as periphyton. The discharge has a minor short term effect on downstream DO concentrations but concentrations very rarely are <5 g/m^3. Temperatures rarely get above 20°C and never above 22°C**,** thus the discharge is not expected to adversely affect benthic invertebrates through alterations to the physical features of the water.

Nutrients and fine sediment are the key causes of declining benthic invertebrate community health in Southland's rivers (Wagenhoff et al. 2008). SRC (2010) state:

The general trend throughout Southland is of good or very good macroinvertebrate indices in headwater and upper areas of catchments, with the indices steadily declining the further downstream the monitoring sites are located. This reflects the influence of increasing intensification of land use lower in catchments, and the effects of point-source and non-point source discharges to rivers and streams.

This description generally fits the Makarewa and Oreti Rivers where MCI scores decrease rapidly down the catchment. Lowland soft-bottomed rivers such as the lower Makarewa and Oreti Rivers typically support a benthic invertebrate community that is tolerant of a range of water and habitat conditions (Stark and Maxted 2007). Harding et al. (1999) reported that the benthic invertebrate community shifted from a mayfly and caddisfly dominated invertebrate community in the upper reaches of the Pomahaka River to a community dominated by snails, worms and midges in the lower reaches in response to the cumulative effects of agriculture (increased sediment, river water temperature and periphyton levels).

There are two sites with similar habitat (lowland soft bed and tidally influenced) to the tidally influenced section of the Makarewa River within the SRC State of the Environment Monitoring Network. The site with the most similar habitat is the Waikiwi River at North Road (Roger Hodson, SRC water quality scientist, pers. comm.). The median MCI scores and range of MCI scores at the Waikiwi River North Road site for surveys between 1997 and 2012 is 78 (range 66–94). *Deleatidium* were recorded in low numbers (0–72) between 1997 and 2003 and have been absent from the site since 2004. Another site with some similarity to the tidally influenced section of the Makarewa River is the tidally influenced section of the Waihopai River. The median and range of MCI scores at the Waihopai River Queens Drive Site for surveys between 1997 and 2012 is 78 (range 62–104). *Deleatidium* were recorded in low numbers (0–156 individuals) and were absent from the site in 8 out of the 12 surveys.

The median and MCI score range at Site D1, within the mixing zone of the discharge, calculated from four surveys (March 2010, March 2013, November 2013 and March 2014) was 67 (range 60–76). The median MCI score at Site D1 (67) is consistent with the lower indices for the Waikiwi and Waihopai Rivers and a community characteristic of a tidal depositional environment with fine, soft substrate and macrophyte dominance.

As discussed in the Stark and Maxted (2007) report for MFE, caution must be exercised in applying the macroinvertebrate indices to assessment of effects and in particular environments with low flows and non-wadeable waterways. This would also apply to tidally influenced stretches of rivers. As previously outlined, the Makarewa River water velocity in the vicinity of the discharge decreases and the water becomes still during periods of high tide (note that the water is not saline). Different indices are now available for soft and hard-bottom streams and thus using indices to compare different habitats throughout the Makarewa River is not appropriate other than to assist in describing the communities and their tolerances. In the case of the Makarewa River, the hard-bottom indices were used but some of the differences are likely to be the result of the tidal influence and more depositional environment near the discharge and in the lower Makarewa River.

Median annual Amm-N concentrations at the Bridge, 350 m and Boundary Sites for the period 2001–2014 (without pH and temperature adjustment) ranged from 0.055–0.1 g/m^3 (95%-ile: 0.14–0.77 g/m^3), 2.7–5.4 g/m^3 (95%-ile: 5.7–12.0 g/m^3) and 1.8–4.2 g/m^3 (95%-ile: 4.1–11.0 g/m^3) respectively. The Amm-N concentrations downstream of the discharge are relatively high compared with the levels found to be toxic to aquatic organisms (Table 2). However, they are not considered likely to be the major factor affecting *Deleatidium* abundance. *Deleatidium* prefer shallow riffles (<0.75 m), velocities between 0.2–1.0 m/s, coarse gravel and cobble substrate and thin algal films on which to graze (Jowett et al. 1991). There are no areas downstream or immediately upstream of the discharge that provide the habitat and water characteristics preferred by *Deleatidium,* although small numbers were found at Site D2 a small distance upstream of the discharge. As described earlier the tide exerts a strong influence on the lower Makarewa River and even at low river flows the water velocity decreases at the riffles at Sites D1 and D2 during the incoming tide. In fact the flow direction is upstream during the latter half of the incoming tide (Freshwater Solutions 2014c) and for long periods of each 24 hour period the habitat at Sites D1 and D2 (just above the discharge and at high tide within the mixing zone) would be outside the preferred depth and velocity range for *Deleatidium* and a range of other habitat sensitive benthic macroinvertebrate taxa.

Further evidence for the dominant role of habitat in structuring the macroinvertebrate community comes from a comparison of the patterns of benthic invertebrate indices scores upstream and downstream of the discharge during the off season (November 2013) which were similar to during the processing season (March 2013 and March 2014). If the discharge was having a significant effect on the benthic invertebrate community health in March 2013 and March 2014 then it could reasonably be expected that some species of benthic invertebrate would have increased at Sites D1 and D2 in November 2013 during the off season. This was not the case as for example, *Deleatidium* was absent or in very low numbers at Sites D1 and D2 among all three surveys.

Freshwater mussels are an important mahinga kai species. Their populations have declined throughout New Zealand due to a number of factors including land-use changes, sedimentation, river regulation, channel straightening, eutrophication, contamination of waterways and changes in their host fish species. Habitat in the tidally influenced section of the Makarewa River is not suitable for freshwater mussels as they prefer a firm and stable substrate. There is anecdotal evidence that there were significant populations in a nearby oxbow nearly 50 years ago (Jane Kitson, Kitson Consulting Ltd., pers. comm.) but there is no evidence of viable populations in this area or indeed throughout the lower Makarewa River today or in recent times (i.e., last few decades).

New River Estuary

Monitoring indicates that exposed sites with good habitat quality continue to support moderately abundant and diverse benthic communities in New River Estuary (Robertson and Stevens 2012b). Intertidal monitoring of sandy sites carried out in 2012 reported that numbers for species with a preference or strong preference for sand (including pipis) were low, while two species with a moderate preference for mud (a small spionid worm *Microspio maori* and *A. bifurca*) occurred in high numbers. High numbers of *Potamopyrgus* spp. (which have a strong preference for mud) also occurred at Bushy Point. Robertson and Stevens (2012b) also noted that pipi numbers had declined since 2001 and were virtually absent in 2012. They suggested that this was possibly due to increasing amounts of mud.

In contrast, benthic communities in grossly eutrophic sites within the Waihopai Arm and Daffodil Bay are severely degraded. Benthic communities at these sites are characterised by a limited number of pollution and mud tolerant, surface-feeding taxa, including the amphipod *Paracorophium excavatum*, the scavenging-predator isopod *Exospheroma* sp., the small deposit-feeding bivalve *Arthritica bifurca*, the small estuarine snail *Potamopyrgus* sp., and the surface deposit-feeding spionid polychaete *Scolecolepides benhami* (Robertson and Stevens 2012a). This is consistent with ecological responses expected for sites with muddy, anoxic and sulfide-rich sediments.

As noted above, the relative contribution of the existing discharge to sedimentation in the estuary is considered to be insignificant but the discharge is estimated to contribute approximately 4% of the TN load that is contributing to eutrophication and associated benthic community responses in New River Estuary.

4.4 Fish

Makarewa and Oreti River

The lower Makarewa and Oreti Rivers are typical of lowland rivers and, despite their highly modified habitat, they support moderate-high native fish diversity, a whitebait fishery and a locally significant trout fishery. Juvenile inanga, banded kokopu, giant kokopu, koaro, juvenile and adult common bully, adult eels, black flounder and trout have all been caught or observed in the river downstream of the discharge. The Southland Region Fish Integrated Biological Index (IBI) score for the site immediately upstream (50 m – 2 km upstream) and downstream (150 m – 1.2 km downstream) of the discharge using the survey methodology (electric fishing, fyke netting and minnow traps) and results presented in Freshwater Solutions Ltd (2015a) was 58 placing the sites in the ‘excellent’ class.

The discharge has the potential to adversely affect fish by:

- Reducing the size or number of fish through low dissolved oxygen and elevated Amm-N concentrations.
- Reducing the size and number of fish through reduced benthic invertebrate abundance and size, reduced small fish abundance and size and reduced clarity (reducing feeding efficiency).
- Contributing to microbial contaminants that may affect fish health and human consumption.

