THE SOUTHLAND ECONOMIC PROJECT
POND-BASED WASTEWATER SYSTEMS

PREPARED FOR | ENVIRONMENT SOUTHLAND

June 2020

Stantec

QUALITY STATEMENT

PROJECT MANAGER	PROJECT TECHNICAL LEAD
Ilze Rautenback	Kirsten Norquay

PREPARED BY		
Kirsten Norquay		15/6/2020
CHECKED BY		
Sue Bennett		15/06/2020
REVIEWED BY		
Sue Bennett		15/06/2020
APPROVED FOR ISSUE BY		
Kirsten Norquay		15/06/2020

DUNEDIN
Level 3 John Wickliffe House, 265 Princes Street, Dunedin 9016
PO Box 13-052, Armagh, Christchurch 8141
TEL +64 3 477 0885, FAX +64 3 477 0616

REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
1	28 June 2019	Outline Draft for Comment	KN	SB	SB	KN
2	26 Sept 2019	Draft for Comment	KN	SB	SB	KN
3	13 Feb 2020	Draft	KN			
4	15 June 2020	Final incl ES comments	SB	KN	KN	KN

Image on front cover: Riversdale Wastewater Treatment Plant

Summary

An oxidation pond is an ecosystem where wastewater treatment occurs primarily through complex processes involving the interaction of sunlight, algae and bacteria. The dominant treatment process in an oxidation pond at any one time is dependent on climate (including variability between seasons) and site-specific factors (e.g. incoming wastewater load and system design). The performance of an oxidation pond affects the quality of the treated wastewater that is discharged to a receiving environment. The main contaminants of consern in treated wastewater are usually biochemical oxygen demand, total suspended solids, nutrients and pathogens.

This research assessed the treated wastewater quality of four oxidation pond-based systems with considerable monitoring data in Nelson and Waikato regions and considered their applicability in Southland where there is less monitoring data available. It was found that, whilst there are seasonal patterns in the concentrations of biochemical oxygen demand and total suspended solids, there is greater variability (both from year to year for a given season and between sites) in nutrient and pathogen concentrations. Treated wastewater discharge concentrations are also influenced by stormwater inflow and groundwater infiltration (typically but not always lower in summer) as well as evaporation (typically higher in summer). The net effect of this is that summer treated wastewater discharge concentrations may be higher, however the load may be similar to winter. Analysis of loads was outside the scope of this report.

Based on these findings, it is not appropriate to adopt a "typical" profile (either annual or seasonal) for treated wastewater quality from an oxidation pond-based system receiving municipal wastewater to apply universally across the Southland Region. This conclusion is due to the inherent variability in oxidation pond-based systems and the communities that they serve. Care needs to be taken not to treat oxidation pond systems as an homogenous group.

A wastewater treatment system based around an oxidation pond is typically used as a relatively low cost option in many towns around New Zealand. The technology is a low energy, low carbon, low cost, and resilient solution to treat wastewater.

Abbreviations

BOD	Biochemical Oxygen Demand
E. coli	*Escherichia coli, E. coli*
FC	faecal coliform
log	logarithm base 10 (log_{10})
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids

Environment Southland

Pond-Based Wastewater Systems

CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

1. Introduction

1.1 The Southland Economic Project

In 2016, as part of The Southland Economic Project[1], Stantec helped Environment Southland and the three Southland territorial authorities develop eight case studies for towns with wastewater schemes. All of these schemes discharge treated wastewater to water.

Treatment upgrade scenarios were developed for each case study town with continued discharge to surface water (with improved liquid treatment) and new discharge to land (that included treatment within the soil). Likely concentrations and loads discharged to surface water or the underlying aquifer were then calculated for each scenario. Details of each town case study is provided in the technical report titled 'The Southland Economic Project – Urban and Industry' (or the 'Urban and Industry Report')[2].

The locations of the case study towns are shown in Figure 1-1, as well as the remaining towns in the Southland Region with wastewater schemes. Stantec have since used the eight town case studies (and associated treatment scenarios) to identify the current loads and potential upgrades for a further 13 schemes ("remaining towns" in Figure 1-1)[3]. The four towns with a wastewater scheme for which upgrade scenarios were not identified are Riverton[4] and Riverton Rocks (as both schemes have coastal discharges and so do not contribute load to the relevant estuary), Monowai (as it is a very small scheme that discharges to land), and Wallacetown (as the scheme discharges to a private wastewater treatment plant at the Alliance Lorneville meat processing plant).

Many of the wastewater treatment systems for these towns are based around oxidation ponds. To further support The Southland Economic Project, Environment Southland engaged Stantec to use an evidence-based approach to provide a qualitative understanding of the seasonal variability in the treated wastewater discharge quality expected from an oxidation pond-based system in terms of nutrients (i.e. nitrogen and phosphorus) and pathogens (i.e. *E.coli* as an indicator). This report summarises the key findings of this work.

[1] https://www.waterandland.es.govt.nz/setting-limits/research/southland-economic-project

[2] Moran, E et al. (2018). The Southland Economic Project: Urban and Industry. Technical Report. Publication no. 2018-17. Environment Southland, Invercargill, New Zealand. 383pp

[3] Stantec (2020) Applying Town Case Studies to other Southland Towns, for Environment Southland

[4] The original scope from Environment Southland for this report included Riverton, however the treated wastewater from the existing rapid infiltration basins discharges to groundwater, then filters through Oreti beach sands to Foveaux Strait. It does not discharge to Aparima River or Jacobs River Estuary.

Figure 1-1: Locations of Wastewater Schemes in Southland Region

1.2 Purpose of Report

Oxidation pond based wastewater treatment systems are not all equal nor well understood. The purpose of this report is to investigate variability in the design and performance of these systems both within a locality, and between seasons (generally summer and winter). The report develops this information for selected wastewater schemes from other regions and then outlines how the findings might apply to similar systems in Southland, where there is less monitoring data. In doing so, the report presents basic information on oxidation ponds for a general audience.

The wastewater schemes from other regions were selected based on oxidation pond-based systems that:

- were geographically close to each other (<20km) to help control for biophysical factors when making comparisons, and
- where the treated wastewater discharge has routinely been monitored at least monthly for 5 years or more for nutrients and pathogens.

Recent investigations of the discharge through the base of the oxidation ponds at Tokanui in Southland are also presented.

We note that oxidation ponds are a unique technology and are quite different to dairy effluent ponds. The latter are used for storage (not treatment) and typically receive higher wastewater loads. Dairy effluent ponds are often operated as anaerobic ponds (i.e. without oxygen) and are discussed in Water New Zealand's s Good Practice Guide (i.e. are not in the scope of this report).

While this report discusses the quality of the treated wastewater discharge, and the factors that influence this, it does not consider compliance issues with resource consent conditions. Compliance issues at wastewater treatment plants with an oxidation pond do not necessarily relate to the oxidation pond itself. For example they may result from issues arising in the network or the remainder of the scheme.

The environmental effects of the treated wastewater depend on a wide range of factors, including seasonal variability and the sensitivity of downstream receiving environments. This aspect has not been included in the assessment in this report because its focus is on the technology, and we address the quality of the treated wastewater only prior to its discharge.

2. Background

2.1 Current Southland Schemes

The Southland Region has three territorial authorities, each with several wastewater schemes in one or more Freshwater Management Units (FMUs)[5]. Whilst there are similarities across the region, each territorial authority has its own unique wastewater challenges. The wastewater schemes include many oxidation pond-based treatment systems. The general nature of the schemes managed by the three territorial authorities is summarised below in Table 2-1, with further detail of each scheme provided in Appendix A. Their location was shown in Figure 1-1 above.

Table 2-1: Overview of Wastewater Schemes in the Southland Region

Territorial Authority	Nature of Schemes	Pond-based Schemes as share of Total Schemes (%)
Invercargill City Council	• One large scheme that discharges to New River Estuary, which is significantly degraded • Two smaller schemes that both discharge to the Coastal Marine Area, which is controlled by the Regional Coastal Plan for Southland (currently under review) • All schemes receive industrial and domestic loads, except Omaui, which is primarily domestic • All scheme boundaries are located within the Oreti FMU	2 out of 3 schemes (>60%)
Gore District Council	• Two medium schemes and one smaller scheme, all within the Mataura FMU • All schemes receive industrial and domestic loads, except Waikaka, which is primarily domestic • All schemes discharge to the Mataura River. The River has water quality and quantity issues, and discharges to the Fortrose Estuary. The Estuary has a low susceptibility to eutrophication due to its well flushed nature but it is showing signs of stress	3 out of 3 (100%)
Southland District Council	• Large number of predominantly small schemes spread across all FMUs • All schemes primarily receive domestic loads, except Te Anau and Winton which also include commercial and industrial loads • Most schemes discharge to fresh water (either directly or via groundwater connected to fresh water), however a few schemes discharge to the Coastal Marine Area • Southland District Council is currently developing a wastewater strategy to rationalise its consenting processes, and the prioritisation and funding of upgrades	13 out of 20 (>60%)

The treated wastewater from most of these schemes is analysed for nutrients (TN and TP) and pathogens (indicator organisms – *E.coli* or FC) only two to four times a year. As a result, there is limited data to draw definitive conclusions about seasonal variability in treated wastewater quality. Invercargill and Bluff wastewater schemes are analysed more frequently, but they both have a higher proportion of

[5] A Freshwater Management Unit

industrial/commercial wastewater, and so may not reflect typical performance for wastewater schemes that largely receive domestic wastewater.

There is a range of climatic conditions across the Southland schemes and seasonal variability at each location. In particular, the treatment performance of wastewater schemes is also related to pond configuration, pond organic areal loading rates, and pond hydraulic retention time which are also quite variable across the Southland schemes. In Southland, there is a wide range of pond systems from a single small oxidation pond, to two ponds connected in series, to a number of ponds and partitioning within ponds to control flow pathways.

2.2 Historical Perspective

Wastewater management in Southland has evolved over the past 100 years, with change initially driven by an urgent need to protect public health. More recently the focus has turned to addressing adverse environmental, cultural and social effects, which includes concerns about the discharge route (i.e. whether treated wastewater is released to water or to land).

Early dwellings had an 'out-house' over a 'cesspit' in the backyard, with new pits dug when filled. In urban areas, initially nightcart services were introduced, which saw 'night soil' (or human waste) being collected from individual houses and transported to the outskirts of town for disposal.

Municipal wastewater schemes were progressively installed in Southland over the 20th century to improve public health. The schemes were funded through a mix of public investment and community fundraising. Most wastewater schemes started with the reticulated (or piped) collection of wastewater, often combined with stormwater collection, and untreated sewage was discharged directly to waterbodies.

In smaller towns, individual on-site wastewater treatment and disposal systems (i.e. 'septic tanks') were typically installed. However, in several cases, a reticulated system has replaced these individual systems, primarily where a significant proportion of them were failing (e.g. due to poorly draining soils, undersized systems and small section sizes)

In the latter part of the 20th century the wastewater schemes were further developed to include treatment, which was typically via oxidation pond-based systems. Oxidation ponds are particularly suitable for small towns with largely domestic wastewater. These treatment systems focused on reducing or removing suspended sediment and biochemical oxygen demand, and to some extent, pathogens. When suitable land is available, such systems are a relatively low cost option with minimal mechanical technology. To minimise the costs, typically the smallest area of land was purchased and the treatment systems were unpowered.

There is a perception that oxidation ponds are outdated and should be fully replaced by mechanical treatment as a matter of course. However, there has been considerable investment in oxidation ponds in Southland for the following important reasons[6].

- A well designed, constructed, operated and managed oxidation pond can reliably reduce organics, solids, pathogens and some nutrients.
- An oxidation pond is a complex ecosystem and treatment occurs primarily through the interaction of sunlight, algae and bacteria. As such, a pond requires minimal inputs (e.g. power, chemicals, and labour) compared to mechanical treatment, which will require a power supply to the site.
- Where higher treated wastewater quality is required, an oxidation pond system can have mechanical plant added to it (where there is land available) to further reduce nitrogen, phosphorus or pathogens. In addition, treated wastewater from an oxidation pond can be applied to land, which also reduces nitrogen, phosphorus and pathogens prior to discharge to the aquifer.
- Oxidation ponds can accommodate stormwater inflows and groundwater infiltration, which is expected to increase with climate change, minimising the potential for treatment bypasses and overflows.

