Prepared for Ministry for the Environment

THE NEW ZEALAND WASTEWATER SECTOR

Beca GHD Boffa Miskell

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Introduction

Purpose of report

Ministry for Environment (MfE) is leading policy work related to the development of a proposed new national environmental standard for wastewater discharges and overflows. This work is being progressed as part of a package of reforms to the Three Waters regulatory system, which was agreed by Cabinet in July 2019.

Further information on the Three Waters Review, including Cabinet papers and related research reports, is available at www.dia.govt.nz/ThreeWatersReview.

To inform their policy work on wastewater, MfE requires detailed information on the operation and performance of Wastewater Treatment Plants (WWTPs) and the wastewater sector in New Zealand to ensure that any future policy and regulatory interventions are appropriately designed and underpinned by strong data and evidence. Accordingly, MfE engaged a joint consultant team of GHD, Beca and Boffa Miskell to provide a series of reports that describe the wastewater sector in New Zealand including details on current and emerging issues for wastewater management.

These reports are intended to provide important baseline data and information to support the Ministry's work related to improving the environmental performance of wastewater networks, which forms part of the Government's ambition to improve outcomes for Three Waters infrastructure and to protect and restore water quality in New Zealand's lakes, rivers and beaches. The reports are also intended to provide a detailed picture of the state of the wastewater sector in New Zealand, including key institutions, actors, regulatory arrangements, and drivers of environmental performance across municipal, trade waste, and industrial discharges. Because of the inter linkages between the areas of interest to MfE the consultant team has chosen to deliver the brief in a single report with Chapters that can be read as individual reports or in combination. The six Chapters include the following:

- Chapter 1 - Description of the Wastewater Sector in New Zealand
- Chapter 2 – Trade Waste
- Chapter 3 – Environmental Performance
- Chapter 4 – Māori Values
- Chapter 5 – Land Based treatment
- Chapter 6 – Climate Change

All Chapters focus primarily on municipal wastewater, however summary data on industrial wastewater management has been included where available.

Approach

The Chapters were developed using a combination of literature reviews, collation of relevant available data, the consultant team's industry knowledge and from information sourced from councils. For each Chapter a number of councils and [1]Iwi representatives participated in interviews and/or contributed case studies that provide valuable insight into both challenges and opportunities in the wastewater sector.

[1] This report employs the spelling Iwi throughout to honour the authors' preferences and for consistency

Context

The management of wastewater in New Zealand is subject to a hierarchy of laws, regulations, regional policies and localised plan rules.

Introduction of new policies including the National Policy Statement (NPS) for Freshwater and government climate change initiatives is driving the need for a change in approach that takes a more holistic view of wastewater management.

Traditionally the focus of wastewater management has been on minimising the impacts of wastewater on both public health and the environment. More recently the potential for wastewater as a resource for both water supply and energy has become more prevalent in council's considerations. New Zealand has high rainfall and a small population relative to international situations, hence the reuse of wastewater as a source of drinking water has not historically had serious review. The recent drought in Auckland and other parts of New Zealand is increasingly opening up consideration of wastewater for re-use, albeit with significant cultural barriers to be addressed (refer Chapter 4). The potential for energy generation from wastewater is also being looked at more seriously and international practise in this regard is explored in Chapter 6.

Other considerations for wastewater management that is continuously updating relates to emerging contaminants (explored in Chapter 1). A further overlay is the advances in technology particularly relating to data management and controls.

Importantly cultural values have an increased focus and are becoming more integral to the decision making process on wastewater solutions and this is explored further in Chapter 4.

Taking all of the above into account there is considerable complexity and opportunity associated with management of wastewater in New Zealand. This suite of Chapters provides summary information on all key aspects.