The discharge has a minor short term effect on downstream DO concentrations but concentrations very rarely are <5 g/m^3 (Freshwater Solutions 2014a) and would only be for very short durations. Thus any changes in DO are not expected to adversely affect fish.

As discussed above for benthic macroinvertebrates, median Amm-N concentrations were much higher at the 350 m and Boundary Sites than at the Bridge Site over the period 2001–2014. However, it is considered that the concentrations found downstream of the discharge will not result in effects on trout; the no observable effects concentration (NOEC) chronic level for rainbow trout at pH 8 and 20°C is 4.84 g/m^3 (Freshwater Solutions 2014). The Amm-N concentrations at the 350 m Site between December 2001 and June 2014 were above this NOEC (allowing for pH adjustment) <4% of the time and never for extended periods (>4 days).

There are no chronic Amm-N toxicity data for New Zealand native fish, but acute Amm-N LC50s for several New Zealand freshwater species have been reported by Richardson (1997) (Table 2). This data is comparable to acute LC50s for rainbow trout, which range from 17–26 g/m^3 Amm-N at pH 8 and 20°C. As such it is considered the native species listed in Table 2 will be no more sensitive to the chronic effects of Amm-N than rainbow trout, which are not present in the Makarewa River, and brown trout that are present throughout the Makarewa River.

There are no known contaminants in the discharge at levels that are expected, on their own, to result in fish from the lower Makarewa River, Oreti River or New River Estuary being rendered unsuitable for human consumption and therefore the discharge should meet this target in the SRWP (Table 7). The discharge may contribute to higher microbial contamination on occasions but the Makarewa River already has high microbial levels before it reaches the discharge part of the river. The issue of discharging treated human waste from Wallacetown with treated wastewater from the Plant will be addressed separately. At present, approximately 4% of the discharge from the Plant is from treated sewage and of that half is from Wallacetown.

The trout population size and the size of trout in the lower Makarewa River is not surveyed by Southland Fish and Game. The poor water clarity prevented trout being surveyed by drift diving during the current study. The trout population in the tidally influenced section of the lower Makarewa River, affected by the discharge, is likely to vary with season with a peak in trout numbers and in the size of trout expected to occur during the whitebait run and when sea run trout are likely to enter the river from the Oreti River and New River Estuary. The Makarewa River supports a reasonable trout population but the extent to which sea run trout contribute to fish numbers is unknown. The discharge does not appear to alter river water quality to the extent that it prevents migration of sea run trout through the lower Makarewa River or through direct effects on resident trout in the tidally influenced sections of the Makarewa River and Oreti River.

As outlined above, the benthic invertebrate community of the lower Makarewa River is typical of a lowland river draining a predominantly agricultural catchment and is dominated by water quality and habitat tolerant taxa. The resident trout population will be adapted to feed on a range of invertebrate taxa including shrimps, worms, chironomids and snails along with common bully that are abundant in the lower Makarewa River. Resident and migratory trout will also feed on whitebait during late winter and spring. The larger trout will be those that spend part of the year (typically winter and mid-summer) in the lower Oreti River and New River Estuary taking advantage of the more favourable water temperatures and greater abundance of food. The potential for the discharge to affect trout size and number through altering their food sources beyond the mixing zone is limited and the effect on trout size and abundance is therefore assessed as minor.

The discharge does reduce water clarity by more than 33–50% on a small number of occasions. It is possible that this decrease in water clarity reduces the feeding efficiency of predominantly visual feeders such as trout at these times. However the river water clarity is naturally low upstream of the discharge. Fish that rely heavily in visual feeding such as brown trout are therefore likely to have adapted their feeding behaviour and prey to the low water clarity in the river. The low background water clarity, adaptability of brown trout to feed on a range of prey items and short periods when the discharge affects water clarity indicates that the overall effect of the discharge on visual feeding efficiency of trout is likely to be minor. Brown trout are expected to feed on whitebait during the spring and early summer months when the discharge is either off or volumes are low. The discharge is therefore not expected to affect the visual feeding by brown trout on whitebait during spring and early summer.

New River Estuary

The actual effects of the existing discharge on coastal fish within the New River Estuary are uncertain, but are likely to be relatively minor compared with other land and marine based stressors (including sediment, other sources of nutrients and fishing). Land-based activities could affect coastal fish indirectly through high nitrogen loads, and both directly and indirectly through high sediment loads. For instance, sediment and nitrogen affect seagrass by reducing the amount of light available for photosynthesis (the latter by promoting phytoplankton growth) (Bricker et al. 2008). Seagrass is a significant nursery habitat for some fish species and can underpin fisheries production through the provision of shelter and prey (Morrison et al. 2014). While it still occurs in New River Estuary, seagrass cover has decreased by around 41% since 2001, with the greatest losses occurring in the areas most affected by sediment and nutrients (Stevens and Robertson 2012).

Conversely, Francis et al. (2011) found that the richness of New Zealand fish species actually increases towards the muddier upper reaches of New Zealand harbours and estuaries, and concluded that the restoration of harbours to a natural state with clear water and sandy substratum, could reduce the richness of small estuarine fishes.

4.5 Recreational Values

Makarewa and Oreti River

Duck hunting and whitebaiting are the most significant recreational values in the lower Makarewa River potentially affected by the current discharge while duck hunting, whitebaiting and trout fishing are the most significant recreational values in the lower Oreti River potentially affected by the current discharge. The discharge has the potential to affect anglers, hunters and whitebaiters by:

- Reducing the size or number of fish through low DO and elevated Amm-N concentrations.
- Reducing the size and number of fish through reduced benthic invertebrate abundance and reducing small fish abundance and size.
- Reducing the number of ducks by reducing food availability.
- Aesthetic effects negatively affecting hunter and angler perceptions/enjoyment.

As outlined above the current DO and Amm-N concentrations or the effects of the discharge on benthic invertebrates and small fish abundance are unlikely to be adversely affecting trout in the lower Makarewa and Oreti Rivers and as a consequence the effect on angler enjoyment and satisfaction is expected to be minor.

Duck populations are tolerant of poor water quality and are more affected by climate, habitat quality, predation, disease and hunting pressure. It is unlikely that the discharge results in any effect on duck numbers within the lower Makarewa River or Oreti River. The wastewater treatment ponds are regularly used by large numbers of ducks. Alliance does not permit ducks on the wastewater treatment ponds to be hunted, however it is highly likely that ducks from the ponds move into the surrounding river and wetland habitat where they are accessible to hunters.

The discharge results in some visible foams and scums at times within and immediately beyond the mixing zone and may reduce the enjoyment of some whitebaiters, anglers and duck hunters. The short section of river affected and the occasional nature of the effect coupled with the small number of hunters, anglers and whitebaiters affected suggests that the effect of the current discharge on recreational values is likely to be minor.

New River Estuary

Fishing, contact recreation (bathing and wading) and boating are likely to be the key recreational values in the New River Estuary potentially affected by the current water and habitat quality. The mechanism for the discharge to adversely affect recreational users of the estuary is through nutrients causing macroalgae growths which can lead to odours, reduced diversity and abundance of shellfish in some areas such as Daffodil Bay and clogging of set and hand held nets used by fishermen. The extent to which any of these effects currently occurs has not been quantified. The relatively small potential contributions that the discharge makes to the overall TN load in the estuary and the small resultant effects on macroalgae growths (that is attributable to the discharge) indicates that the effect of the discharge on recreational users is likely to be minor.

Summary

The actual and potential effects of the current discharge are:

- Amm-N toxicity.
- Increased nutrients concentrations.
- Increased bacteria concentrations.
- Reduced DO concentrations.
- Altered colour and clarity.
- Generation of foams and scums.
- Development of nuisance algal growths.
- Altered benthic invertebrate community.
- Altered fish community.
- Reduced recreational values.

The effects of the discharge were assessed using parameters from the current Alliance Consent (e.g., pH and temperature), MfE (1994) (clarity), SRWP (e.g., ≥10% reduction in nitrate and phosphorus), the NPS (MFE 2014) (e.g., Amm-N, Nitrate-N, DO) and Freshwater Solutions (2014) (Amm-N).

The discharge does not significantly adversely affect pH, temperature or DO. Dissolved oxygen concentrations in the immediate vicinity of the discharge are at times lowered by the discharge but not to a level that would impact on most invertebrates or fish. At times the discharge does elevate faecal coliforms and *E. coli* concentrations in the river. Algae in the discharge does reduce clarity by more than 33% at times. The current nitrate-nitrogen concentrations below the discharge are below the level expected to adversely affect aquatic biota through toxicity. The Amm-N concentrations in the discharge rarely exceed the existing consent, which is based on acute Amm-N effects, but consistently exceeds various chronic Amm-N limits, including the NPS bottom line annual median.