In summary, oxidation ponds are a low energy, low carbon, low cost, and resilient solution to treat wastewater.

[6] Norquay, K. (2019) IPWEA 2020 Conference Abstract. Titled "Waste Stabilisation Ponds – Outdated technology or retro chic?"

2.3 Untreated Wastewater Quality

The eight town case studies for the Southland Economic Project centred on understanding the contaminant reduction achieved by the existing schemes and the reduction that could be achieved by the treatment scenarios considered. The quality of untreated wastewater received at oxidation pond-based systems is seldom routinely monitored. As a result, the same untreated wastewater quality was adopted for all the case studies to estimate the contaminant reductions achieved by the treatment system. For consistency with this work, the same untreated wastewater quality has also been used in this analysis, as given in Table 2-2.

Table 2-2: Untreated Wastewater Quality

Parameter	Unit	Value
Biochemical Oxygen Demand (BOD)	mg/L	250
Total Suspended Solids (TSS)	mg/L	250
Total Nitrogen (TN)	mg/L	50
Total Phosphorus (TP)	mg/L	7
Escherichia coli (E.coli)	no/100mL	10^7 or 10,000,000

The actual untreated wastewater quality for a scheme will depend on the catchment it is located in, and is influenced by factors such as the type of water supply (reticulated, restricted supply, or roof-water), and the proportions of trade waste, stormwater inflow and groundwater infiltration volumes.

3. Key Pond Treatment Processes

3.1 Overview

Wastewater treatment systems based around oxidation ponds include all aspects of conventional wastewater treatment, including settlement of solids, reduction in organics and disinfection of pathogens as well as some reduction in nutrients and heavy metals. This section gives a brief overview of the key treatment processes in facultative (or primary) ponds and maturation (or secondary) ponds. The contaminant focus here is on nutrients (nitrogen and phosphorus) and pathogens because oxidation ponds generally perform well for suspended sediment and biochemical oxygen demand.

Appendix A contains a number of diagrams with further detail on the processes described.

Further information can be found within the following reference material:

- Water Environment Federation. *"Natural Systems for Wastewater Treatment – WEF Manual of Practice No. FD-16"*, 2001
- Shilton, A., *"Pond Treatment Technology"*, IWA Publishing, 2005
- Water New Zealand, "Good Practice Guide for Waste Stabilisation Ponds: Design and Operation", 2017
- Verbyla, M. *et. al*. "Waste Stabilization Ponds", 2017. In: Rose, J. and Jiménez-Cisneros, B. (eds) Global Water Pathogen Project.

3.1.1 Facultative (or Primary) Ponds

Facultative ponds treat wastewater through the interaction of sunlight, bacteria and algae. The ponds operate with distinct vertical layers, with different treatment processes occurring in each layer (Figure 3-1 and Appendix A).

Algae and bacteria exist in a symbiotic (or mutually beneficial) relationship in the upper aerobic layer of a pond. During the day, algae produce oxygen through photosynthesis. Aerobic bacteria use this oxygen to breakdown dissolved and suspended organic material releasing carbon dioxide and nutrients. The substances are then used by the algae to generate more oxygen and sometimes by nitrifying bacteria[7] for growth. At night, both bacteria and algae consume oxygen. Typically, higher algal growth is seen during summer months when there is more hours of, and more intense, sunlight.

The middle anoxic layer of a pond provides habitat for bacteria that survive by reducing oxidized compounds (e.g. denitrification of nitrate to nitrogen gas).

Wastewater solids, as well as bacterial and algal biomass that have settled to the bottom of the pond, are partially digested anaerobically (i.e. without oxygen) and accumulate as digested sludge within a pond's lower anaerobic layer. Anaerobic bacteria in this lowest layer breakdown the organic matter, and release carbon dioxide, methane, and residual matter. The bacteria get their energy from the organic matter they consume.

The level of wastewater treatment achieved by a facultative pond depends on many factors that include: organic loading, hydraulic retention time (accounting for short-circuiting), climate and season (both temperature, sunlight and wind), mixing/stratification, algal population (algae concentration, species type and health as well as algal grazers), wastewater physical characteristics (temperature, pH, dissolved oxygen), and sludge inventory (i.e. the quantity of sludge present in the pond).

While algal blooms in natural water courses are undesirable, algal growth within facultative ponds is desirable and fundamental for treatment. Like other treatment systems, discharged pond algal solids do contribute an organic solids load to their receiving environment, which may be either a surface waterbody or land.

[7] Nitrifying bacteria are a type of microorganisms that use inorganic chemicals as an energy source. They play an important role in the nitrogen cycle as they convert ammonia to nitrate.

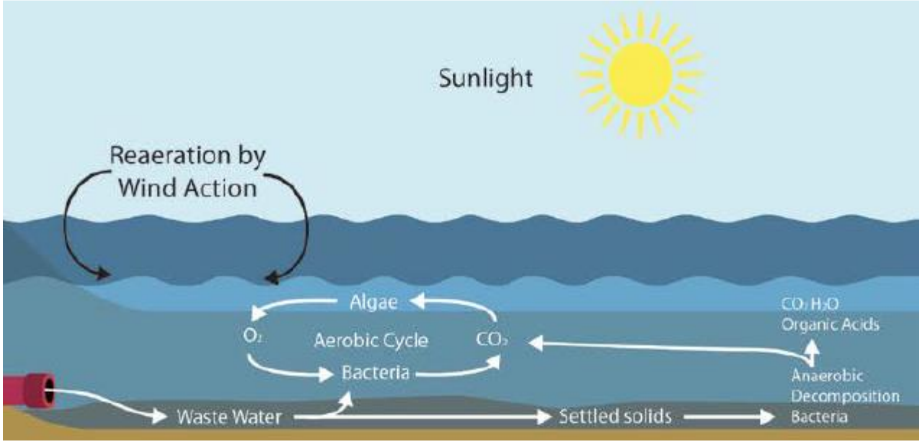

Figure 3-1: Key biological interactions in a facultative pond (WaterNZ, 2017)

3.1.2 Maturation (or Secondary) Ponds

Wastewater flows from the facultative (primary) ponds to maturation (secondary) ponds. These ponds have a low loading of organic matter and are completely aerobic. Their primary function is to reduce pathogens, through the exposure of wastewater to sunlight, grazing by protozoans and invertebrates, and settlement, but they can also reduce nutrients (see Section 2.2).

3.2 Nutrient and Pathogen Reduction

Total nitrogen (TN), total phosphorus (TP) and pathogens may be reduced in oxidation pond-based systems via several different treatment processes, including those noted in Table 3-1. The extent to which any one process occurs within a pond depends on many factors, including pond design, retention time, organic loading rate, wastewater composition, and seasonally variable parameters such as algal production, mixing/stratification and environmental conditions (pH, temperature, dissolved oxygen and sunlight). More detail is given in Appendix B.

Potential mechanical treatment upgrades to further reduce nitrogen, phosphorus and pathogens in treated wastewater from oxidation pond-based systems are also given in Table 3-1. Some of these processes are additional to the oxidation pond. However, if highly treated wastewater quality is required for these contaminants, then the oxidation pond system will need to be replaced with a purely mechanical process. In this situation, a pond system may be retained to provide storage to smooth out variations in incoming flow to the mechanical plant.

As identified in Table 3-1, a number of the treatment processes would be faster in summer and slower in winter. These include processes that can increase the nutrient concentrations in the discharge but, also, those that decrease them. The resulting effects on nutrient concentrations in any season will depend upon the balance and interaction between these processes.

Table 3-1: Nutrient and Pathogen Reduction Processes within Oxidation Pond-based Systems

Parameter	Oxidation Pond-based Process	Potential Mechanical Treatment Upgrades
Nitrogen (TN)	Processes that reduce TN: • Sedimentation • Algal/bacterial assimilation. Summer>Winter (sunlight, warmer) • Volatilisation of ammonia. Summer>Winter (higher pH) • Adsorption to pond sludge or pond walls. • Nitrification / denitrification. Summer>Winter (warmer, higher DO) Processes that increase TN: • Release of nutrients from pond sludge. Summer>Winter (warmer)	Existing pond system + additional mechanical plant: • Trickling filter - combined nitrification/ denitrification. ~50% additional TN reduction • Moving bed bioreactors – separate nitrification/ denitrification. ~50% additional TN reduction Alternative system to replace pond system: • Membrane bioreactor or similar (~75% additional TN reduction)
Phosphorus (TP)	Processes that reduce TP: • Sedimentation • Algal/bacterial assimilation. Summer>Winter (sunlight, warmer) • Precipitation. Summer>Winter (higher pH & warmer) • Adsorption to pond sludge or pond walls. Processes that increase TP: • Release of nutrients from pond sludge. Summer>Winter (warmer).	Existing pond system + additional mechanical plant: • Chemical dosing. ~50% additional TP reduction. Alternative system to replace pond system: • Membrane bioreactor or similar (~75% additional TP reduction)
Pathogens (indicators - *E.coli*, faecal coliforms)	Processes that reduce pathogens: • Sunlight exposure. Summer>Winter • Sedimentation • Grazing by protozoans and invertebrates	Existing pond system + additional mechanical plant: • UV Disinfection. *E.coli* <130 no./100mL Alternative system to replace pond system: • Membrane bioreactor or similar. *E.coli* <10 no./100mL

3.3 Discharge through the Base of the Ponds

Where the nature of the wastewater stream is relatively low risk (i.e. largely domestic waste), an oxidation pond can be designed for seepage[8] or deep drainage through its base. The base of the oxidation ponds typically consists of a "clay-like" liner with low permeability. The sludge layer that accumulates on the base of the pond also has a low permeability. This results in the rate of seepage through the base of the ponds being slow. Hence, it is not common practice in New Zealand to line oxidation ponds unless the underlying soil is permeable and there is no source of clayey material in close proximity to the construction site. Lining

[8] Seepage is a slow-rate discharge to land, as opposed to leakage.

can be required if the ponds drain down during dry and hot periods or if there is a deterioration of water quality in the receiving environment.[9]

Oxidation ponds were typically designed to achieve a retention time of 20 days[10]. This results in an averaging of treated wastewater quality across the ponds. This means that the quality of the discharge through the base of the pond is more similar to the quality of the treated wastewater than that of the incoming wastewater.

The slow rate and the quality of the discharge through the base of an oxidation pond results in the key difference to the discharge from a leak from a dairy effluent pond. A dairy effluent pond is used for storage, not treatment, and the base of the pond is typically lined. Hence, a discharge to ground could occur as a result of a break in the liner with untreated dairy effluent being discharged to ground and hence the aquifer.

Contaminants in the treated wastewater from the pond are further reduced through attenuation as the wastewater percolates (e.g. like coffee) through the sludge layer and base of the pond to the underlying unsaturated zone and then the aquifer. This "discharge pathway" can be highly effective at reducing microbes and sediment, and variably effective at retaining phosphorus, dependent upon the nature of the substrate[11].

The contaminants delivered to an aquifer through pond seepage are primarily nitrogen and/or dissolved reactive phosphorus (i.e. not bound to soil or sediment or in organic forms), depending on the composition of the soil and substrates. Once in the aquifer, the nitrate will typically be dispersed in the aquifer.

In aquifers which do not reduce nitrogen, organic carbon in the treated wastewater can promote microbial activity in the subsurface environment. This microbial activity means denitrification may occur down-gradient of the oxidation ponds that is not generally occurring in the unconfined aquifer[12].

The concentrations of contaminants in groundwater can increase or decrease in the vicinity of the oxidation pond. The extent of adverse effects depends on the levels and type of contamination introduced to the aquifer, the uses of the impacted groundwater (e.g. as drinking water), and any connections with surface water.

---

[9] Evidence of Rainer Hoffmann for Application APP-20181129 by Southland District Council for resource consent to discharge treated wastewater to land and water, and to use land for construction of an effluent storage facility, for the Tokanui township sewage treatment system at 118 McEwan Street, Tokanui

[10] From 2017 WaterNZ Guidelines: "In the 1974 MOW Guidelines, maturation ponds were designed for 20 days retention for indicator bacteria removal."