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CHAPTER 1
DESCRIPTION OF THE WASTEWATER SECTOR IN NEW ZEALAND

1. Chapter 1 Description of the wastewater sector in New Zealand

Chapter Purpose: A detailed description of the wastewater sector in New Zealand, including:

- *the average annual volume of wastewater generated by municipal, industrial (e.g. meat works) and on-site/domestic wastewater systems (e.g. septic tanks) across the country and the estimated level of treatment/quality of these discharges*
- *the types and sources of contaminants in wastewater, including contaminants of emerging concern, that affect the performance of wastewater infrastructure and environmental and public health outcomes*
- *current and emerging practices and technologies for removing or reducing contaminant concentrations in wastewater, both within WWTPs and prior to discharge into a wastewater network (e.g. pre-treatment of trade waste)*
- *current and emerging practices for reducing the frequency and concentration of contaminants in wastewater overflows from wastewater networks*
- *current and emerging practices for treating, disposing, or re-using wastewater or wastewater by-products, e.g. sludge and methane*
- *institutions and actors involved in managing and regulating wastewater systems and discharges.*

1.1 Chapter outline and context

This Chapter provides an overview of the New Zealand wastewater sector, setting the basis for subsequent Chapters that focus on the specific topics of trade waste, cultural aspiration, land treatment and climate change adaptation.

As per the MfE brief, summary information is provided on municipal WWTP metrics, typical wastewater characteristics, wastewater treatment technologies commonly used in New Zealand, wastewater overflows, biosolids and what regulations govern the sector. The Chapter also touches on emerging contaminants and new technologies and approaches that are increasingly influencing wastewater management.

Key Chapter sections include:

- **Wastewater and its constituents** – this provides a general overview of wastewater contaminants commonly found in municipal wastewater.
- **Overview of wastewater treatment in New Zealand –** this provides an introduction to wastewater treatment.
- **Overview of WWTPs in New Zealand –** this section presents a stocktake of the existing municipal WWTPs across the country including a breakdown of treatment types, discharge locations and populations serviced. A general description of industrial wastewater treatment and onsite wastewater systems is also included.
- **Managing wastewater network overflows –** this section presents a review of types, extent and causes of wastewater network overflows along with a summary of

- current and emerging measures to minimise the impacts of these on public health and the environment.
- **Biosolids and byproducts management –** Biosolids and biogas are two common by-products from the biological wastewater treatment processes. This section presents a review of the current state of biosolids management and biogas utilisation in New Zealand, and some of the new trends emerging in local and overseas practices.
- **Contaminants of emerging concern –** this section provides a general overview of contaminants of emerging concern related to wastewater treatment and discharges.
- **Regulation and management –** An overview of the key regulatory and management systems that apply to wastewater in New Zealand is provided

1.2 Wastewater and its constituents

1.2.1 General Summary

Wastewater consists of a number of contaminants which have environmental and public health concerns. The key constituents of municipal wastewater are summarised in Table 1 along with their sources.

Table 1: Key components of municipal wastewater

Constituent	Measurement	Source
Water	Volume and flow rate of water	Domestic and commercial consumption Infiltration from groundwater Inflow of stormwater
Organic	Biological Oxygen Demand (BOD)	Food preparation/waste Human waste Cleaning
Nitrogen	Ammonia, Total Kjeldhal Nitrogen (TKN), Nitrate, Total Nitrogen	Urine Proteins in food and similar Cleaning products
Phosphorus	Total Phosphorus Dissolved Phosphorus	Organic compounds Detergents
Fats, oils, greases (FOG)	FOG	Food preparation Human excreta and skin Industries such as wool scourers, abattoirs,
Bacteria and viruses	Target/indicator species per volume – e.g. faecal coliforms	Human and animal waste Biological processes in wastewater system
Chemicals	Target chemicals	Industrial activities Cleaning products

Constituent	Measurement	Source
		Pharmaceuticals
Grit	Inert solids	Stormwater inflows Abrading of sewers and sumps Cleaning of abradable concrete surfaces Laundries
Metals	Heavy metals	Mainly commercial and industrial Can be naturally occurring in water supply or food stuffs.
Rag	Not normally measured	Anything that will fit down the wastewater system e.g. sanitary products, clothes, toys

The concentration of these contaminants is influenced by specific catchment characteristics such as wastewater flow per capita, inflow and infiltration, seasonal trends and contribution from trade waste discharges.