The discharge contributes 53% of the total TN load and 68% of the total TP load to the lower Makarewa River. The percent contribution of the TN and TP load from the discharge to the New River Estuary has been estimated as 4% and 5% respectively. Nutrients from the discharge potentially elevate river sediment nutrient concentrations immediately downstream and at times upstream of the discharge.

The TSS load to the river and estuary from point sources is very low and the contribution the discharge makes to sedimentation is insignificant. The key contaminant in the discharge with the potential to adversely affect the estuary, through macroalgae growth, is nitrogen. The discharge potentially contributes, in a very minor way, to the approximately 11% cover of nuisance macroalgae cover in the estuary.

The tidal section of the lower Makarewa River, which includes the region where the discharge occurs, is unsuitable for periphyton growths because of unsuitable substrate and physical characteristics and thus any potential effect of the discharge on periphyton is assessed as minor. The discharge increases nitrogen and phosphorus concentrations in the water column and in river sediments and this is likely to contribute to macrophyte growths which provide important cover for eels, bullies and trout.

The habitat in the tidally influenced section of the lower Makarewa River is not suitable for freshwater mussels because of the finer substrate, variable water level and other anthropogenic activities such as channel straightening. No mussels were found during surveys in 2013 and 2014 and anecdotal evidence indicates that they have not been present in the lower Makarewa River for some time. The habitat in the tidally influenced section of Makarewa River is also not suitable for the mayfly *Deleatidium*. The macroinvertebrate community and MCI score at Site D1, within the mixing zone, is similar to other Southland tidally influenced river sites. Given the highly modified state of the habitat, poor background water quality and the dominance of water and habitat tolerant taxa within the Makarewa River (including around the discharge) the effect of the discharge on benthic invertebrates is not assessed as significant. The benthic macroinvertebrate communities in the Waihopai Arm and Daffodil Bay in the New River Estuary are severely degraded due to the muddy anoxic, sulphide rich sediments and the discharge makes a very small contribution to enrichment; thus any effect on estuarine benthic invertebrates is assessed as minor.

The fish community at sites immediately upstream and immediately downstream of the discharge are in the ‘excellent’ Southland fish IBI class. The effect of the discharge on clarity may cause some minor effect on the visual feeding efficiency of trout and some native fish species during late summer – early winter.

The discharge results in some visible foams and scums at times within and immediately beyond the mixing zone and may reduce the enjoyment of some whitebaiters, anglers and duck hunters. Foams have also been observed when the plant is not discharging. The short section of river affected and the occasional nature of the effect, coupled with the small number of hunters, anglers and whitebaiters affected, suggests that the effect of the current discharge on recreational values is likely to be minor but the issue needs to be addressed as it is an RMA requirement. Further work to assess the recreational values and effects of the discharge is currently underway.

The relatively small contribution that the discharge makes to the overall TN load in the estuary and the small resultant effects on macroalgal growths (that is attributable to the discharge) indicates that the effect of the discharge on recreational users is likely to be minor.

Overall the most significant potential effects of the discharge on the Makarewa and Oreti Rivers and New River Estuary relate to the potential Amm-N toxicity and TN and TP loads. Under the RMA and latest NPS standards, water clarity and microbial levels also need to be addressed as they do not meet the required standards but these along with nutrient loadings need to be addressed at the catchment scale.

5.0 The Effects of the Discharges and Mitigation Required

The previous sections in this assessment have described the potential effects of the Alliance discharge, identified targets for the receiving environments based on the scientific literature and various plans and guidelines, and discussed the effects observed with the present discharge. This section:

- Identifies the main risks and issues that need to be addressed.
- Recommends what reductions and changes are required to ensure the targets are met and that there is an improvement in the health of aquatic systems below the discharge.

5.1 Main Risks and Issues

The main risks and effects identified in Sections 1–4 are as follows:

- The increase in ammonia levels below the discharge impacting directly on water quality and through toxicity on the macroinvertebrate and fish communities
- Increases in TN and TP from the discharge contributing to growths of nuisance algae and eutrophication of the lower Makarewa and Oreti Rivers and New River Estuary.
- Development of foams and scums as a result of the discharge and their associated effects on aesthetics and recreation.
- Decrease in water clarity with its associated aesthetic and recreational impacts as well as potential for impacts through light attenuation on primary production and on physiological and feeding processes for macroinvertebrates and fish communities.
- Increases in microbial contamination in the lower Makarewa River below the discharge, lower Oreti River and New River Estuary reducing aquatic health, cultural values and potentially rendering fish and shellfish unsafe for consumption.

Each of these risks/issues is dealt with below. The reasons for addressing these issues are to improve the health of the receiving environments and to address limits/standards in the latest NPS (MFE 2014) and regulatory standards in the SRWP and in the RMA.

5.2 Water Quality

This section presents the changes in water quality needed to meet the target receiving environment standards and guidelines that have been identified.

Makarewa and Oreti Rivers

With the present discharge and assuming this discharge volume will not be increased in future, then the targets for temperature, pH, DO, BOD and nitrate toxicity outlined in Section 3.0 and Table 3 will continue to be met. The targets for key parameters of water quality where effects have been identified, assessed as potentially significant and needing to be addressed are summarised in Table 8.

The major contributor to potential toxicity and to the TN loadings to the lower Makarewa and Oreti Rivers and the New River Estuary is Amm-N, which typically contributes approximately 87% of the TN in the discharge. At present the concentrations in the river at the 350 m Site (outside the mixing zone) meet the Alliance consent 99% of the time but the limits identified in Table 8, which are required to avoid chronic toxicity effects for the more sensitive species, would require significant reductions in Amm-N in the discharge.

Table 8: Environmental parameters where actions are required to meet standards/limits.

Parameter	Target	Source
Ammonia -nitrogen	Annual median <1.3 g/m^3 (at pH 8.0 and temperature 20°C) Annual maximum <2.2 g/m^3 (at pH 8.0 and temperature 20°C)	MFE (2014)
	Annual median <1.9 g/m^3 (at pH 8.0 and temperature 20°C) Annual 95%-ile <2.4 g/m^3 (at pH 8.0 and temperature 20°C)	Freshwater Solutions (2014)
TN	>10% reduction before January 2010	SRWP (2013)
TP	>10% reduction before January 2010	SRWP (2013)
Water clarity	Not <33% of upstream	MFE (1994)
Foams and scums	No conspicuous	RMA

Freshwater Solutions (2015a) has derived site-specific Amm-N limits based on the ANZECC (2000) methodology. It is considered the most appropriate ammonia limits for the Makarewa River downstream of the Alliance discharge are:

- 1.9 mg/L (pH = 8, 20°C), as an annual median.
- 2.4 mg/L (pH = 8, 20°C), as an annual 95%-ile.

These limits are lower than both the ANZECC (2000) 80% trigger value and the USEPA (2013) chronic criteria (no mussels, early life stage fish present) and only slightly higher than the NPS attribute state bottom lines which will be applied to Freshwater Management Units.

It is considered appropriate that NOEC-based limits may be exceeded on occasion. Hence the use of annual medians in the NPS is supported because they are based on NOECs. It is also considered appropriate that NOEC-based limits be used in conjunction with some effects based limits (such as LOECs or Threshold Effects Concentrations (TECs)). The application of annual maxima in the NPS (MFE 2014) is not appropriate for point source discharges. Firstly, the approach is one that is appropriate in the management of acute effects but not the chronic effects on which the limits are based. Secondly, the supporting document reports application of the TEC-based ammonia on 95%-ile monitoring data (MfE 2014); this is an appropriate approach since infrequent exceedances of a TEC will not result in chronic effects.

Neither the NPS (MFE 2014) nor the USEPA (2013) provide any guidance regarding the management of diurnal changes in pH, both of which may have a marked effect on ammonia toxicity. As the diurnal changes are relatively small (median change 0.38, Freshwater Solutions 2014a) and the issue being addressed is chronic toxicity in the NPS then we have not adjusted values for diurnal change.

In order to assess the required reduction to meet the NPS bottom lines and site-specific ammonia limits, the entire data set (2001–2014) was used with the required standard (NPS bottom line) and site specific values (Freshwater Solutions 2014) being converted for each daily measurement of pH and then comparing the median, 95th percentile and maximum value of pH derived limits with actual Amm-N measurements taken downstream (as per recommendations to MFE, NIWA 2014). To obtain the reduction required the entire dataset was iterated until compliance was met 50, 95 and 100% of the time.

Table 9 presents the estimated reductions required to meet compliance with the NPS bottom lines.

Table 9: Reductions required to meet Amm-N NPS limits for 80% species protection.