[11] Pearson, L., and Rissmann, C. (2018). Tokanui Wastewater Treatment Plant: Assessment of the Physiographic Setting. Land and Water Science Report 2019/17. p16. Filed with the evidence for Application APP-20181129 by Southland District Council for resource consent to discharge treated wastewater to land and water, and to use land for construction of an effluent storage facility, for the Tokanui township sewage treatment system at 118 McEwan Street, Tokanui

[12] Evidence of Brydon Hughes for Application APP-20181129 by Southland District Council for resource consent to discharge treated wastewater to land and water, and to use land for construction of an effluent storage facility, for the Tokanui township sewage treatment system at 118 McEwan Street, Tokanui

4. Mid North Island Wastewater Treatment Plants

4.1 Nature of Sites

Huntly and Ngaruawahia wastewater treatment plants (WWTPs) are oxidation pond-based systems located within about 12km of each other in the Waikato Region. The location of both WWTPs is shown in Appendix C. Table 4-1 summarises the two systems. Both WWTPs discharge treated wastewater to fresh water (Waikato River), with the discharge being monitored at least monthly throughout the year for nutrients and pathogens.

Table 4-1: Overview of Mid North Island Oxidation Pond-based Systems

Item	Huntly WWTP	Ngaruawahia WWTP
Photograph		
Residential Population (2014)	7,600	6,400
Influent Characteristics	• Predominantly domestic wastewater plus landfill leachate • Regional septage[13] receival facility at WWTP • Reticulated water supply (except Te Ohaki)	• Predominantly domestic wastewater • Septage not accepted • Reticulated water supply
Liquid Treatment Processes	• Inlet screen • Septage receival plant (screen, septage pond, supernatant to inlet) • Facultative pond with aerators and curtains • Maturation pond with aerator • UV disinfection • Surface-flow wetlands • Gravel channels NB: 2008 upgrade (Year 3 of monitoring period) included a new regional septage receival plant. 2013 upgrade (Year 8 – UV) included new UV, modified gravel beds to gravel channels, and remediated wetlands	• Inlet screen • Facultative pond with aerators and series of perforated curtains to form maturation zones • Ballasted flocculation with high rate clarification (e.g. Actiflo) • UV disinfection • Gravel channels NB: 2013 upgrade included new UV, modified gravel beds to gravel channels, and decommissioned wetlands (Year 8 of monitoring period) and new Actiflo (Year 9)

[13] Septage is excrement and other waste material contained in or removed from a septic tank.

Item	Huntly WWTP	Ngaruawahia WWTP
Solids Treatment Processes	• Stored in pond • Stored in geobags[14] (from septage pond)	• Stored in pond • Stored in geobags (from Actiflo)
Discharge Route	Limited seepage to ground through base of ponds, wetlands and gravel channels To freshwater (continuous to Waikato River)	Limited seepage to ground through base of pond and gravel channels To freshwater (continuous to Waikato River)

4.2 Treated Wastewater Quality

The quality of treated wastewater, in terms of nitrogen (TN), phosphorus (TP) and pathogens (as indicated by *E.coli*), from oxidation pond-based systems at Huntly and Ngaruawahia WWTPs are shown graphically in Appendix C and summarised in Table 4-2.

Table 4-2: Mid North Island Oxidation Pond-based System Performance

Item	Huntly WWTP	Ngaruawahia WWTP
Sampling Period and location	• At least monthly for 9 years (June 2006 to June 2015) • At pond outlet (after UV from Year 8)	• At least monthly for 9 years (June 2006 to June 2015) • At pond outlet (after Actiflo and UV)
Flow	• Lower median daily outflows typical in summer (combination of less rainfall and higher evaporation)	• Lower or similar daily outflows typical in summer (combination of less rainfall and higher evaporation)
Nitrogen (TN)	• Annual TN median of 10-25 mg/L • No marked change when septage receival plant installed (Year 3) • Summer TN median typically higher than winter. Opposite to expected but coincides with lower outflows (so more concentrated discharge) and when sludge nutrient release may occur	• Annual TN median varied (25-35 mg/L) prior to Year 4 summer • Annual TN median then reduced to 10-20 mg/L. Likely due to septage being sent to new regional septage receival plant at Huntly (Year 3) and improved trade waste controls • Summer TN median similar to winter for domestic wastewater (from Year 6)

[14] Geobags are used for the storage of sludge. They are constructed from porous geotextile material, which sludge is pumped into, the solids are retained and liquid filters out over time.

Item	Huntly WWTP	Ngaruawahia WWTP
Phosphorus (TP)	• Annual TP median varied (4-9 mg/L) prior to Year 6 • Annual TP median then reduced to 2-4 mg/L. Likely due to new septage[15] receival plant (Year 3) and improved trade waste controls • Summer TP median typically higher than winter, as seen with TN (lower outflows and sludge nutrient release)	• Annual TP median varied (5-9 mg/L) prior to Year 6 • Annual TP median then reduced to 3-4 mg/L, 1 year later than TN reduction occurred (septage[15] to Huntly, improved trade waste) • Annual TP median reduced to ≤1 mg/L when Actiflo installed (Year 9) • Summer TP median similar to winter, as seen with TN
Pathogens (indicator - *E.coli*)	• Annual *E.coli* median of 10^3-10^4 cfu/100mL prior to Year 8 summer • No marked change when septage receival plant installed (Year 3) • Annual *E.coli* median reduced to 10^1-10^2 cfu/100mL when UV installed (Year 8 summer) • Summer *E.coli* median typically lower or similar to winter. Different to TN and TP pattern as greater sunlight exposure (more disinfection) in summer	• Annual *E.coli* median of 10^3-10^5 cfu/100mL, prior to Year 8 summer. Slightly higher values seen prior to Year 3 (septage to Huntly) • Annual *E.coli* median reduced to 10^2 cfu/100mL when UV installed (Year 8 summer) • Annual *E.coli* median further reduced to <10^1 cfu/100mL when Actiflo was fully commissioned (Year 9 summer) • Summer *E.coli* median typically similar to winter. Different pattern (and higher values) to Huntly, possibly due to having one pond versus two
Indicative Annual Reduction Based on Southland Economic Project Influent[16]	• TN : 50%-80% • TP: 40%-70% • *E.coli*: 3 - 4 log (5 – 6 log with UV)[17]	• TN : 60%-80% • TP: 40%-60% (90% with Actiflo) • *E.coli*: 2 – 4 log (5 – 6 log with UV)[17]

[15] Septage is excrement and other waste material contained in or removed from a septic tank.
[16] Based on the influent (untreated wastewater) quality discussed in Section 2.3 to the treated wastewater quality identified in this report.
[17] "Log reduction" means a reduction of a factor of 10. A single log reduction means to reduce the concentration by a factor of 10 (i.e. 100 reduces to 10). A two log reduction is to reduce the concentration by a factor of 100 (i.e. 1,000 reduces to 10). A three log reduction is to reduce the concentration by a factor of 1,000 (i.e. 10,000 reduces to 10). And so on.

5. Upper South Island Wastewater Treatment Plants

5.1 Nature of Sites

Bell Island and North Nelson wastewater treatment plants (WWTPs) are oxidation pond-based systems located within about 17km of each other in Tasman Bay. The location of both WWTPs is shown in Appendix D. Table 5-1 summarises the two systems. Both WWTPs discharge to the coastal marine area in Tasman Bay, with the treated wastewater discharge monitored at least monthly throughout the year for nitrogen and pathogens. Bell Island is also monitored at least monthly for phosphorus.

Table 5-1: Overview of Upper South Island Oxidation Pond-based Systems

Item	Bell Island WWTP	North Nelson WWTP
Photograph		
Population	~50,000[18] (2013 estimate)	~25,000[19] (2018 estimate)
Influent Characteristics	• Domestic and industrial wastewater (about 50/50 from a load perspective). • Septage[20] receival plant within network. • Reticulated water supply. Water restrictions applied if required (e.g. 2018/19 summer).	• Predominantly domestic wastewater. • Septage not accepted. • Reticulated water supply. Water restrictions applied if required (e.g. 2018/19 summer).
Liquid Treatment Processes	• Inlet screen • Grit removal • Primary clarifier • Pre-treatment plant (aeration basin and clarifier, operated as required) • Facultative ponds (three in parallel with aerators) • Maturation ponds (two in series) NB: Pre-treatment plant (aeration basin and clarifier) used to reduce organic load to the ponds. It is not designed to reduce TN.	• Grit removal • Step screen • Pre-treatment plant (trickling filter and clarifier, operated as required) • Facultative pond • Maturation pond • Wetlands NB: Pre-treatment plant (trickling filter and clarifier) used to reduce sulphides and organics as required based on pond health. It is not designed to reduce TN.

[18] 2013 estimate of contribution from Nelson City and Tasman District.
[19] 2018 estimate, about half Nelson City's population.
[20] Septage is excrement and other waste material contained in or removed from a septic tank.

Item	Bell Island WWTP	North Nelson WWTP
Solids Treatment Processes	• Stored in pond • Digestor / Class A biosolids applied to land at Rabbit Island (for primary clarifier and pre-treatment plant sludges)	• Stored in pond • Thickener / off-site disposal to Bell Island (for pre-treatment plant sludge)
Discharge Route	Limited seepage to ground through base of ponds. To seawater (pumped tidal discharge, to Tasman Bay).	Limited seepage to ground through base of ponds and wetlands. To seawater (pumped tidal discharge, to Tasman Bay).

5.2 Treated Wastewater Quality

The treated wastewater quality, in terms of nitrogen (TN or a surrogate – ratio of TBOD to cBOD), phosphorus (TP) and pathogens (faecal coliforms), from oxidation pond-based systems at Bell Island and North Nelson WWTPs are shown graphically in Appendix D and summarised in Table 5-2. A discussion on use of TBOD:cBOD as a nitrogen surrogate is also given in Appendix D.1.

Both Bell Island and North Nelson WWTPs discharge to the coastal marine area, and so treated wastewater is analysed for faecal coliforms rather than *E.coli*. To gain a conservative estimate of *E.coli*, the faecal coliform concentrations can be assumed to be the same as *E.coli*. This estimate is conservative because *E.coli* are a subset of all faecal coliforms.

Table 5-2: Upper South Island Oxidation Pond-based System Performance

Item	Bell Island WWTP	North Nelson WWTP
Sampling Period and location	• At least weekly for 6 years (April 2013 to June 2019). • Final discharge (maturation pond 2 outlets).	• At least monthly for 5 years (April 2014 to June 2019, weekly for first 4 years). • Final discharge (wetland outlet).
Flow	• Tidal discharge with ponds regularly used for flow balancing to limit outflow to 25,000 m^3/day. • Lower median daily outflows typically in summer (combination of less rainfall and higher evaporation).	• Tidal discharge • Lower or similar daily outflows typically in summer (combination of less rainfall and higher evaporation).
Nitrogen (TN)	• Annual TN median of 15-30 mg/L • Summer TN median typically higher than winter. Opposite to expected but coincides with lower outflows (so more concentrated discharge) and when sludge nutrient release may occur. Not seen in Year 6 summer when water restrictions altered industrial loads. • Ratio of TBOD:cBOD is often close to 1 in winter (no nitrification) and >1 in summer (nitrification). However, nitrifying bacteria are sensitive to high inflows (wash-out) or loads (die-off), with TBOD:cBOD ratio dropping to 1.	• TN not routinely monitored • Similar but less consistent pattern to ratio of TBOD:cBOD at North Nelson than Bell Island. Shows nitrification within pond systems is variable.

Item	Bell Island WWTP	North Nelson WWTP
Phosphorus (TP)	• Annual TP median varied (4-8 mg/L) • Summer TP median (6-9 mg/L) higher than winter TP median (3-5 mg/L). This result is likely to be due to combination of seasonal variation in industrial wastewater composition, lower outflows (so more concentrated discharge), and when sludge nutrient release may occur.	• TP not routinely monitored.
Pathogens (indicator – faecal coliforms, FC)	• Annual FC median of 10^3-10^5 cfu/100mL • Summer FC median typically 1 log (10 times) lower than in winter. Summer median typically 10^3-10^4 cfu/100mL and winter typically 10^4-10^5. Likely due to greater sunlight exposure (more disinfection) in summer.	• Annual FC median of 10^3 cfu/100mL. Lower values to Bell Island due to FC reduction within wetland • Summer FC median typically similar to winter in discharge. However, lower FC values are seen in pond 2 outlet in summer than in winter, likely due to greater sunlight exposure
Indicative Annual Reduction Based on Southland Economic Project Influent[21]	• TN : 40%-70% • TP: (-10%)-40% *(inaccurate due to trade waste)* • FC: 2 -4 log[22]	• TN not routinely monitored. • TP not routinely monitored. • FC: 4 log[22]

At North Nelson the wetlands after the secondary oxidation pond typically provide further reduction in BOD, TSS and faecal coliforms, which is atypical for wetlands following oxidation ponds. It may be because the wetlands are currently unvegetated shallow ponds, essentially acting as an extension of the maturation pond. Appendix D shows the monitoring data for BOD, TSS and faecal coliform from the outlet of pond 2 and the wetland for the last 5 years graphically. It is noted, however, that this pattern was not seen during the 2019/20 summer (raw data not provided in this report).