As an example, Table 2 below summarises the wastewater concentrations of a seasonal township between winter/off-peak season and peak summer.

Table 2 Municipal wastewater characteristics general summary

Parameters (mg/L unless stated otherwise)	Typical municipal average concentration	Summer season range – from a coastal township*	Peak summer day – a coastal township*
pH (pH unit)	7-7.5		
Alkalinity	250-350	320-380	400
TSS	180-400	800-1400	1500
cBOD5	180-350	430-650	750
COD	400-600	1000-1600	1800
TKN	60-70	80-110	160
Amonnia - N	45-55	70-85	100
Total Phosphorus	10-12	12-16	18
Bacterial indicator E coli (cfu/100mL)	10^7 to 10^8		
Heavy metals	Not regularly monitored		
Pesticides	Not regularly monitored		

** - TCDC WWTP peak summer influent data 2011-2014*

The above comparison shows that the wastewater characteristics in seasonal communities such as coastal townships and villages with a high influx of visitors are markedly different to “normal” municipal wastewater. In these circumstances, the transient loads dictate the sizing and operational regime of the wastewater infrastructure, for example a standby bioreactor will be brought online only during the 10-20 day summer holiday period. As such, these communities have experienced significant financial burden to pay for the construction and operation of additional assets and infrastructure to handle the transient loads (Ho, et al., 2015).

1.2.2 Other contaminants

There are other contaminants causing issues in the wastewater collection network and WWTPs. One such contaminant is wet wipes. Wet wipes have been marketed as a “flushable” product, but unlike toilet tissue paper, they do not disintegrate or dissolve in wastewater. This causes blockages and overflows of pump stations and treatment plant equipment, as shown in Figure 1 below.

Figure 1: Wet wipes causing sewer blockage

1.3 Overview – Wastewater treatment

This section describes the common unit operations and processes used for the treatment of municipal wastewater. Other processes are specifically designed to treat industrial waste, but these are not covered in this section.

1.3.1 Wastewater treatment processes

The core treatment processes at municipal WWTPs typically rely on bacteria to undertake biological treatment for the removal of contaminants. Bacteria are present in the human waste discharged to the WWTP, and the processes are designed to enhance the growth and retain the bacteria in the system at an optimised growth rate. Different mixes of particular bacterial species can be optimised to remove targeted contaminants from the wastewater; such as Nitrosomonas and Nitrobacter for ammonia removal through the nitrification processes. As the treatment relies on biological processes, they are vulnerable to shock loading, fluctuations in flows or loads, and toxic effects of particular contaminants.

The characteristics of wastewater arriving at WWTPs are dependent on various factors such as water use within the community, trade waste volume and concentrations, amount of inflow and infiltration into the sewer network, etc. The processes installed at WWTPs will depend on both the incoming wastewater characteristics and the discharge consent conditions. Very often WWTP processes will evolve over time at each site, as resource consent conditions change with each consent iteration and growth occurs in the wastewater catchment.

Treatment of municipal wastewater typically consists of four main stages – preliminary, primary, secondary and tertiary treatment. The main functions of each step are shown in Figure 2. Each of the stages is described further following.