Limit	Annual median (g/m^3)	Annual 95%-ile (g/m^3)	Annual maximum (g/m^3)
NPS *	25 (0–55)	69 (0–77)	79 (35–90)

Note: * NPS 80% species protection is the Bottom Line.

Annualised values for data from 2003–2014 show the required reductions ranged from 0–55% for what would be required to meet the annual median and 0–77% for the 95%-ile. Based on these estimates it is recommended that a 75% reduction in Amm-N should be the long-term goal for Alliance for their point source discharge. The NPS numeric attribute states for ammonia (MFE 2014) are based on ANZECC (2000) methodology. The application of the NPS (MFE 2014) limits is currently very uncertain, however we understand that they are designed to be applied to Freshwater Management Units (possible catchment or sub catchment scale) and not to assess the effects of particular discharges. For the reasons given earlier we consider the 95%-ile as more appropriate for assessing toxicity of biota which are in the Makarewa River and can tolerate short periods at higher levels. Monitoring is yet to be developed but consideration should be given to a 30 day rolling average for chronic levels and a maximum of 2.5x these values for acute toxicity level as per USEPA (2013).

The recommended long-term reductions in Amm-N levels in the wastewater discharge of 75% will also address the key effects of the current discharge on nutrient loadings by significantly reducing TN (56 t/season) in the Makarewa River and the New River Estuary.

Nutrient concentrations downstream of the discharge measured between 2001–2014 indicate the median DIN:DRP ratio was approximately 9:1–16:1 at the 350 m Site and 10:1–17:1 at the boundary site. Hence downstream of the discharge the Makarewa River is co-limited (Larned et al. 2011) with respect to nitrogen and phosphorus. This is in contrast to the Makarewa River upstream of the discharge where the DIN:DRP ratio was approximately 15:1–71:1 between 2001 and 2014, and approximately equally co-limited and phosphorus limited, thus it is important to eventually reduce N by at least 75% and P by at least 10%.

The algal concentration in the discharge has reduced visual clarity of the Makarewa River in the immediate vicinity of the discharge by more than 20% on approximately 20% of sampling occasions, >33% on 5% of occasions and >50% on <1% of occasions. The clarity of the lower Makarewa River is low due to a range of catchment scale influences. The recommended future wastewater quality will be higher than the existing discharge but any change in algal concentrations and therefore influence on river water clarity is unknown. The lower Makarewa River in the vicinity of the discharge has low water clarity due to catchment influences, supports limited contact recreation and has no designated bathing, and therefore the effect of the discharge on river clarity in the future is not assessed as significant. However the RMA requires that there is no conspicuous change in colour or clarity as a result of a discharge. At present, the <5% of the time it is >33% and the <1% of time it is >50% of that upstream is not considered significant based on the limited use of the lower Makarewa for recreation.

New River Estuary

The effects of the recommended reduction in N in the discharge on New River Estuary, were assessed by applying the proportional load reductions to the nitrogen loads from the discharge and total catchment loads estimated by Robertson and Stevens (2013). The recommended reduction in N will reduce the contribution that the discharge makes to the overall nitrogen load going to New River Estuary. As a result, the estimated contribution that the future discharge would make to the TN load to the estuary is estimated at 1.3%. A reduction of this magnitude is significant in relation to the discharge. However, it is insignificant relative to the total reduction required to improve the trophic state of the estuary. Robertson and Stevens (2013) suggested that the estimated total areal N load to the estuary would need to be reduced by 69–84% (from 320 $mgN.m^{-2}.d^{-1}$ to 50–100 $mgN.m^{-2}.d^{-1}$) to maintain a moderate trophic status in the estuary. While the recommended reductions would result in an improvement in water quality and reduce loadings, on its own it is unlikely that any change to the discharge quality will result in an observable improvement in estuary eutrophication. The reduction of 69–84% could only be achieved through a catchment-wide reduction of nitrogen loads. The assessment of effects report prepared by Mitchell Partnerships Ltd addresses Alliance's proposed approach to the catchment wide management of nutrients proposed by the SRC.

5.3 Scums and foams

The RMA and SRWP (2013) require that, after reasonable mixing, there should be no production of any conspicuous scums or foams. As discussed earlier, at present these can occur on occasions below the discharge and also when not discharging. Although the lower Makarewa River below the discharge is not used extensively for recreation, it is recommended improvements be made to avoid or at least minimise or mitigate their production.

5.4 Microbial

The annual median for faecal coliform counts in the discharge since 2001 has averaged 3,515 cfu/100 mL with the highest levels being 6,000 cfu/100 mL. Although most of the time the current discharge does not appear to elevate faecal bacteria concentrations in the lower Makarewa River there are occasions when counts are elevated above that recorded upstream. Results of measurements over the last 13 years show that levels in eight of those years at the 350 m Site were above the limit of 1,000 MPN/100 mL and are likely to have been above the bottom line in the NPS (2014) for *E.coli* a similar number of times. Thus even with treatment, levels would still at times be above the 1,000 cfu/100 mL standard. Further treatment of the effluent could on occasions reduce the microbial levels at the 350 m Site to <1,000 cfu/100 mL but this would have only been effective in two of the last 13 years because of the high microbial levels above the discharge point. Thus any further treatment for microbial contamination would have to be part of a longer-term catchment-wide plan.

If there is a cost-effective way to treat the effluent further and a catchment-wide plan to reduce levels of microbial contaminants upstream developed then Alliance should consider available options in the longer term. It is also likely that such treatment would reduce the occasional high suspended solids levels as filtration is likely to be included in the treatment process.

5.5 Aquatic Plants

Makarewa and Oreti Rivers

Reducing nitrogen concentrations in the discharge may result in a small reduction in macrophyte growth and cover in the vicinity of the discharge but, because of the very low gradient and tidal nature of the lower river, this is not expected to increase the amount of riffle habitat preferred by most water and habitat sensitive benthic invertebrate taxa. Overall the effect of reducing the nitrogen load in the discharge to macrophyte growths in the lower Makarewa River is likely to be neutral.

New River Estuary

As indicated above, reducing the Amm-N load in the discharge by 75% will significantly reduce the TN load and improve water quality in the River but on its own this is unlikely to have an observable effect on nuisance macroalgae in New River Estuary. A significant reduction in nuisance macroalgae is only likely to be achieved through a major, catchment-wide reduction in total nitrogen loads.

5.6 Benthic Macroinvertebrates

Makarewa and Oreti Rivers

Reducing nutrient loads from the discharge will not change the habitat so there is unlikely to be any observable changes in the benthic invertebrate community. As a consequence the abundance of benthic invertebrates that prefer riffle habitat such as mayflies are not expected to increase and the composition of the benthic invertebrate community is expected to remain similar to the current community. We have not recommended any target states for MCI or other indices because these are not appropriate for the tidal, depositional, soft-bottomed habitat that exists downstream of the discharge.

Given the unsuitable nature of the habitat and water characteristics within this tidally influenced section of the river, mussels and the mayfly *Deleatidium* would not be expected to colonise the area with or without the recommended reductions in nutrients in the discharge.

New River Estuary

Habitat quality is relatively good in exposed, sandy sites, which have moderately abundant and diverse benthic communities. Improving the discharge quality would help improve, but not necessarily prevent, the degradation of the benthic macroinvertebrate community in these areas unless there is a whole of catchment reduction.

5.7 Fish

Makarewa and Oreti Rivers

Any change in macrophyte growths and the cover that they provide to fish is expected to be minor and no adverse effects on eels, trout or bullies associated with habitat changes are expected.

Based on the study findings the current Amm-N concentrations in the discharge do not appear to be adversely affecting fish, with the Southland Fish IBI scores in the 'excellent' class immediately upstream and downstream of the discharge. The current Amm-N concentrations in the discharge are not expected to be having chronic adverse effects on fish and none were identified in the current study. A 75% reduction in Amm-N inputs would provide further assurance that no adverse effects on fish populations or their ability to migrate upstream would occur.

Fish in the lower Makarewa River appear to be healthy (Freshwater Solutions 2015a). Any consideration of fish health would need to be part of a catchment-wide programme as water quality is already low and they are mobile and not confined to this stretch of river.

New River Estuary

The potential impacts of both existing and recommended future discharges on coastal fish within New River Estuary will be relatively minor compared with other land and marine based stressors (including sediment, other sources of nutrients and fishing).

5.8 Recreation

Makarewa and Oreti Rivers

The recommended improvement in wastewater quality will lead to a significant improvement in water quality in the lower Makarewa River below the discharge. Because of the poor background water quality associated with catchment wide land use and river management effects, and the existing recreational use which does not involve swimming in the lower Makarewa River, the effects of the recommended improvement in discharge quality on recreational values/users is expected to be minor. If the risk of microbial contaminants and formation of foams and scums is reduced longer-term then this would result in some potential improvement in recreational enjoyment and reduced risk of rendering of fish unsuitable for human consumption.