[21] Based on the change from the influent (untreated wastewater) quality discussed in Section 2.3 to the treated wastewater quality identified in this report.

[22] "Log reduction" means a reduction of a factor of 10. A single log reduction means to reduce the concentration by a factor of 10 (i.e. 100 reduces to 10). A two log reduction is to reduce the concentration by a factor of 100 (i.e. 1,000 reduces to 10). A three log reduction is to reduce the concentration by a factor of 1,000 (i.e. 10,000 reduces to 10). And so on.

6. The Southland Situation

The evidence from the four oxidation pond-based WWTPs from Waikato and Nelson highlight the variability in treated wastewater quality achieved by an individual scheme (within a year and from year to year) and between schemes located in close proximity geographically (and so experiencing similar climates). This variability is due to a wide range of factors over and above the pond design parameters that influence the contaminant reduction processes occurring within a pond at a given time. That being said, Table 6-1 identifies some commonalities.

Table 6-1: Commonalities in Oxidation Pond-based System Performance

Item	Comments
Flow and Load	• Median outflows are typically lower in summer due to a combination of less rainfall, less infiltration in network and higher evaporation. These factors can essentially "concentrate" the contaminants in the discharge. The exception to this being schemes which usually service summer tourist activity, such as Te Anau, and have higher inflows during this season. • Water restrictions can result in considerable reductions in inflows and may alter volume and concentration of industrial loads of wastewater. • Pond-based systems are able to attenuate flow often without overflows or bypasses, whilst continuing to provide treatment. This resilience is beneficial as the frequency, intensity, duration and timing of flood and storm events is expected to increase with climate change. • Appropriately designed and managed pond-based systems can accommodate varying incoming loads.
Nitrogen (TN)	• Typically annual TN median of 20-30 mg/L, provided that septage[23] is treated appropriately and trade waste is managed. • Summer TN concentrations were generally of a similar order to winter TN concentrations. This is likely due to increased removal during summer balanced by lower outflows (so more concentrated discharge) and/or sludge nutrient release in summer. • Nitrification, when seen, is variable within the pond systems and impacted by high inflows, high loads and low temperatures. • Mechanical processes (e.g. trickling filters, moving bed bioreactors) can be used to further reduce TN together with oxidation ponds, however none of the WWTPs included these processes.
Phosphorus (TP)	• Typical annual TP median of around 4-5mg/L, provided the septage is treated appropriately and trade waste is managed. • Trade waste can have a large impact on TP. At Bell Island WWTP, which had a summer TP median of 4-8 mg/L, when relatively large industrial loads are received, vs a winter TP median of 3-5 mg/L with minimal industrial loads. • Chemical dosing can reduce TP from pond-based systems by around 50% (e.g. Ngaruawahia WWTP).

[23] Septage is excrement and other waste material contained in or removed from a septic tank.

Item	Comments
Pathogens (Indicator – *E.coli* or faecal coliforms, FC)	• Typical annual *E.coli*/FC median of 10^3-10^5 cfu/100mL. • Lower *E.coli*/FC median by up to 1 log seen at some WWTPs in summer (e.g. Bell Island WWTP), coinciding with greater sunlight exposure (and hence more disinfection). However, this is not seen consistently (e.g. Huntly and Ngaruawahia WWTPs). • UV disinfection can reduce indicator organisms from pond-based systems to around 10^2 cfu/100mL (e.g. Huntly and Ngaruawahia WWTPs). • Further reductions can be achieved in combination with chemical dosing and clarification (e.g. to around 10^1 cfu/100mL at Ngaruawahia WWTP)

7. Conclusions

Oxidation ponds are natural treatment systems that have been typically used for decades by many towns around New Zealand. They are a particularly suitable solution for small towns that largely generate domestic wastewater and need to manage stormwater inflows and groundwater infiltration.

A well designed, constructed and managed oxidation pond is a complex ecosystem that uses biotechnology to reliably reduce concentrations of organics, solids, pathogens and some nutrients. Treatment occurs primarily through the interaction of sunlight, algae and bacteria, and as such, a pond requires minimal inputs and is relatively low cost. The dominant treatment process in such systems at any one time depends on climatic (and seasonal variability) and site-specific factors (including incoming wastewater load and system design).

The evidence from four WWTPs from the Waikato and Nelson regions are presented in this report. The results show that whilst there are seasonal patterns (summer vs. winter) in treated wastewater discharge concentrations of BOD and TSS, there is greater variability (both year to year for a given season and from site to site) in concentrations of nutrients and pathogens.

Treated wastewater discharge concentrations of nutrients and pathogens are influenced by stormwater inflow and groundwater infiltration (typically but not always lower in summer) as well as evaporation (typically higher in summer). The net effect of these drivers is that in summer the concentrations of contaminants in treated wastewater discharges may be higher, however the load may be similar. Analysis of loads was outside the scope of this report.

It would be inappropriate to adopt a “typical” profile (annual or seasonal) for treated wastewater quality from an oxidation pond-based system receiving municipal wastewater to apply universally across the Southland Region. This is due to the inherent variability in oxidation pond-based systems and the communities that they serve. Care needs to be taken not to treat oxidation pond systems as a homogenous group.

An oxidation pond is a complex ecosystem and treatment occurs primarily through the interaction of sunlight, algae and bacteria. In summary, oxidation ponds are a low energy, low carbon, low cost, and resilient solution to treat wastewater.

8. Acknowledgements

Stantec and Environment Southland wish to acknowledge the contributions from the following parties: Waikato District Council, Nelson Regional Sewerage Business Unit (NRSBU), and Nelson City Council. These organisations have provided the data used to develop this report in good faith to support The Southland Economic Project, and improve the collective understanding of typical nitrogen, phosphorus and pathogen reductions observed in oxidation pond-based systems in New Zealand.

We also wish to acknowledge the Information previously provided by Southland District Council, Gore District Council and Invercargill City Council for The Southland Economic Project has been used to provide a perspective on nature of pond-based systems in Southland. Data provided in this report shall not be reproduced or used without prior approval from the relevant party.

Appendices

Appendix A Southland Wastewater Schemes

This Appendix summarises information collected or developed as part of the Southland Economic Project – namely for the "Urban and Industry Technical Report"[24] (Case Study Town) or the "Applying Town Case Studies"[25] (Mapping) – for each municipal wastewater scheme in Southland Region. This was augmented by further information from Southland District.

The wastewater schemes are shown in Figure 1-1. The schemes are summarised in Table A-1, with those that are not oxidation pond-based schemes shaded in grey.

Table A-1: Overview of Municipal Wastewater Schemes in Southland

FMU	Scheme	WWTP	Land Contact / Land Application	Discharge Route	Source
Invercargill City					
Oreti	Invercargill	Liquid: • Screen • Pre-aeration • Sedimentation tanks • Trickling filter • Secondary clarifier • Facultative ponds • Solids: • Digester • Sludge lagoons	• Wetland • Discharge to New River Estuary	To water (to New River Estuary)	Case Study Town
	Omaui	Liquid: • 1x ox. pond Solids: • stored in pond	• Seepage through base/walls of ponds (assumed SRI) or, in warm weather, evaporation	To land via base of pond (GWZ, to sea)	Mapping

[24] Moran, E et al. (2018). The Southland Economic Project: Urban and Industry. Technical Report. Publication no. 2018-17. Environment Southland, Invercargill, New Zealand. 383pp

[25] Stantec (2020) Applying Town Case Studies to other Southland Towns, for Environment Southland

FMU	Scheme	WWTP	Land Contact / Land Application	Discharge Route	Source
Oreti (coastal, not via Oreti River or New River Estuary)	Bluff	Liquid: • 6mm screen • Aerated lagoon • Clarifier • UV disinfection Solids: • Sludge Tanks	• Discharge to Foveaux Strait	To water (to Foveaux Strait)	Case Study Town
Gore District					
Mataura	Gore	Liquid: • 3mm screen • Primary Pond • Secondary Pond • Actiflo (operational during low river flows) Solid: • Storage in pond	• Discharge to Mataura River	To water (to Mataura River)	Case Study Town
	Mataura	Liquid: • Oxidation pond • Wetland Solid • Storage in pond	• Wetland • Discharges to Mataura River	To water (to Mataura River)	Case Study Town
	Waikaka	Liquid: • 1x ox pond Solids: • stored in pond	• Wetland • Discharges overland to farm drain, to Waikaka Stream	To water (Waikaka Stream, to Mataura River)	Mapping
Southland District					
Fiordland and Islands	Oban	Liquid: • 1x ox. pond • 2x mat. ponds Solids: • stored in ponds	• Soakage area within forest, above ground pipelines (SRI)	To land (GWZ, Little River, Halfmoon Bay)	Mapping
Aparima	Nightcaps	Liquid: • 1x ox. pond Solids: • stored in pond	• 1x rock filter • Weeded drain • Drain discharges to Wairio Stream	To water (Wairio Stream, Aparima River)	Case Study Town

FMU	Scheme	WWTP	Land Contact / Land Application	Discharge Route	Source
	Otautau	Liquid: • bar screen • 1x ox. pond Solids: • stored in pond	• Filter • Irrigation field, spray irrigators (SRI)	To land (GWZ, Aparima River)	Mapping
Aparima (coastal, not via Aparima River)	Riverton	Liquid: • 1x ox. pond • storage (offline) Solids: • stored in pond	• Rapid Infiltration Basins (RIBs)	To land (GWZ, Oreti Beach, Foveaux Strait)	SDC
	Riverton Rocks	• Liquid: • 1x ox. pond • Solids: • stored in pond	• Wetland / infiltration ponds • Remainder filtered through beach sands to Foveaux Strait	To land (contact) and then Foveaux Strait (coastal)	SDC
Mataura	Balfour	Liquid: • 1x Imhoff tank • 1x trickling filter • 1x humus tank Solids: • Dried, disposed off-site	• Weeded drain • Drain discharges to Longridge Stream	To water (Longridge Stream, to Mataura River)	Mapping
	Riversdale	Liquid: • 1x ox. pond Solids: • stored in pond	Existing • Soakage channel (RIB) • Periodic overflows to Meadow Burn Proposed upgrade: • Soakage channel (existing) + RIBs (new)	Existing: • To land when possible else to water (Meadow Burn to Mataura) *(assumed 70% to land, 30% to water)* Proposed upgrade: • To land (GWZ, Mataura River)	Mapping
	Edendale – Wyndham	Liquid: • 2x 3mm screen • 2x balance tanks • Filter belt • Holding tank • Biofiltro beds • Alum dosing (partial) • Balance Tank • UV disinfection Solids: • Disposed off-site	• Treated wastewater pumped to Mataura River	To water (Mataura River)	Mapping

FMU	Scheme	WWTP	Land Contact / Land Application	Discharge Route	Source
	Gorge Road	Liquid: • individual septic tanks • 1x ox pond Solids: • stored in pond	• Wetland • Discharges overland to Gorge Creek	To water (Gorge Creek, to Mataura River)	Mapping
Mataura (not via Mataura River)	Tokanui	Liquid: • 1x ox. pond • 1x mat. pond Solids: stored in pond	Existing: • Seepage through base/walls of ponds (assumed SRI) or, in warm weather, evaporation • Any overflow discharges to Tokanui Stream (seldom) Proposed upgrade: • land contact/partial land discharge prior to discharge to Tokanui Stream	Existing: • Generally to land via base of pond (GWZ, Tokanui Stream, to sea) else to water (Tokanui Stream, to sea) *(assumed 70% to land, 30% to water)* Proposed upgrade: • As for existing, with greater proportion to land)	Mapping
	Curio Bay	Liquid: • screen • Membrane Bioreactor (MBR) Solids: • Disposed off-site	• rock contact bed • weeded drain • Drain discharges to Cook Creek	To water (Cook Creek via drain to sea)	SDC
Oreti	Lumsden	Liquid: • 1x ox. pond, partitioned Solids: • stored in pond	• Rapid Infiltration Basins (RIBs)	To land (to GWZ, Oreti River)	Mapping
	Browns	Liquid: • individual septic tanks • 1x activated sludge plant (bioreactor, clarifier) • 1x trickling filter • Hydrogen peroxide disinfection Solids: • stored in pond	Summer (Nov to Mar, when < field capacity): • soakage area within forest, above ground pipelines (SRI) Otherwise: • No land contact • Treated wastewater discharges to tributary of Tussock Creek	Summer: • to land (GWZ, to tributary/Tussock Creek/Oreti River) Otherwise: • To water (Tributary of Tussock Creek (to Oreti River) *(assumed 50% to land, 50% to water)*	Mapping
	Winton	Liquid: • coarse screening • fine screening • 1x ox. pond with aerators Solids: • stored in pond	• Wetland • Wetland discharges to Winton Stream	To water Winton Stream (to Oreti River) NB: Winton Stream contributes ~1% of Oreti River flow	Case Study Town