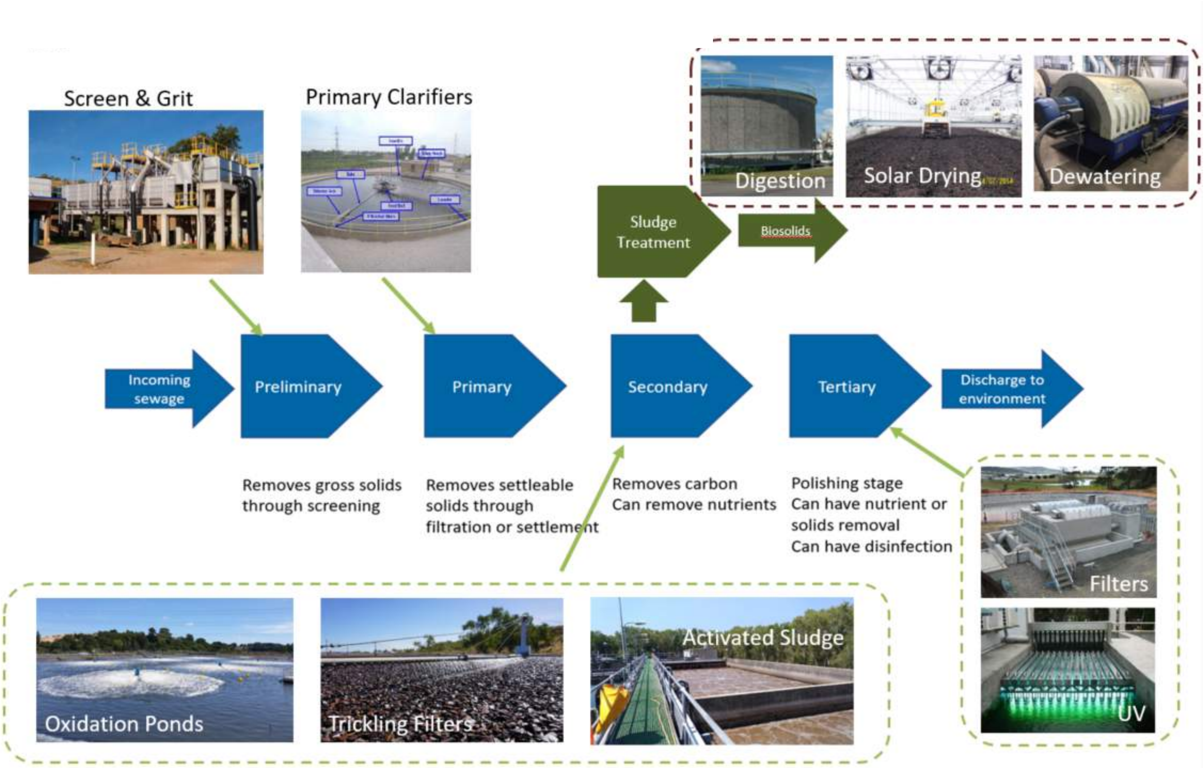


Figure 2 Typical process stages in a WWTP

Refer to Chapter 3 for an in-depth synopsis of wastewater treatment performance standards.

1.3.2 Preliminary treatment

Preliminary treatment is used to remove coarse solids and grit from the incoming wastewater in order to protect downstream processes and mechanical equipment. Screens and grit chambers are commonly used for preliminary treatment in WWTPs. Waste from these is sent to landfill. The two screens shown in Figure 3 are an 'in channel' drum screen and screening compactor.

Figure 3 Cambridge WWTP inlet screen (left) and Queensland Mount Isa WWTP inlet package plant – Screening compactor on top of an aerated grit chamber (right)

1.3.3 Primary treatment

Primary treatment is used for the removal of settleable organic and inorganic solids by sedimentation and materials that float by skimming (see Figure 4 for an example of a rectangular primary sedimentation tank). The primary treatment stage provides a significant removal of suspended solids (typically up to 65%), oil and grease. Some removal of nutrients and BOD (up to 40%) associated with solids is achieved at this stage, but it does not affect the colloidal or dissolved constituents of wastewater.

The simplest form of this is primary lagoons where sludge settles and undergoes stabilisation in the lagoon. Primary sedimentation produces a raw, highly putrescible solids residual (sludge) stream. This raw sludge requires stabilisation typically by an anaerobic sludge digestion process to both reduce the quantity of solid material and stabilise the solids material. Biogas containing methane and carbon dioxide is produced.