New River Estuary

The recommended future discharge quality will further reduce the already small relative contribution the discharge makes to the quality of the New River Estuary. As a consequence any positive effects of the recommended wastewater quality upgrade on recreational values within the estuary are expected to be minor.

5.9 Overall Effects of the Discharge

The NPS and likely changes to the future management of the Southland Region catchments are expected to require improvements in water quality in the Makarewa River, Oreti River and New River Estuary. The recommended level of TN, TP and Amm-N reduction for the future discharge are expected to have significant positive effects on water quality and ecological health in the immediate receiving environment and will assist in meeting the future water quality targets set by the NPS and SRC for the Freshwater Management Unit within which the Alliance discharge occurs. The reductions would result in some improvement, although it is not likely to be observable without a catchment-wide approach, to the health of the estuary.

Summary

The main effects on the receiving environments from the current discharge are:

- Increased Amm-N levels which can cause toxicity effects in biota in the river.
- Increases in N and P which make a small contribution to increases in nuisance algae and eutrophication of rivers and the estuary.
- Development of foams and scums impacting on aesthetics and recreational values.
- Reduced water clarity which can impact on aesthetics, recreation and ecological values.
- Increased microbial contamination that can impact on aquatic health, recreation and cultural values and consumption of fish and shellfish.

The current discharge meets standards for temperature, pH, DO, BOD and nitrate toxicity and these will continue to be met.

The current discharge does not meet the Amm-N bottom lines in the NPS (MFE 2014) or the site-specific values derived for the lower Makarewa. However, the NPS attribute states are intended for Freshwater Management Units and thus there is currently considerable uncertainty over how these states will be applied to individual point source discharges, such as that from the Alliance processing plant.

An assessment of the estimated compliance with the NPS bottom lines and site-specific Amm-N limits developed for the Makarewa River indicate that a 75% reduction in discharge Amm-N would be required to meet compliance with the site-specific Amm-N limits and the more conservative NPS bottom line. This would provide a significant improvement in water quality in the Makarewa River downstream of the discharge.

The SRWP (2013) requires at least a 10% reduction in nitrate and phosphorus before January 2020 Because of the very large contribution of nitrate and TN from diffuse sources within the Makarewa River Catchment the proposed improvement in discharge and water quality alone, is not expected to deliver an observable or tangible improvement in estuarine quality. However, the 10% target for reduction in TN should be met in the short-term to ensure there is a start made to improving in water quality and estuary health. The 10% reduction in phosphorus should be as part of the larger long-term upgrade.

The clarity of the lower Makarewa River is low due to a range of catchment scale influences. The lower Makarewa River in the vicinity of the discharge is thought to support limited contact recreation due to difficulty accessing the river and therefore the effect of the discharge on river clarity is not assessed as significant. Under the RMA conspicuous changes in water clarity should not occur and which in the case of the lower Makarewa River is assessed as <33% change in upstream clarity

Scums and foams occur at times in the Makarewa River below the discharge and occasionally when the plant is not discharging. Under the RMA and the SRWP no conspicuous foams or scums should be produced below a discharge after reasonable mixing thus improvements need to be made to minimise this effect.

The current discharge can elevate faecal bacteria concentrations in the lower Makarewa River on occasions and in some years but in other years appears to dilute the contamination from microbial sources. Further treatment would reduce the overall loading and would on occasion ensure compliance with SRWP and NPS standards. For most years the standards would not be met because of the high levels in the upper catchment. Without a catchment wide approach this will remain an issue.

The habitat in the lower Makarewa River including the area around the discharge is a tidal, soft-bottomed, macrophyte dominated depositional environment and thus even with an improvement in water quality the benthic invertebrate community downstream of the discharge is expected to remain broadly similar to the current community. The unsuitable nature of the habitat excludes mussels and *Deleatidium* from the tidal section of the Makarewa River and these are not expected to return to this strongly tidally influenced section of the lower Makarewa River

Reducing the Amm-N concentrations in the discharge would reduce the potential for the discharge to cause chronic toxicity effects on fish although at present there are no obvious effects on the community.

Due to the very large relative contribution from the catchment the positive effects of the recommended improvement in discharge quality on recreational values/users in the river and estuary are expected to be minor. However improvements to reduce foams and scums should be made and treatments which will improve fish health, microbial status and water clarity should be considered, where practical as part of longer-term and catchment-wide programmes.

The NPS and likely changes to the future management of the Southland Region catchments are expected to result in improvements in water quality in the Makarewa River, Oreti River and New River Estuary. The recommended level of TP, TN and Amm-N reduction for the future discharge are expected to have positive water quality and ecological health effects in the receiving environment and will assist in meeting the future water quality targets set by the NPS and SRC for the Freshwater Management Unit within which the Alliance discharge occurs.

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APPENDIX 1

Ammonia Limits for the Makarewa River

report

November 2014

Ammonia Limits for the Makarewa River

Submitted to:
Alliance Group Ltd
PO Box 1410
Invercargill

fresh water solutions
environmental consultants

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1.0 Introduction

1.1 Background

Alliance Group Limited (Alliance) operates a meat processing site at Lorneville (the Plant). As part of its operations Alliance holds resource consents to discharge treated meat processing wastewater (the discharge) to the Makarewa River (Discharge Permit 92195). Discharge Permit 92195 expires on 6 August 2016.

As part of a review of the Alliance environmental standards (Freshwater Solutions, 2013) it was identified that the Alliance resource consent defines ammoniacal nitrogen (ammoniacal nitrogen = ammonia + the ammonium ion; for the purpose of this report it is referred to as 'ammonia') limits for the Makarewa River based on 1984 USEPA acute criteria (Salmonids present). As such, the on-going relevance of the 1984 USEPA criteria for providing the appropriate protection to aquatic biota in the Makarewa River is considered tenuous. Indeed, since the promulgation of the 1984 USEPA criteria, USEPA have updated their criteria on three occasions, the latest being in 2013 (USEPA, 2013). These updates were driven by numerous new publications on the effects of ammonia on aquatic biota.

The current framework for the protection of aquatic ecosystems in New Zealand is the National Policy Statement (NPS) for Freshwater Management 2014 (MfE, 2014). The ammonia limits in the NPS are derived based on ANZECC (2000) methodology, but are no longer referred to as trigger values but 'Numeric Attribute States'. There is considerable evidence that the ANZECC (2000) trigger values were overly conservative and, in some cases, not based on the soundest possible science (Kingett Mitchell, 2004). Hence, confidence in the NPS ammonia limits is also uncertain and their applicability to the Makarewa is potentially questionable.

The purpose of this report is to present ammonia limits that are suitable for application to the Makarewa River downstream of the Alliance discharge, and that can be used for the purposes of evaluating potential treatment system upgrade options. Hence the aim of this report is to:

- Summarise the overall ANZECC (2000) approach to trigger value derivation.
- Review the derivation of the ANZECC (2000) freshwater trigger values for ammonia.
- Review the derivation of the NPS freshwater Numeric Attribute States for ammonia.
- Review the toxicological data for ammonia, including data published since ANZECC (2000).
- If required, present ammonia toxicity data that is appropriate for use in the derivation of ammonia limits and re-calculate Numeric Attribute States for ammonia based on ANZECC (2000) methodology.
- Recommend ammonia limits suitable for application to the Makarewa River downstream of the discharge that can also be used for the purposes of evaluating potential treatment system upgrade options.

2.0 Current Ammonia Levels

Ammonia monitoring data collected between December 2001 and June 2014 upstream (Bridge Site), 200 m downstream (200 m Site) and 1200 m downstream (Boundary Site) is presented in Table 1.

Table 1: Ammonia data upstream and downstream of the discharge.

	Temp (°C)	pH	Ammonia (g/m^3)
Bridge			
med	13.9	7.2	0.072
min	1.5	5.4	0.005
max	21.2	8.1	1.9
5%-ile	7.0	6.5	0.029
95%-ile	18.8	7.6	0.39
200 m DS			
med	13.9	7.3	3.9
min	1.5	6.1	0.060
max	21.5	9.0	22
5%-ile	7.0	6.7	0.32
95%-ile	19.1	7.7	9.1
Boundary			
med	14.0	7.3	2.5
min	1.5	6.1	0.027
max	21.5	8.8	14
5%-ile	6.9	6.8	0.23
95%-ile	19.1	7.7	8.1

The Alliance consent contains two ammonia conditions, one to be met in the first two years of the consent and the other for the remaining term of the consent. For the first two years of the consent the receiving water was not to exceed 0.11 g/m^3 unionised ammonia, or any five consecutive samples (taken on different days) exceed a median unionised ammonia concentration of 0.08 g/m^3. Both of these conditions were met with the exception of one occasion in March 2003 when the unionised ammonia concentration was 0.15 g/m^3. Following the first two years of the consent the ammonia condition reverted to the 1984 USEPA acute criteria, which are pH and temperature dependant and summarised in a table in the consent. This condition was not met on 12 out of 1250 occasions between November 2003 and June 2014, most recently in April 2013.