FMU	Scheme	WWTP	Land Contact / Land Application	Discharge Route	Source
	Wallacetown	Conveyed to Alliance Group Limited's WWTP at its Lorneville Meat Processing Plant	• No land contact • Treated wastewater discharges to Makarewa River	To water Makarewa River NB: Makarewa River contributes 15% of Oreti River flow	SDC
Waiau[26]	Te Anau	Liquid: • coarse screening • fine screening • 1x ox. pond with aerators • 2x mat. ponds Solids: • stored in ponds Proposed upgrade: • membrane filtration in final pond	• Wetland • Wetland discharges to Upukerora River Proposed upgrade: • Pumped to irrigation area (Kepler Block), subsurface driplines (SRI) to replace wetlands	Existing: • To water Upukerora River (to Lake Te Anau, Waiau River, Lake Manapouri, Waiau River) Proposed upgrade: • To land (GWZ, Waiau River, Lake Manapouri, Waiau River) NB: proposed discharge route differs from existing	Case Study Town
	Manapouri	Liquid: • 1x ox. pond Solids: • stored in pond	• Seepage through the base/walls of the ponds (assume SRI) or, in warm weather, evaporation • Any overflow discharges to Home Creek (seldom)	Generally to land via base of pond (to GWZ, Home Creek, Waiau River) else to water Home creek (to Waiau River) *(assumed 70% to land, 30% to water)*	Mapping
	Ohai	• Liquid: • 1x coarse screen • 2x Imhoff tank • 2x trickling filter • 2x humus tank • UV disinfection Solids: • Dried, disposed of in forestry block Proposed upgrade: • Upgrade existing UV disinfection	• No land contact • Treated wastewater discharges to tributary of Orauea Stream NB: Treated wastewater dominant source of flow in the ephemeral tributary, a ditch with intermittent flow and "undergrounds" in sections along length before draining to a duck pond (private land, buffers flows) then continuing down hill	To water Tributary of Orauea Stream (to Waiau River)	Case Study Town

[26] Monowai is not included in the table as it is a very small scheme (27 people in 2013) that includes a septic tank with a soakage field that discharges to land.

FMU	Scheme	WWTP	Land Contact / Land Application	Discharge Route	Source
	Tuatapere	Liquid: • coarse screening, mechanical • 1x ox. pond • 1x mat. pond Solids: stored in ponds	• Wetland /infiltration area (SRI) • Upper weeded drain / infiltration area (SRI), • Rock passage • Lower weeded drain / infiltration area (SRI) • Any overflow to Waiau River (seldom)	Generally to land via base of wetlands and weeded drains (to GWZ, Waiau River) else to water (Waiau River) *(assumed 100% to land)*	Mapping

Appendix B Oxidation Pond Treatment Processes

This Appendix provides further detail on the oxidation pond treatment processes, including schematics of processes to reduce concentrations of organics, solids, nitrogen and phosphorus.

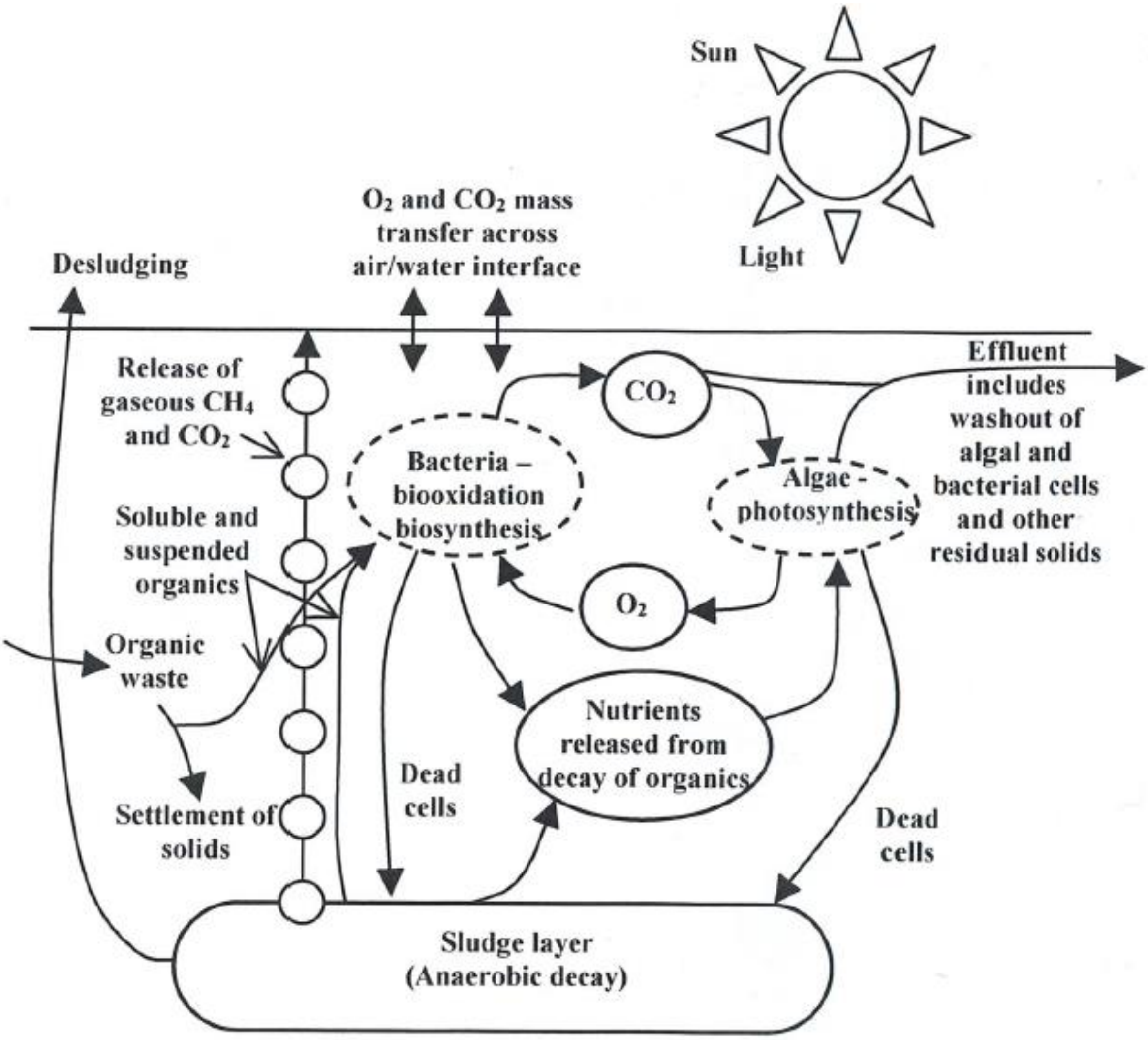

Figure A-1: Key biological interactions in a facultative pond with emphasis on solids and organics transformations (Shilton, 2005)

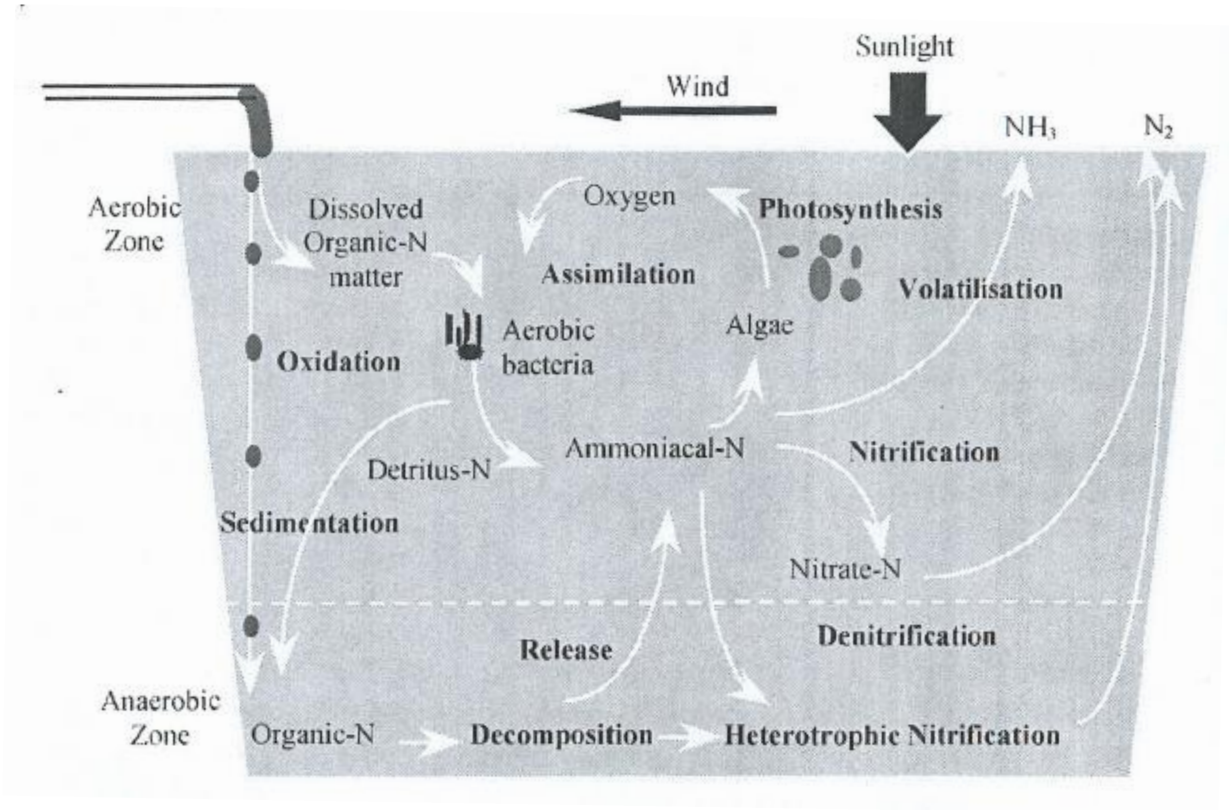

Figure A-2: Nitrogen removal processes in oxidation ponds (Shilton, 2005)