In its simplest form, this digester is a septic tank where the sedimentation and digestion take place in the same tank. Some smaller and older (pre 1970) plants in New Zealand (e.g. Milton) used an Imhoff tank that received solids from primary tanks or trickling filters. At the larger scale (e.g. Whangarei, Hamilton, Rosedale, Bromley), formal external anaerobic digesters with subsequent gas and solids management systems were and are currently employed. These facilities allow the size of subsequent systems to be reduced or overall plant effluent quality improved. They also provide options for sustainable energy and other resource recovery (e.g. phosphorus through struvite precipitation).

Figure 4 Primary sedimentation tanks, Pukete WWTP, Hamilton

1.3.4 Secondary treatment

Secondary treatment is used for further removal of organic matter and suspended solids in wastewater. In most cases, secondary treatment follows primary treatment (although in New Zealand, primary treatment is often not included) and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes.

Waste stabilisation ponds have been widely used in New Zealand as a relatively simple process that can provide secondary treatment. The two main categories of biological secondary treatment used in New Zealand for more advanced treatment of municipal waste are biofilm and activated sludge processes.

Waste stabilisation ponds

In New Zealand, waste stabilisation ponds (also known as oxidation ponds) have formed the basis of municipal wastewater treatment for a long time. These systems were constructed throughout New Zealand in the 1960s through 1980s. They are still the most common form of wastewater treatment in New Zealand. Over time, more stringent discharge consent conditions have resulted in modifications to some ponds, with the addition of further polishing stages or their replacement by more advanced technologies in some cases.

Waste stabilisation ponds are configured as a single unit, or as a series of two or more ponds, which can provide primary, secondary and tertiary treatment depending on their configuration. They require a considerable land area, but their capital and operational costs are relatively low and are simple to operate. Ponds can be run as a fully passive system with no mechanical equipment installed, however most ponds now will have some form of aeration installed. An example of a waste stabilisation pond with a horizontal aerator is included as Figure 5. Good (approximately 80%) removal of BOD and TSS is achieved if ponds are loaded and designed appropriately. They also can cope with fluctuations in flows and loads due to the large buffering volume of the pond.

Due to the high surface area combined with a nutrient-rich environment, algae growth is one of the biggest issues with waste stabilisation ponds in summer, when high sunshine levels and water temperatures can induce high algae growth rates. This increases solids levels (algal cells) in the treated wastewater, which is one of the main reasons for exceeding discharge consents. If Ultra Violet (UV) disinfection is used prior to the discharge, its performance can be affected due to the presence of algae in the treated wastewater.

Figure 5 Waste stabilisation pond, Huntly WWTP

While waste stabilisation ponds can remove some nitrogen (with small amounts of phosphorus through natural cell metabolism), when discharge consents require significant nitrogen removal a fundamentally different treatment process is required. This is because most ponds in New Zealand do not come close to removing (via nitrification or volatilisation) all of the influent or recycled ammonia nitrogen. Nitrification is not normally prevalent in most New Zealand waste stabilisation ponds although there are some that do perform reliably (e.g. Pahiatua). Phosphorus is comparatively easily removed from pond effluent via the use of coagulation (with a metal salt such as Alum) and a settlement or floatation process stage.

There have been many innovative modifications for waste stabilisation ponds appearing on the market in New Zealand, with the aim to improve treatment performance or target nitrogen reduction, but these are very often not sustainable solutions, with poor long-term performance.

Another challenge with the operation of waste stabilisation ponds is the need for desludging at regular intervals. In theory, stabilisation ponds should be de-sludged every 5-8 years, but this rarely happens since de-sludging and disposal costs are prohibitive (in excess of $200,000 for a small pond). Typical intervals are 20 to 25 years for de-sludging. As a result, most waste stabilisation ponds in New Zealand have only been de-sludged once in their operating history.