Freshwater Solutions (2013) reported that the unionised ammonia limit in the New River Estuary was breached on < 10% of sampling occasions between 2005 and 2010.

3.0 ANZECC Approach to Trigger Value Derivation

ANZECC (2000) has published trigger values for a wide range of chemical contaminants. Generally the trigger levels are derived from toxicity tests on single species under laboratory conditions. The majority of trigger values are termed ‘moderate reliability’ because they are based, in part or whole, on acute toxicity data. However, some trigger values, such as those for ammonia, are afforded ‘high reliability’ status; ANZECC state that these high reliability trigger values are based on No Effects Concentration (NOEC) data alone.

The ANZECC (2000) NOEC data for all published toxicants was compiled from various sources, including data from the USEPA AQUIRE (1994) database, data from other regulators and data direct from scientific journals. ANZECC (2000) stipulates that unpublished data may not be used to derive high reliability trigger values. NOEC data was also reviewed by ANZECC in order to satisfy data quality requirements.

Once the NOEC data was compiled it was reviewed for final selection. In cases where multiple data was present for a species, data for the most sensitive effect was preferred. If more than one NOEC was present for the most sensitive effect, the geometric mean of the NOECs was used in the final trigger value calculation.

A Burr-type statistical distribution was then fitted to the final data set. The computer software (BurrliOZ, Campbell et al., 2000) fits Burr Type III statistical distributions to the data and then uses a maximum likelihood method to determine which distribution fits best. The software then uses the best fit to calculate the concentration that will protect any specified percentage of species at a confidence level defined by the user; the confidence level that was used by ANZECC was 50% and this is the default level set by the software. The 95% level of protection is the level most commonly applied in the ANZECC (2000) Guidelines because it applies to slightly or moderately disturbed ecosystems.

BurrliOZ is available as freeware (http://www.cmis.csiro.au/Envir/burrlioz). A more recent version than that used to derive the trigger values reported by ANZECC is now available. ANZECC do note that users of BurrliOZ may obtain slight differences in trigger values even when using the same data as was used to derive the original trigger values.

Hence, ANZECC have derived the following high reliability trigger values for ammonia (i.e., total ammonia = ionised ammonia (NH_4^+) + unionised ammonia (NH_3)).

- Protection of 95% of aquatic species: 0.90 mg/L.
- Protection of 90% of aquatic species: 1.4 mg/L
- Protection of 80% of aquatic species: 2.3 mg/L

Although ANZECC (2000) does adjust toxicity data to account for the pH effect it does not use temperature conversions in the procedures for assembling an ammonia toxicity data set. ANZECC argued that the effects of temperature were not sufficiently large or consistent enough to allow adjustment of the USEPA model that was in use at the time (USEPA, 1998). For the purpose of this report a more recent (USEPA, 1999, 2013) method was used to adjust toxicity data to allow for pH effects. This is discussed further in Section 6.

4.0 Review of the Toxicological Data for Ammonia

4.1 ANZECC (2000) Approach

The NOEC data used by ANZECC in the development of the ammonia trigger value is contained in a data set included with the ANZECC (2000) guidelines; 'ANZECC and ARMCANZ Water Quality Guideline Database for Toxicants', which was created by staff from the Ecotox Section, NSW Environment Protection Authority.

The ammonia data set is comprised of 36 data from 16 species (three crustaceans, nine fish, two insects and two molluscs). However, much of the data used by ANZECC (2000) is inconsistent with ANZECC's own published methodology; i.e., only NOEC data should be used. In fact much of the data simply appears to have been reproduced from Table 5 in the 1999 USEPA aquatic life criteria (USEPA, 1999), which is EC20 data not NOEC data. Although endpoints such as EC10 and IC25 are generally considered as acceptable replacements for NOEC, they should not be used in cases where actual NOEC data exists. Other endpoints, such as LOECs and LC50s are also included in the ANZECC (2000) dataset, but this data should not be used. In addition, some data should have been excluded by ANZECC (2000) because of inappropriate test conditions, such as dissolved oxygen concentrations being too low, and other data is simply mis-cited. Of the 36 data presented by ANZECC only four are valid for use in a NOEC data set.

4.2 Review of the 2014 NPS Attribute States for Ammonia

The NPS ammoniacal nitrogen limits are based on a non-peer reviewed, unpublished memorandum from NIWA to MfE (NIWA, 2014). The reported numeric attribute state limits, A, B and C, as annual medians and annual maxima, respectively, are:

- A = Protection of 99% of aquatic species: 0.03 and 0.05 mg/L.
- B = Protection of 95% of aquatic species: 0.24 and 0.40 mg/L.
- C (Bottom lines) = Protection of 80% of aquatic species: 1.30 and 2.2 mg/L

The derivation of the numeric attribute states as annual medians follows ANZECC (2000) methodology, i.e., NOEC data is used. Although NIWA (2014) states, '*Both temperature and pH affect the ionisation of ammonia and the associated toxicity to aquatic species'*, data is only adjusted to pH 8 and not temperature corrected as required.

The data set contains 20 species. NIWA (2014) refer to the limits as an 'indicative' update to the ANZECC (2000) trigger values and readily acknowledge that, '*A thorough literature review and updating of the ANZECC (2000) freshwater data database has not been undertaken as part of this review'.* In actuality the NPS numeric attribute states are untenable because they do not review the data behind the ANZECC (2000) trigger values or consider all available data post-ANZECC (2000); rather, only low sensitivity data (from freshwater mussels) are selected. Even here, the NOEC of 0.24 mg/L used for the most sensitive species (Rainbow mussel) is not based on any reported data, but is calculated based from the geometric mean of the control and the LOEC in the Rainbow mussel experiment (Wang et al., 2007). Hence, the NPS data set is unrevised, incomplete, unjustifiably biased toward ammonia sensitive species, and hinged on a incorrect critical data point.

The derivation of the numeric attribute states as annual maxima does not follow any published methodology, ANZECC (2000) or otherwise. Rather the approach appears to be based on an unpublished technical report in which 'surveillance' nitrate-nitrogen values are derived for compliance assessment based versus 95%-ile monitoring data (NIWA, 2013); the term 'surveillance' being appropriated from descriptors that are applied to microbiological standards. In this fashion the average value of the Threshold Effect Concentration (TEC = geometric mean of the NOEC and the LOEC) values for only the most sensitive freshwater mussel and clam species were used to calculate a NOEC/TEC ratio, which was then applied to estimate the TEC-based guideline values for the dataset. While the overall approach is not unreasonable, in this case it is flawed because only four of the 20 species in the overall NIWA data set are selected. Once again, the data set is incomplete and biased toward ammonia sensitive species. And although NIWA (2014) reports the TEC-based ammonia guidelines as suitable for assessment based on 95%-ile monitoring data, the NPS (2014) inexplicably applies them as annual maxima (i.e., 100%-ile).

4.3 Review of Toxicological Data for Ammonia

NOEC data that are valid for use in deriving an updated ANZECC trigger values are presented in this section. This includes toxicity data for ammonia that was either not selected by ANZECC (2000) or published after the ANZECC (2000) guidelines were compiled. Apart from the ANZECC data toxicity data was sourced from the USEPA toxicological database (ECOTOX, data extracted July 2014), from published scientific papers, and from existing ammonia criteria from other regulators.

It is noted that the USEPA released its current ammonia criteria as recently as April 2013; the basis for this most recent revision being recent studies on freshwater mussels which "suggest that some freshwater mussel species may be more sensitive to ammonia exposure than the aquatic organisms considered in deriving the current ammonia criteria" (USEPA, 2009).

The 2013 USEPA criteria use a more up to date and highly detailed approach than that of ANZECC 2000 for the adjustment of toxicity data to allow for both pH and temperature effects (USEPA, 1999; USEPA, 2009; USEPA, 2013). The pH and temperature dependence of ammonia toxicity in fresh water were revised by USEPA in 1999 to take into account newer data, better models, and improved statistical methods, although USEPA still acknowledge that definitive, thorough theoretical approaches for describing pH and temperature effects on ammonia toxicity are lacking. They conclude that the most reasonable approach was to adopt the best empirical descriptions that could be obtained from available data.