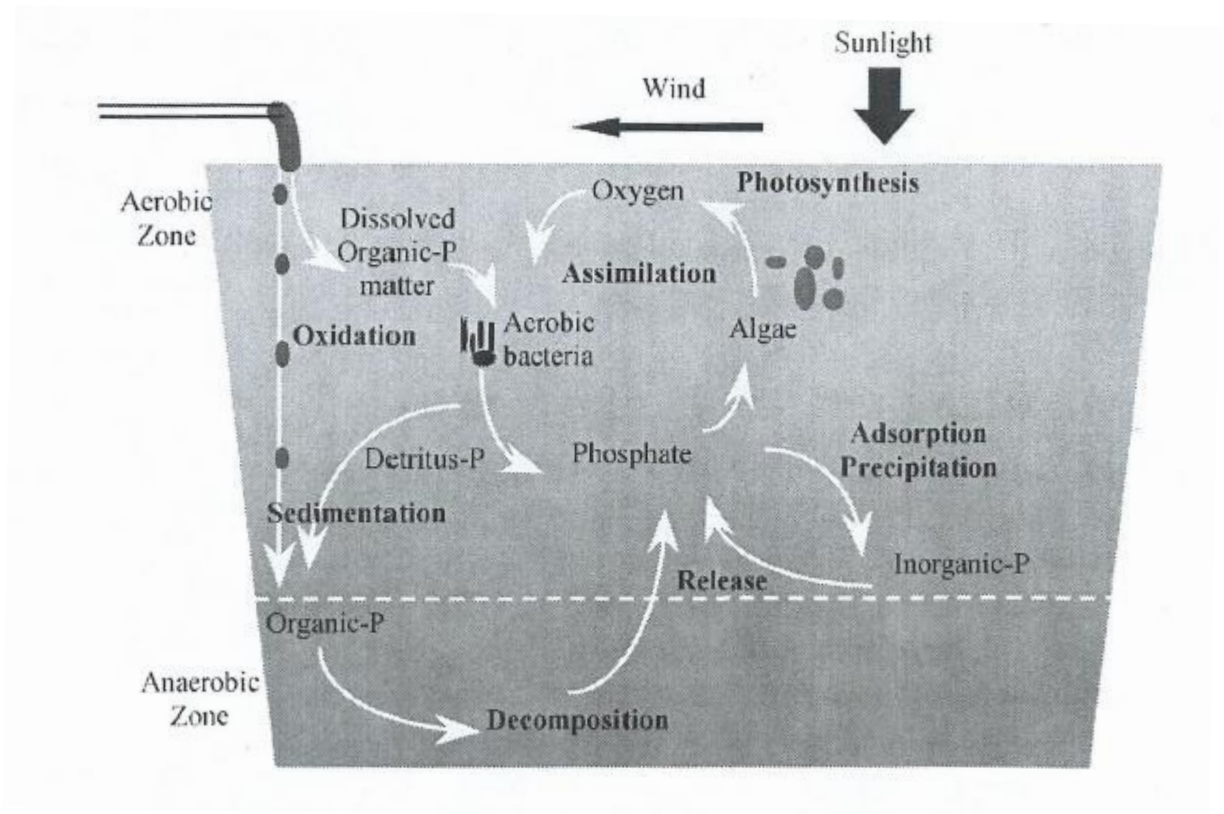

Figure A-3: Phosphorus removal processes in oxidation ponds (Shilton, 2005)

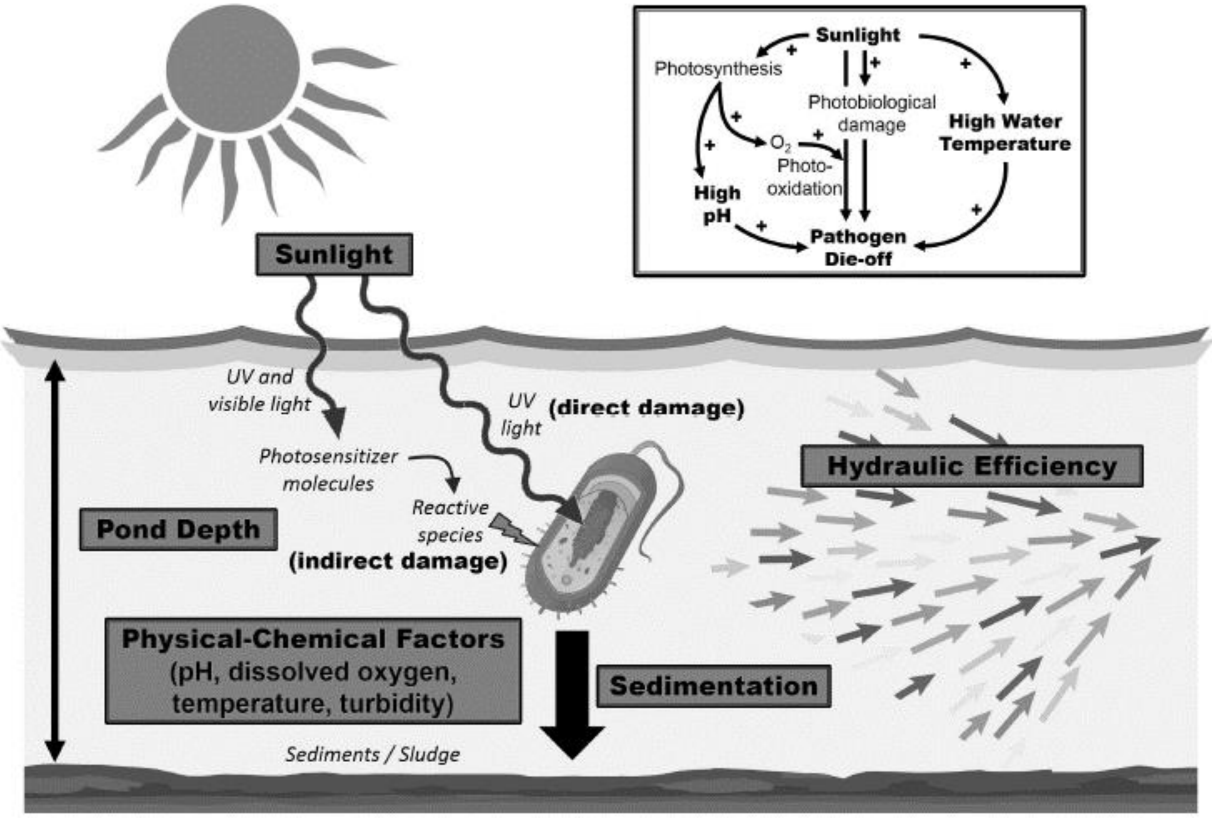

Figure A-4: Pathogen removal processes in oxidation ponds (Verbyla et. Al, 2017). Note: Grazing by protozoans and invertebrates not shown

Appendix C Mid North Island Wastewater Treatment Plants

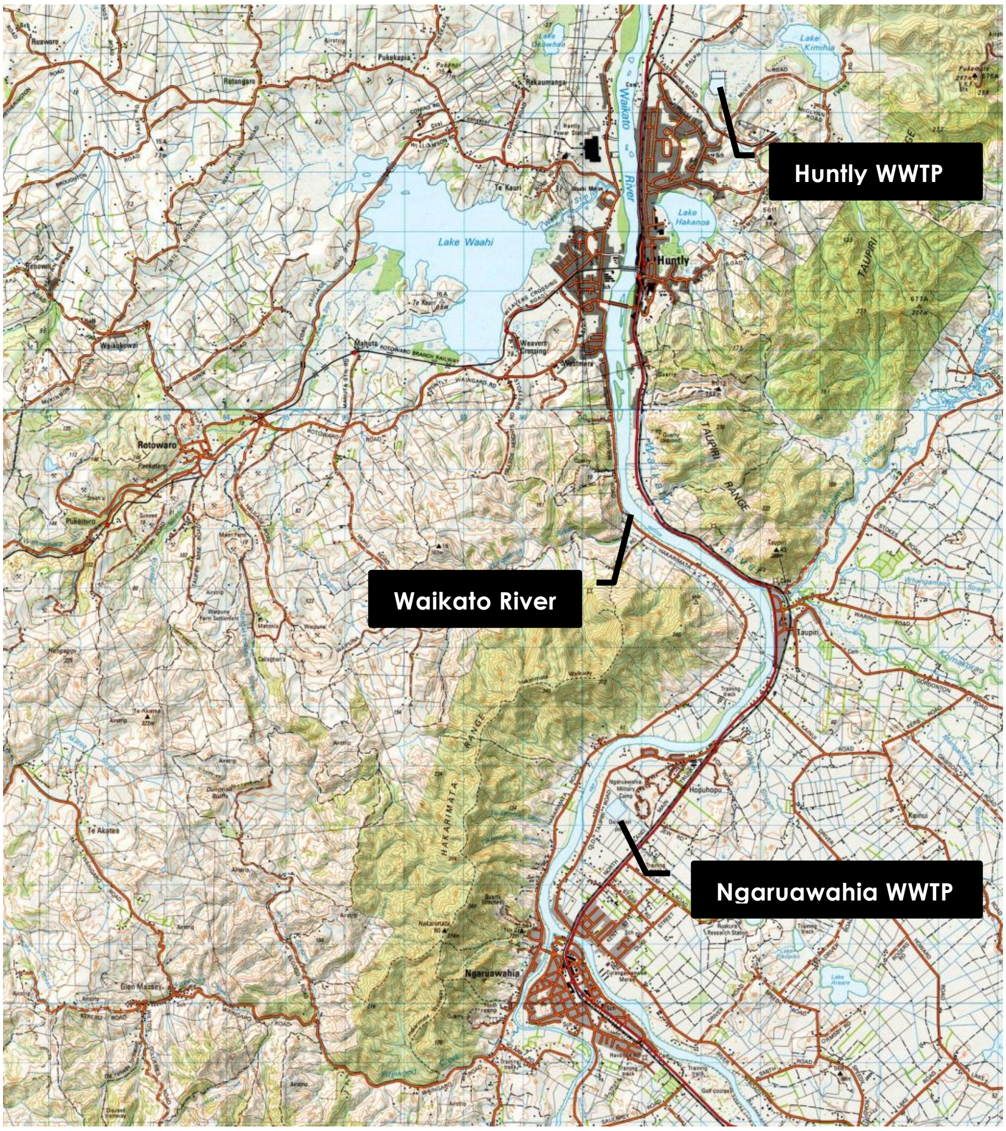

Figure B-1: Location of Mid North Island Wastewater Treatment Plants – Ngaruawahia WWTP and Huntly WWTP

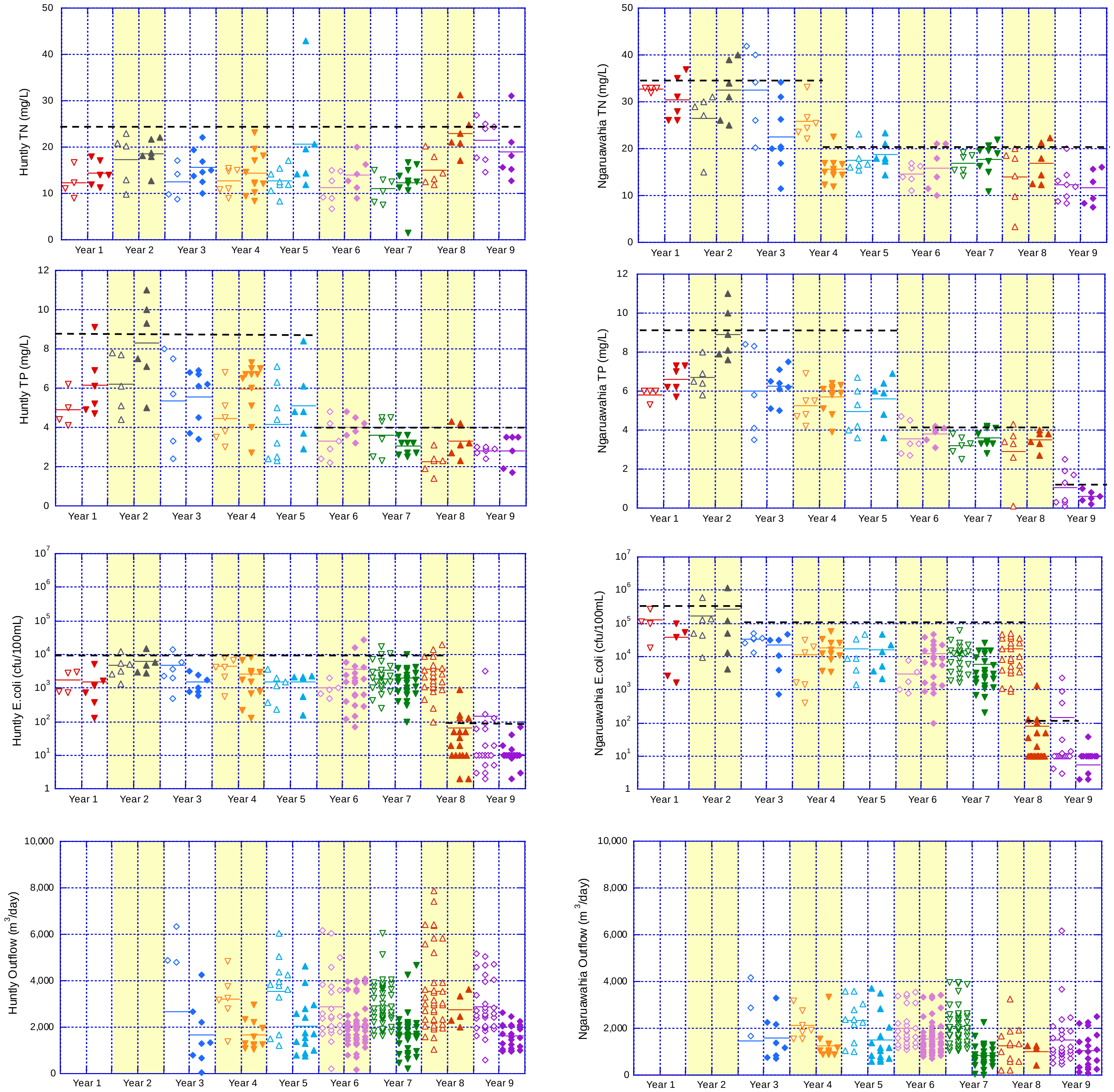

Figure B-2: Treated Wastewater Discharge Quality and Discharge Flow from Huntly WWTP (LHS, Pond 2 outlet) and Ngaruawahia WWTP (RHS, Pond outlet / UV outlet)