Disposal routes for the sludge from stabilisation ponds are also limited, particularly if there are heavy metals and/or plastics in the sludge. Sludges tend to go to landfill or a vermiculture composting facility to be diluted with other waste streams.

Biofilm processes

In biofilm processes, media is provided for the bacteria to adhere to. The mechanisms involved are shown in Figure 6. The media can be in the form of sheets or individual pieces, which either have flows trickling over them (Figure 7), or are submerged in the wastewater in the tank (Figure 8). The term “biofilm” refers to the thin layer of microorganisms that forms on the surface of the media, held together by extracellular polymeric substances which act as a glue and as protection for the bacterial cells. Biofilm growth is controlled by the action of water over/around the media and by the contaminant loading on the process unit.

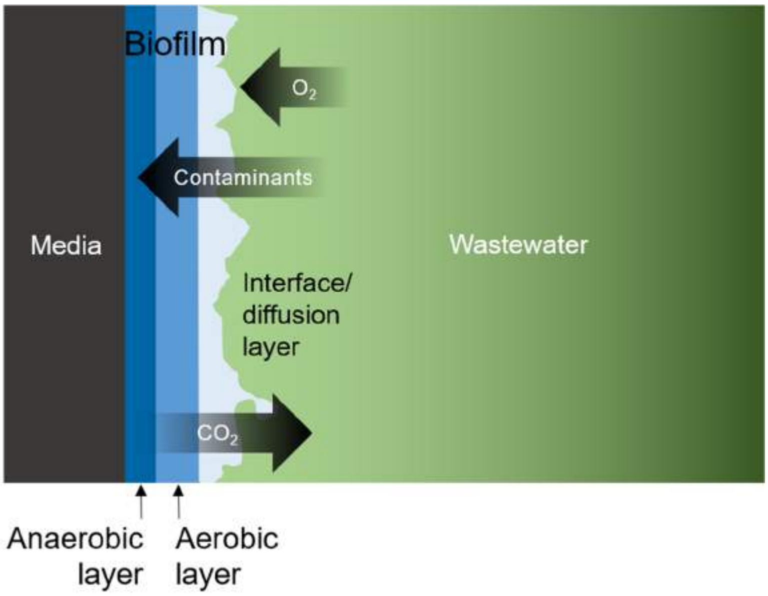


Figure 6 Functionality of a biofilm

Where submerged processes are used, aeration is required to keep the media suspended and to provide oxygen for bacteria. In trickling filters, oxygen is transferred from the surrounding air as the water splashes over the media surface.

In New Zealand, biological trickling filters have been used as a single process step following screening, with no further treatment prior to discharge. To produce a better quality treated wastewater, they can be installed with primary treatment, secondary clarification and or tertiary processes to further remove contaminants. Biological trickling filters in some locations have been introduced to provide cultural treatment of wastewater through biological transformation processes that occurs through the biofilm (e.g. Hastings, Napier).

Figure 7 Flow distribution over top of trickling filter at Napier WWTP

For small systems, submerged aerated filters can be used as the main biological process and these usually require secondary clarification as a minimum for adequate treatment performance.

Fixed film technology can be combined with activated sludge to form a hybrid system, such as that shown in Figure 8. This configuration is known as a moving bed bioreactor (MBBR).

This process has the advantage of being able to carry a greater amount of biomass (active treatment capacity) within a given volume than a purely suspended growth or fixed growth reactor can.

Figure 8 Submerged biofilm media at a moving bed biofilm reactor

Source: www.arvindenvisol.com/moving-bed-biofilm-reactor-mbbr-process/, June 2020

Operational costs for trickling filters are lower than submerged aerated filters, which have higher power requirements for aeration. On the other hand, trickling filters are more susceptible to fluctuations in flows and loads due to the low retention time in the system and the (typically) one-pass nature of the process.

Generally speaking, the biofilm processes discussed here will remove TSS, and BOD, and can be configured to nitrify ammonia.