USEPA used an adjustment of toxicity data to allow for pH effects based on Erickson (1985). Based on empirical data, USEPA reported that available data suggested minimal dependence of fish ammonia toxicity on temperature, hence their toxicity data adjustment and criteria formulation assumed no temperature dependence for fish endpoints. However it was also noted that available data suggested a strong dependence of invertebrate acute ammonia toxicity on temperature. No data was available regarding the temperature dependence of invertebrate chronic toxicity, but USEPA conclude that the best approach was to adjust invertebrate chronic ammonia toxicity data for temperature effects.

A summary of the current NOEC and, where available, associated LOEC data for ammonia is presented in Table 2. Only NOEC data that represented true No Observable Effect Levels (NOELs) was used (TenBrook et al. 2005); some EC20 and IC25 data was used but only when NOEC data did not exist. All reported data is adjusted to pH 8.0 as per ANZECC (2000). The data set is comprised of 36 species (three amphibians, three crustaceans, 19 fish, two insects and nine molluscs) and contains 49 discreet data. As such, the data represents a good cross-section of species that are either found in New Zealand, or would act as useful surrogates for species found in New Zealand. This data set is used to derive what can be considered updates to the ANZECC (2000) ammonia trigger values as well as correctly derived annual median and annual 95%-ile numeric attribute states.

Table 2: Revised toxicity data for the re-calculation of ammonia trigger values.

Name	Duration (h)	Effect	Endpoint	Conc (mg/L*)	Endpoint	Conc (mg/L*)	TEC (mg/L*)	Reference
Amphibians								
Pseudacris regilla (Pacific chorus frog)	240	GRO	NOEC	5.5	LOEC	10.7	7.7	Schuytema and Nebeker (1999)
	240	GRO	NOEC	2.6	LOEC	5.0	3.6	Schuytema and Nebeker (1999)
	240	GRO	NOEC	6.7	LOEC	13.4	9.5	Schuytema and Nebeker (1999)
Rana Clamitans (Green frog)	2472	GRO	NOEC	10.6	LOEC	13.4	11.9	Jofre and Karasov (1999)
Xenopus laevis (Clawed toad)	120	GRO	NOEC	3.4	LOEC	6.0	4.5	Schuytema and Nebeker (1999)
	120	GRO	NOEC	1.2	LOEC	2.9	1.9	Schuytema and Nebeker (1999)
Crustaceans								
Ceriodaphnia acanthina (Water flea)	168	REP	NOEC	12.3	LOEC	28.6	18.8	Mount (1982)
Ceriodaphnia dubia (Water flea)	168	REP	NOEC	17.0	LOEC	22.1	19.4	Nimmo et al. (1989)
	168	REP	NOEC	15.5	LOEC	17.5	16.5	Nimmo et al. (1989)
	168	REP	NOEC	11.5	LOEC	27.7	17.8	Nimmo et al. (1989)
Daphnia magna (Water flea)	504	REP	NOEC	8.5	LOEC	18.2	12.5	Gersich et al (1985)
	504	REP	NOEC	18.1	LOEC	29.9	23.3	Reinbold and Pescitelli (1982)
Fish								
Catostomus commersoni (White sucker)	720	GRO	NOEC	4.8	-	-	-	Reinbold and Pescitelli (1982)
Cyprinella monocha (Spotfin chub)	168	GRO	IC25	13.7	-	-	-	Dwyer et al. (2005)
Cyprinus carpio (Common carp)	672	GRO	EC20	4.6	LOEC	7.0	5.6	Mallet and Sims (1994)
Esox lucius (Northern pike)	1248	MORT	EC20	9.4	LOEC	19.0	13.4	Harrahy et al. (2004)
Gila Elegans (Bonytail chub)	168	GRO	IC25	9.6	-	-	-	Dwyer et al. (2005)
Ictalurus punctatus (Channel catfish)	720	MORT	NOEC	8.7	LOEC	9.9	9.3	Colt and Tchobanoglos (1978)

Name	Duration (h)	Effect	Endpoint	Conc (mg/L*)	Endpoint	Conc (mg/L*)	TEC (mg/L*)	Reference
Lepomis cyanellus (Green sunfish)	1056	BIOMASS	NOEC	4.5	LOEC	10.0	6.7	McCormick et al. (1984)
Lepomis macrochirus (Bluegill)	768	BIOMASS	NOEC	1.4	LOEC	3.1	2.1	Smith et al. (1984)
Micropterus dolomieui (Smallmouth bass)	768	BIOMASS	NOEC	5.5	LOEC	9.6	7.3	Broderius et al. (1985)
	768	BIOMASS	NOEC	5.5	LOEC	9.3	7.1	Broderius et al. (1985)
	768	BIOMASS	NOEC	5.2	LOEC	8.6	6.7	Broderius et al. (1985)
	768	BIOMASS	NOEC	3.1	LOEC	4.8	3.8	Broderius et al. (1985)
Notropis mekistocholas (Cape Fear shiner)	168	GRO	IC25	7.7	-	-	-	Dwyer et al. (2005)
Notropis Topeka (Topeka shiner)	720	GRO	NOEC	7.4	LOEC	16.6	11.1	Adelman et al. (2009)
Oncorhynchus clarki (Cutthroat trout)	864	MORT	NOEC	11.9	LOEC	14.3	13.0	Thurston et al. (1978)
Oncorhynchus mykiss (Rainbow trout)	1728	MORT	NOEC	0.77	LOEC	1.9	1.2	Calamari et al. (1977)
	1320	MORT	NOEC	10.7	LOEC	21.0	15.0	Daoust and Ferguson (1984)
	1008	MORT	NOEC	13.8	LOEC	20.3	16.7	Burkhalter and Kaya (1977)
	37440	MORT	NOEC	4.9	-	-	-	Thurston et al. (1984)
Pimephales promelas (Fathead minnow)	720	GRO	NOEC	5.5	LOEC	13.5	8.6	Adelman et al. (2005)
Poeciliopsis occidentalis (Yaqui topminnow)	168	GRO	IC25	21.0	-	-	-	Dwyer et al. (2005)
Ptychocheilus lucius (Colorado squawfish)	672	GRO	NOEC	5.4	LOEC	10.1	7.4	Fairchild et al. (2005)
Salvelinus namaycush (Lake trout)	1440	GRO	NOEC	6.6	LOEC	10.2	8.2	Beamish and Tandler (1990)
Tilapia nilotica (Nile tilapia)	1800	GRO	NOEC	1.4	LOEC	2.9	2.0	El Shafai et al. (2004)
Xyrauchen texanus (Razorback sucker)	672	MORT	NOEC	10.2	LOEC	16.4	12.9	Fairchild et al. (2005)

Name	Duration (h)	Effect	Endpoint	Conc (mg/L*)	Endpoint	Conc (mg/L*)	TEC (mg/L*)	Reference
Insects								
Coloburiscus humeralis (Mayfly)	696	MORT	NOEC	3.2	LOEC	8.6	5.2	Hickey et al. (1999)
Deleatidium sp. (Mayfly)	696	MORT	NOEC	1.3	LOEC	3.2	2.0	Hickey et al. (1999)
Molluscs								
Fontigens aldrichi (Aquatic snail)	672	MORT	NOEC	0.96	LOEC	1.3	1.1	Besser et al. (2009)
Lampsilis fasciola (Freshwater mussel)	672	MORT	IC25	0.60	LOEC	1.4	0.91	Wang et al. (2007)
Lampsilis siliquoidea (Freshwater mussel)	672	MORT	NOEC	0.38	LOEC	0.66	0.50	Wang et al. (2007)
Lampsilis stagnalis (Freshwater mussel)	672	GRO	NOEC	1.6	LOEC	3.2	2.2	Besser et al. (2009)
Potamopyrgus antipodarum (Aquatic snail)	960	MORT	NOEC	1.8	LOEC	3.3	2.5	Alonso and Camargo (2009)
Pyrgulopsis idahoensis (Jackson lake springsnail)	672	GRO	NOEC	5.7	LOEC	12.6	8.5	Besser et al. (2009)
Sphaerium novaezelandiae (Fingernail clam)	1440	MORT	NOEC	0.57	LOEC	3.2	1.3	Hickey and Martin (1999)
Sphaerium transversum (Long Fingernail clam)	1008	MORT	NOEC	1.1	LOEC	1.5	1.3	Sparks and Sandusky (1981)
	1008	MORT	NOEC	9.1	LOEC	11.3	10.2	Anderson et al. (1978)
Villosa iris (Freshwater mussel)	672	GRO	NOEC	1.1	LOEC	2.3	1.6	Wang et al. (2007)

Note: BIOMASS (biomass), GRO (growth), MORT (mortality), REP (reproduction), TEC (Threshold Effect Concentration)

* Reported data adjusted to total ammonia at pH = 8.0, temperature = 20°C except for fish.