Key: Winter (Apr – Sep): unfilled shape (e.g. Δ). Summer (Oct – Mar):filled shape (e.g. ▲). Black dotted horizontal line: typical median (upper value)

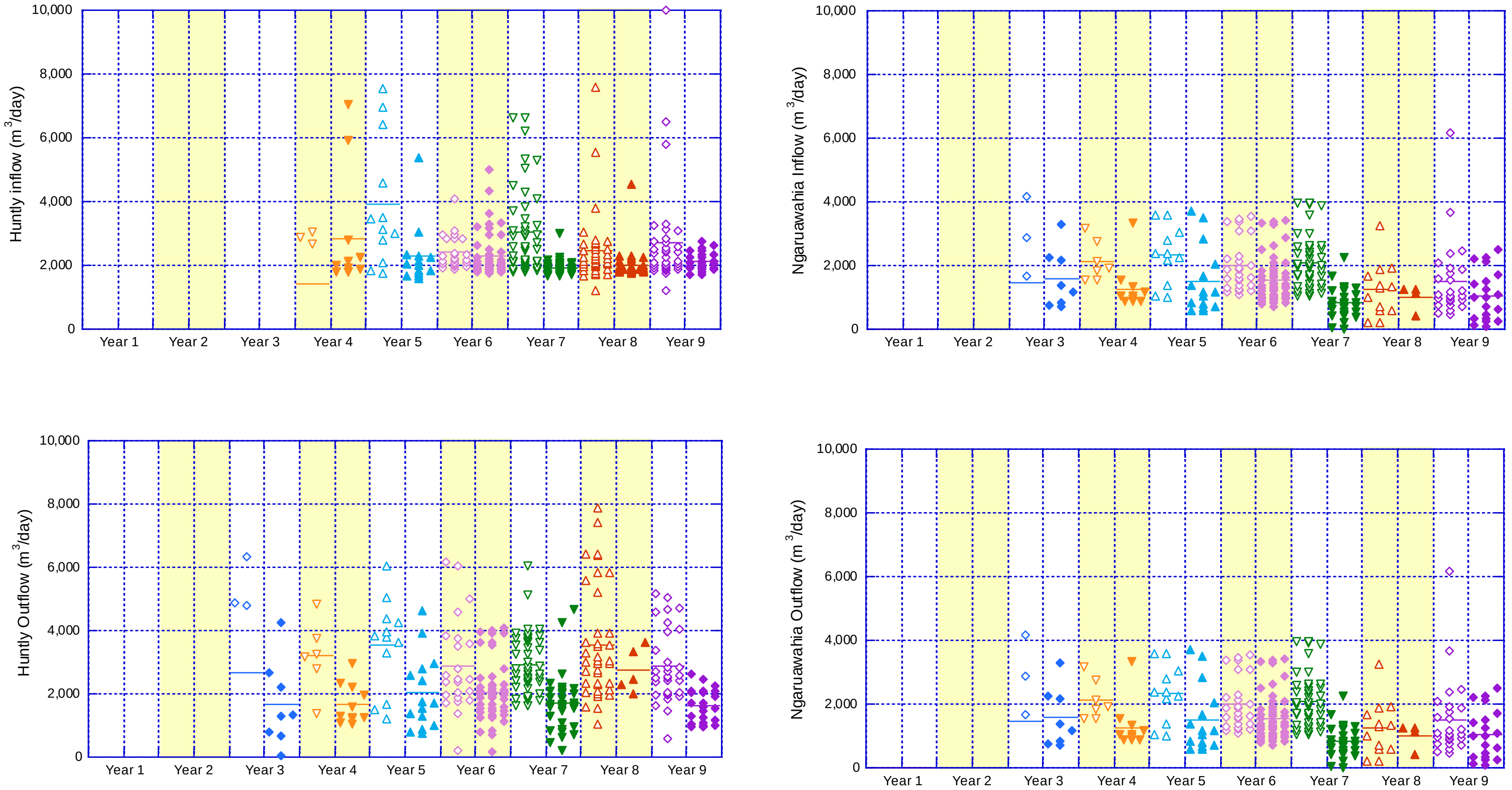

Figure B-3: Inflow and Outflow from Huntly WWTP (LHS) and Ngaruawahia WWTP (RHS)

Key: Winter (Apr – Sep): unfilled shape (e.g. Δ). Summer (Oct – Mar):filled shape (e.g. ▲).

Appendix D Upper South Island Wastewater Treatment Plants

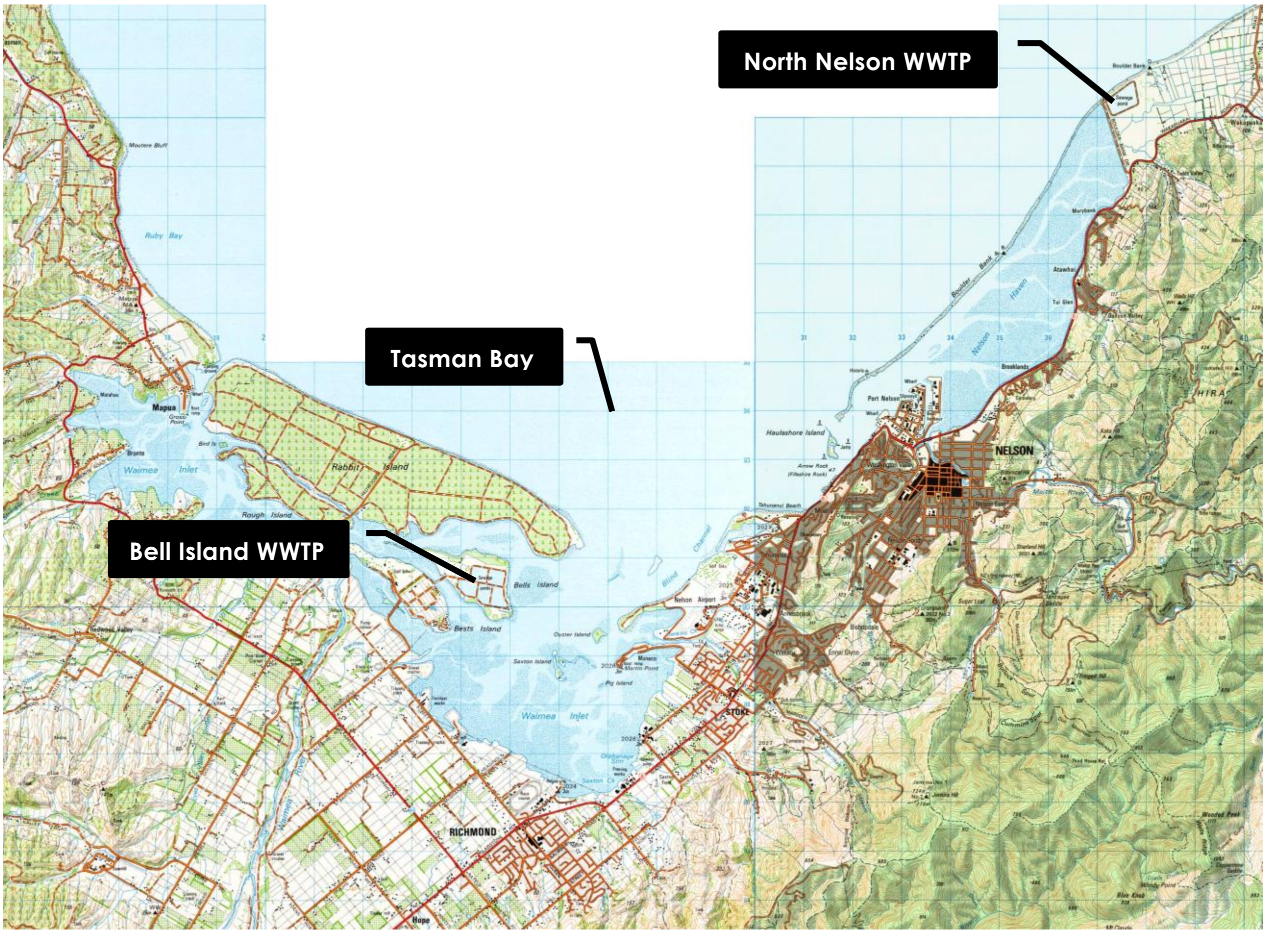

Figure C-1: Location of Upper South Island Wastewater Treatment Plants – Bell Island WWTP and North Nelson WWTP

D.1 Nitrogen Surrogate (Ratio of TBOD:cBOD)

Nitrogen reduction typically occurs by a two step process: ammonia is converted to nitrate in oxygen-rich conditions (nitrification) and then nitrate is converted to nitrogen gas in oxygen-poor conditions (denitrification), which bubbles out of the wastewater into the atmosphere.

The ratio of TBOD:cBOD in treated wastewater from an oxidation pond provides an indication of the extent of nitrification (the first step in process). The terms BOD, TBOD and cBOD are described below in the context of TBOD:cBOD being a surrogate for nitrogen.

BOD is the amount of dissolved oxygen consumed by aerobic micro-organisms to break down organic material present in a given water sample at certain temperature over a specific time period. cBOD is the amount of oxygen consumed in breaking carbonaceous compounds (ie organic carbon) whereas TBOD is the amount of oxygen consumed in breaking down carbonaceous compounds and nitrogenous compounds (ie organic nitrogen, ammonia and nitrite).

When the cBOD test is carried out in the laboratory, an inhibitor is added to prevent oxidation of nitrogenous compounds.

When the TBOD test is carried out in the laboratory, there are typically two stages of decomposition that occur based on the micro-organisms that are present in the sample. The first stage is the carbonaceous stage, where organic carbon is converted to carbon dioxide. The second stage is the nitrogenous stage, where carbonaceous compounds continue to be oxidised and nitrogenous compounds (organic nitrogen, ammonia and nitrate) are oxidised to nitrate. The nitrogenous stage generally begins after about six days, which means that values for five-day cBOD and five-day TBOD are generally similar as the BOD test duration is only five days.

For some wastewater, nitrification can occur in less than five days if nitrifying bacteria (and nitrogenous compounds) are present in the sample, resulting in five-day TBOD values that are greater than five-day cBOD values. Nitrifying bacteria are commonly present in treated wastewater discharge from biological nutrient removal WWTPs. These WWTPs are specifically designed and operated to maintain an inventory of nitrifying bacteria, which are sensitive to temperature, low dissolved oxygen and pH.

Pond-based WWTPs typically have a low density of nitrifying bacteria in treated wastewater, resulting in five-day TBOD values that are similar to cBOD values. However, at North Nelson and Bell Island WWTPs there are periods when there has been a divergence between cBOD and TBOD values in the treated wastewater, indicating nitrifying bacteria are present. This is also supported by reduced ammonia concentrations coinciding with increased nitrate concentrations and divergence between cBOD and TBOD.