Activated sludge

In activated sludge processes the bacteria form “flocs” (clumps of bacteria held together by extracellular polymeric substances), which are kept in suspension in a tank by the action of mixing and/or air bubbles continuously rising through the wastewater within the tank. The term “activated sludge” was coined over a hundred years ago. Research and technology advances have taken activated sludge processes to many forms and different process names are now used. Targeted contaminants in wastewater can be removed by sequencing prevailing conditions in a series of tanks to promote the growth or enhanced activity of particular bacteria at a specific stage in the sequence. Sedimentation tanks of physical separation devices such as membranes, at the end of the process allow the recycling of the bacteria back into the main process units.

Activated sludge processes use large amounts of power for wastewater aeration, and the more complex they get, the tighter the monitoring and control needs to be on the processes, and the bigger the impact of swings in flows and loads of contaminants in the incoming wastewater. Prevailing conditions in process units can change due to the characteristics of the incoming wastewater changing or lack of control in the process. This can encourage the proliferation of bacteria which are detrimental to the treatment process by competing with the bacteria used to remove the target contaminants, and ultimately cause non-compliance against discharge consent conditions. These issues can be difficult to turn around, as the bacteria take several life-cycles to recover (2-10 days per life cycle).

Activated sludge processes will remove TSS and BOD, can be configured to remove particular species of nitrogen (measured as nitrate, nitrite, ammonia for example) and can remove phosphorus depending on the particular process configuration. Long-chain compounds can be broken down through the treatment process by using long residence times.

The activated sludge family of processes includes a very wide range of variants that differ in both spatial and temporal characteristics i.e. some are defined by the duration of treatment, some by the types of reaction zone and some by the means of biomass separation. Some commonly used in New Zealand are summarised in Table 3.

Table 3 Commonly used aerobic processes

Name	Defining features	Environmental performance
Aerated lagoon	Lagoon, surface aerators, no clarifier. (Bacteria) Sludge retention time (SRT) same as hydraulic retention time (HRT)	Basic BOD & TSS reduction
Activated sludge configurations (SRT >> HRT)		
MLE (Modified Ludzack Ettinger)	Anoxic & aerobic zones Large recycles Conventional or membranes	High levels of BOD, TSS & TN removal
SBR (Sequenced Batch Reactor)	Single tank with a timed sequence of treatment steps	BOD, TSS, Ammonia, TN removal
IDEA (Intermittently decanted extended aeration)	Single tank hybrid of MLE & SBR	High levels of BOD, TSS & TN removal
4 Stage Bardenpho	Second anoxic and aerobic stages Conventional clarifier or membranes	High levels of BOD, TSS & TN removal
5 Stage Bardenpho	Anaerobic zone added to the 4 stage configuration. Conventional clarifier or membranes	High levels of BOD, TSS & TN removal plus biological phosphorus removal

There are a range of plant sizes using an activated sludge process in New Zealand, ranging from Mangere (~1.2M population) to Kawakawa Bay (approximately 600 people), as shown in Figure 9.

Figure 9 Kawakawa Bay WWTP (left) and Mangere WWTP (right)

Biomass separation

Secondary sedimentation/settlement is usually required after a biofilm or activated sludge process. In an activated sludge process this returns the biomass back to the start of the process.

For biofilm processes, the biomass is settled out and treated with other sludge from the site. This improves the TSS content of the treated effluent.

The biomass separation can be achieved via gravity settlement (conventional clarifiers, flotation (Dissolved Air Flotation - DAF) or by membrane separation (membrane bioreactor - MBR). Figure 10 shows an example of a secondary clarifier at Palmerston North WWTP.

Figure 10 Secondary clarifier, Palmerston North WWTP

1.3.5 Tertiary treatment

Tertiary treatment can be used for either polishing treated wastewater (reducing treated contaminants such as BOD, TSS or ammonia down to discharge consent levels), or targeting specific contaminants which could not be treated in the main treatment processes, like pathogens or phosphorus.