5.0 Calculation of Ammonia Limits According to ANZECC (2000) Methodology

The data in Table 2 has been used to calculate ammonia limits using the BurrliOz software. The BurrliOz documentation states that there is a high level of uncertainty in calculating trigger values based on eight or less species, hence there is easily sufficient data to fit a Burr Type III statistical distribution.

Table 3 presents the BurrliOZ outputs from both the data set (refer Table 2) that can be considered generic to New Zealand. The NOEC-based limits are comparable with the NPS numeric attribute states annual medians, and the TEC-based limits are comparable with NPS numeric attribute states annual maxima.

A comparison of these outputs with other relevant ammonia water quality criteria is presented in Table 4. The updated ammonia trigger values and their application to the Makarewa River are discussed further in Section 6.

Table 3: Updated ammonia limits based on updated toxicity data.

Protection level	NOEC-based	TEC-based
99%-ile	0.06	0.08
95%-ile	0.39	0.50
90%-ile	0.86	1.1
80%-ile	1.9	2.4

Note: All trigger values are at pH = 8, 20ºC.

Table 4: Updated ammonia limits and other published ammonia limits.

Water Quality Criteria/Limits	Ammonia (mg/L)	Reference
NPS (95%-ile)[a]	0.24	MfE (2014)
Updated (95%-ile)	0.39	This report
USEPA (chronic, mussels and ELS fish)	0.78[b]	USEPA (2013)
ANZECC (95%-ile)	0.90	ANZECC (2000)
NPS (80%-ile bottom lines)[a]	1.3	MfE (2014)
USEPA (chronic, no mussels and ELS fish)	2.7[c]	USEPA (2013)
AGL Lorneville Consent	5.7	SRC Permit 92195

Note: All water quality criteria/limts are at pH = 8, 20ºC, ELS = early life stage. [a] Annual median. [b]As a 30-day rolling average; the maximum four-day average within the 30-day period is not to exceed 2.5 times the value (i.e., 1.9 mg/L at pH =8, 20ºC) more than once in three years on average. [c]As a 30-day rolling average; the maximum four-day average within the 30-day period is not to exceed 2.5 times the value (i.e., 6.7 mg/L at pH =8, 20ºC) more than once in three years on average.

6.0 Discussion

In the NPS, MfE (2014) provide numeric attribute states for ammonia that are based on ANZECC (2000) methodology. The NPS values are lower than the ANZECC (2000) trigger values, which is consistent with the publication of recent data showing freshwater mussels are ammonia sensitive.

The current USEPA ammonia criteria are robust; they were first issued as a draft in 2009 and subjected to extensive peer review prior to promulgation in 2013. The USEPA chronic criteria (mussels and ELS fish present) is 0.78 mg/L (pH = 8, 20ºC) and is lower than the default (95%-ile) ANZECC (2000) trigger values, again reflecting new data for freshwater mussels. In the absence of mussels (ELS fish present) the USEPA chronic criteria is 2.7 mg/L (pH = 8, 20ºC).

By comparison the 95%-ile NOEC-based ammonia limits presented in this report, which is based on a thorough review of the ANZECC (2000) data set and includes relevant data published since ANZECC (2000), is 0.39 mg/L (pH = 8, 20ºC) - approximately 2.3 times lower than the ANZECC (2000) 95%-ile and half the USEPA chronic criteria (mussels and ELS fish present). This limit is an appropriate replacement of the default ANZECC (2000) trigger value of 0.90 mg/L for New Zealand freshwaters whereas, for reasons previously discussed, the NPS ammonia limits do not provide a legitimate replacement.

How the ammonia limits derived here are applied to the Makarewa River requires discussion. The ANZECC (2000) trigger values were intended to be applied according to their quality rating of an ecosystem. Hence, the 99%-ile trigger values were appropriate for high ecological value systems, the 95%-ile for slightly to moderately disturbed systems and the 80-90%-ile for highly disturbed systems.

Mussels are not present in the tidally influenced section of the Makarewa River and the lower Makarewa River is considered a highly-disturbed system (FWS, 2014). Hence the appropriate NOEC-based ammonia limit is 1.9 mg/L (pH = 8, 20ºC) and the appropriate TEC-based ammonia limit is 2.4 mg/L (pH = 8, 20ºC). These limits are more conservative than the USEPA (2013) chronic criteria (no mussels, ELS fish present), which is 2.7 mg/L (pH = 8, 20ºC).

ANZECC (2000) did not provide detailed guidance on the day-to-day application of the ammonia trigger values due to the fact that the trigger values were not considered regulatory limits, rather as values that if exceeded would result in some investigation. In contrast, USEPA ammonia criteria have a history of being more prescriptive. The 2013 chronic criteria are applied as 30-day rolling averages and, in addition, the maximum 4-day average within the 30-day period may not exceeded by more than 2.5 times more than once in three years on average (USEPA, 2013).

The NPS offers more prescriptive guidance than ANZECC (2000) as to how the ammonia limits should be applied, stating the NOEC-based limits are annual medians and the TEC-based limits are annual maxima. The use of an annual median for the NOEC-based limits requires further definition since in systems where the pH and/or temperature is variable there is no single annual median value. USEPA (1999) has noted this and state:

'if samples are obtained from a receiving water over a period of time during which pH and/or temperature is not constant, the pH, temperature, and the concentration of total ammonia in each sample should be determined. For each sample, the criterion should be determined at the pH and temperature of the sample, and then the concentration of total ammonia nitrogen in the sample should be divided by the criterion to determine a quotient. The criterion is attained if the mean of the quotients is less than 1 over the duration of the

averaging period'.

Alliance monitors the Makarewa River pH, temperature and ammonia concentrations on each day that discharge occurs. Hence, the daily calculation of the quotient of the sample ammonia versus a NOEC-based limit is readily achievable. Alliance would be complaint with the annual median if the median of the quotients was < 1 for the year.

The application of annual maxima to the TEC-based limits in the NPS (MfE, 2014) is difficult to rationalise. Firstly, the approach is one that is appropriate in the management of acute effects, but not the chronic effects on which the limits are based. Secondly, the supporting document reports application of the TEC-based ammonia on 95%-ile monitoring data (NIWA, 2014); this is an appropriate approach since infrequent exceedances of a TEC will not result in chronic effects. Using this approach Alliance would be complaint with the annual 95%-ile if the 95%-ile of the quotients was < 1 for the year.

Hence, it is considered that appropriate ammonia limits for the Makarewa River downstream of the Alliance discharge are:

- Annual median (assessed using the quotient approach) = 1.9 mg/L (pH = 8, 20ºC).
- Annual 95%-ile (assessed using the quotient approach) = 2.4 mg/L (pH = 8, 20ºC).

These limits are lower than both the ANZECC (2000) 80%-ile trigger value and the USEPA (2013) chronic criteria (no mussels, ELS fish present).

Neither the NPS (MfE 2014) or the USEPA (2013) provide any guidance regarding the management of diurnal changes in pH and temperature, both of which may have a marked effect on ammonia toxicity. It is considered the most appropriate way to allow for such diurnal effects is to either (i) conduct monitoring during the time of day when pH and temperature are highest (i.e., typically mid to late afternoon), or (ii) conduct site-specific investigations in order to gain insight into pH and temperature fluctuations in a system, and then apply appropriate corrections to monitoring data.

7.0 Summary and Conclusions

This report has summarised the ANZECC (2000) approach to trigger value derivation and has reviewed both the ANZECC (2000) freshwater trigger values and the NPS (MfE, 2014) numeric attribute states for ammonia. The ANZECC (2000) approach is sound but the trigger values are flawed.

This report also provides a review of the toxicological data for ammonia, including data published since ANZECC (2000), which has afforded the compilation of an ammonia toxicity data set that is appropriate for use in the derivation of generic ammonia limits. The NOEC-based and TEC-based ammonia limits subsequently derived herein are more conservative than, but compare favourably with, the recently promulgated USEPA (2013) ammonia criteria.

It is considered that appropriate ammonia limits for the Makarewa River downstream of the Alliance discharge are:

- Annual median = 1.9 mg/L (pH = 8, 20ºC);
- Annual 95%-ile = 2.4 mg/L (pH = 8, 20ºC);

The practical application of these limits requires an understanding of diurnal pH and temperature patterns in the Makarewa River.

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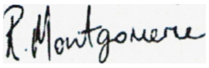

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