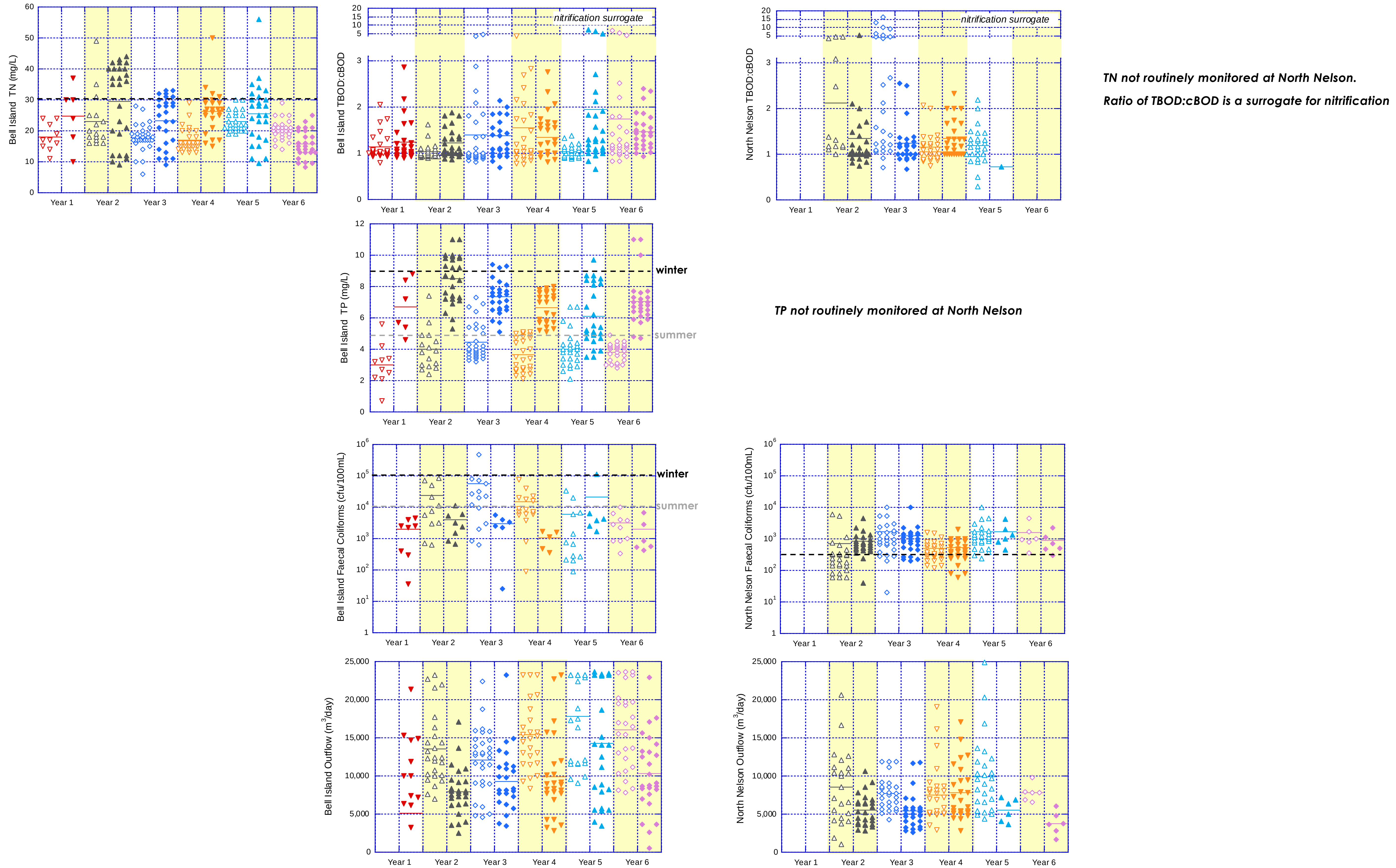

Figure C-2: Treated Wastewater Discharge Quality from Bell Island WWTP (LHS, Maturation Pond 2 outlet) and North Nelson WWTP (RHS, Pond 2 outlet)

Key: Winter (Apr – Sep): unfilled shape (e.g. Δ). Summer (Oct – Mar):filled shape (e.g. ▲). Black dotted horizontal line: typical median (upper value)

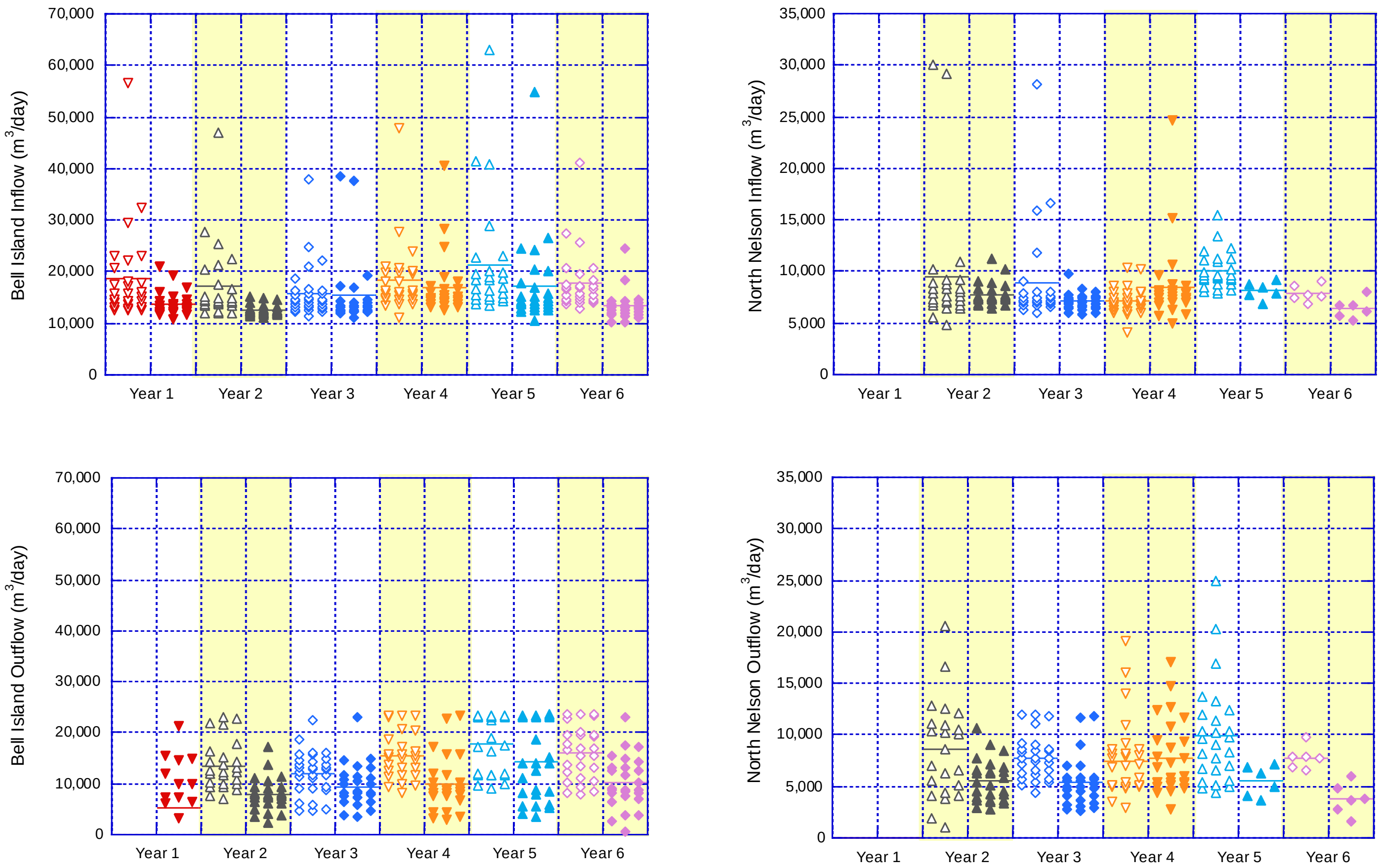

Figure C-3: Inflow and Outflow from Bell Island WWTP (LHS) and North Nelson WWTP (RHS)

Key: Winter (Apr – Sep): unfilled shape (e.g. ∆). Summer (Oct – Mar):filled shape (e.g. ▲).

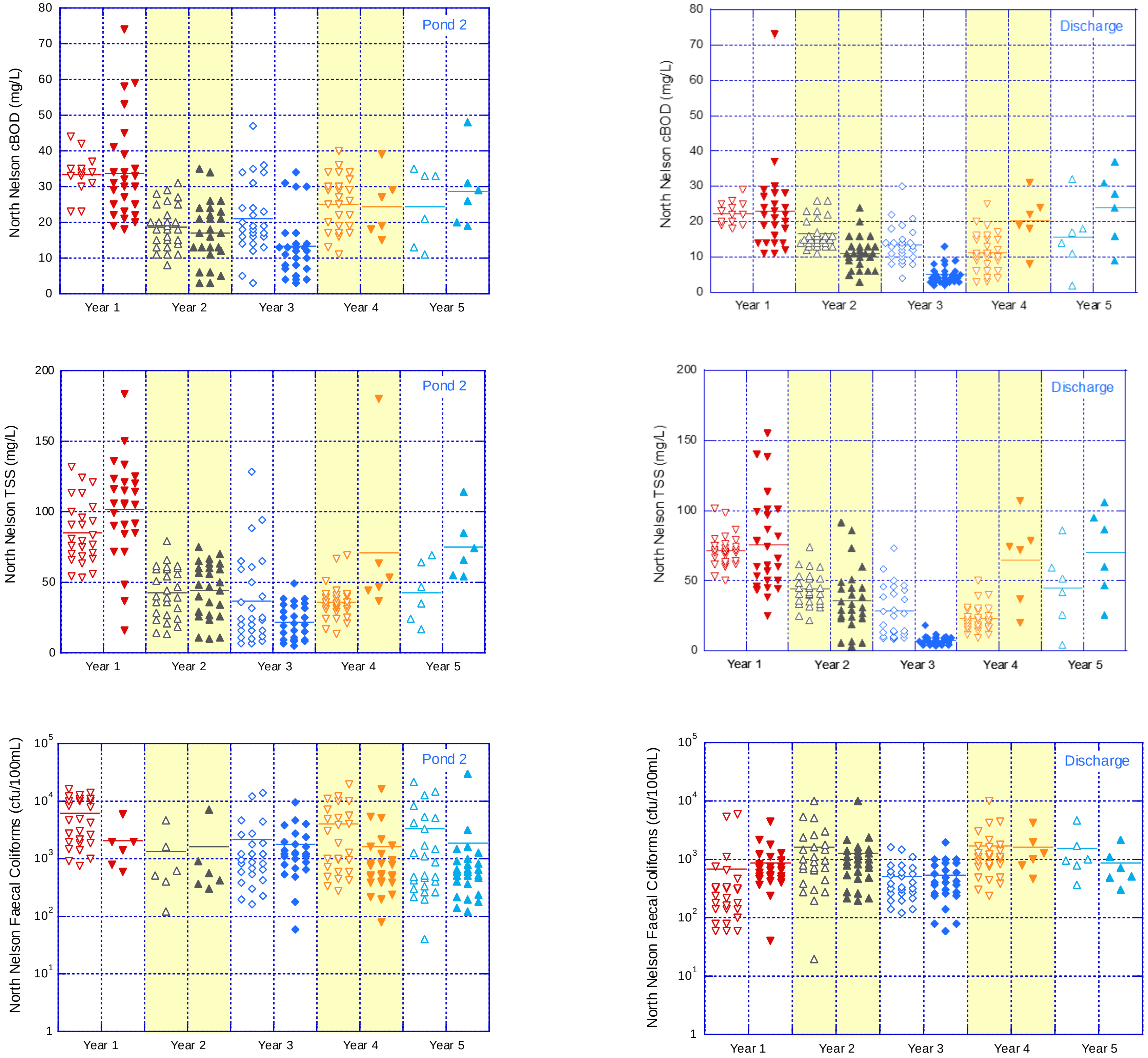

Figure C-4: Treated Wastewater Discharge Quality from North Nelson WWTP - Pond 2 outlet and final discharge (wetland outlet) (Note: Year 1 in this figure is Year 2 in previous figure)

Key: Winter (Apr – Sep): unfilled shape (e.g. Δ). Summer (Oct – Mar):filled shape (e.g. ▲).

Note: At North Nelson the wetlands after the secondary oxidation pond typically provide further reduction in BOD, TSS and faecal coliforms, which is atypical for wetlands following oxidation ponds. It may be because the wetlands are currently unvegetated shallow ponds, essentially acting as an extension of the maturation pond. It is noted, however, that this was not seen during the 2019/20 summer (raw data not provided in this report).

Dunedin

Level 3 John Wickliffe House, 265 Princes Street
Dunedin 9016
PO Box 13-052, Armagh
Christchurch 8141
Tel +64 3 477 0885
Fax +64 3 477 0616

Stantec