Tertiary treatment processes can by biological, chemical, physical or a combination of these, and are summarised in Table 4.

Table 4 Examples of tertiary treatment processes

Category	Examples
Chemical	Chlorine disinfection (Rarely used in NZ) Phosphorus removal with metal salts
Biological	Anoxic process for denitrification Nitrifying trickling filter
Physical	Sand filters Disc filters (Figure 11) UV disinfection (Figure 12) DAF Membrane filtration

Figure 11 Tertiary cloth disc filters, Pauanui WWTP

Figure 12 UV disinfection, Mangere WWTP

1.3.6 Other processes

Membranes

As technology has improved (and also become cheaper), options such as membranes have become a more viable option for incorporation into wastewater treatment systems. Membranes are a physical barrier, with micro meter-sized pores, which allow diffusion of water across the membrane; particles (including pathogens larger than the pore size) cannot pass through and are retained within the process. They also have the advantage of a much smaller footprint than other treatment types and are often used for upgrades where land availability limits treatment options.

Membranes are becoming more commonly used in New Zealand for treatment where the discharge consent limits are very tight.

The membrane can be deployed as a conventional tertiary clarification device after waste stabilisation ponds or high rate secondary processes. It can also be deployed in the MBR configuration mentioned above whereby the membranes are immersed in the activated sludge reactor and take the place of a conventional gravity clarifier.

Membranes enhance environmental performance by removing more particulate matter than other forms of separation device are able to. Algae, sludge flocs, bacteria and inert materials are removed down to very low levels

Biosolids processes

Biosolids (sludge) are the solids removed from the processes in wastewater treatment by settlement or separation. Sludge consists of particles such as toilet paper tissue and food particles and the treatment bacteria that grow and multiply, consuming the waste and being subsequently wasted from the biological processes in order to control their population size.

Biosolids can be treated in a number of ways. The treatment applied is dependent on the type of sludge, the cost to treat and the final disposal route.

Biosolids should not be confused with screenings or grit, which are almost exclusively landfilled due to there being few safe or practical options for their reuse. Refer to Section 1.11 for a more detailed description of biosolids management practice in New Zealand.

1.4 Overview of wastewater treatment in New Zealand

A summary of wastewater treatment facilities in New Zealand follows. This covers the numbers and sizes of WWTPs, treatment and disposal types, and the treatment standards the different treatment types used can generally achieve. Since the DIA work referenced below was completed, three wastewater schemes have been decommissioned and diverted to another plant. New Zealand WWTP locations are shown in Figure 13.

1.4.1 National stocktake of municipal WWTPs

WWTP locations

Information about the numbers and types of municipal WWTPs was extracted from a national treatment plant database, collated by GHD for the Department Internal Affairs (DIA) in 2019. From this database there are 318 active municipal WWTPs within New Zealand.

Figure 13: Location of New Zealand municipal WWTPs

Table 5 shows a breakdown of the number of active WWTPs by region, excluding those that are diverted to other facilities for treatment or decommissioned.

Table 5: Number of operational WWTPs by region

Region	No. of WWTPs
Auckland	17
Bay of Plenty	17
Canterbury	42
Gisborne	2
Hawke's Bay	10
Manawatu-Wanganui	39
Marlborough	4
Nelson	1
Northland	30
Otago	33
Southland	23
Taranaki	10
Tasman	8
Waikato	54
Wellington	15
West Coast	13

Wastewater treatment facilities by plant size

Figure 14 shows the number of WWTPs and their serviced population based on size class. The size class is applied to enable analysis of the WWTPs within a similar size category. This report has adopted the following classification for plant size:

- Very small plants servicing less than 1,000 people, Size Class 1 (SC1)
- Small plants servicing between 1000 and 5000 people, SC2
- Medium size plants servicing between 5000 and 10,000 people, SC3
- Major plants servicing between 10,000 and 100,000 people, SC4
- Large plant servicing more than 100,000 people, SC5

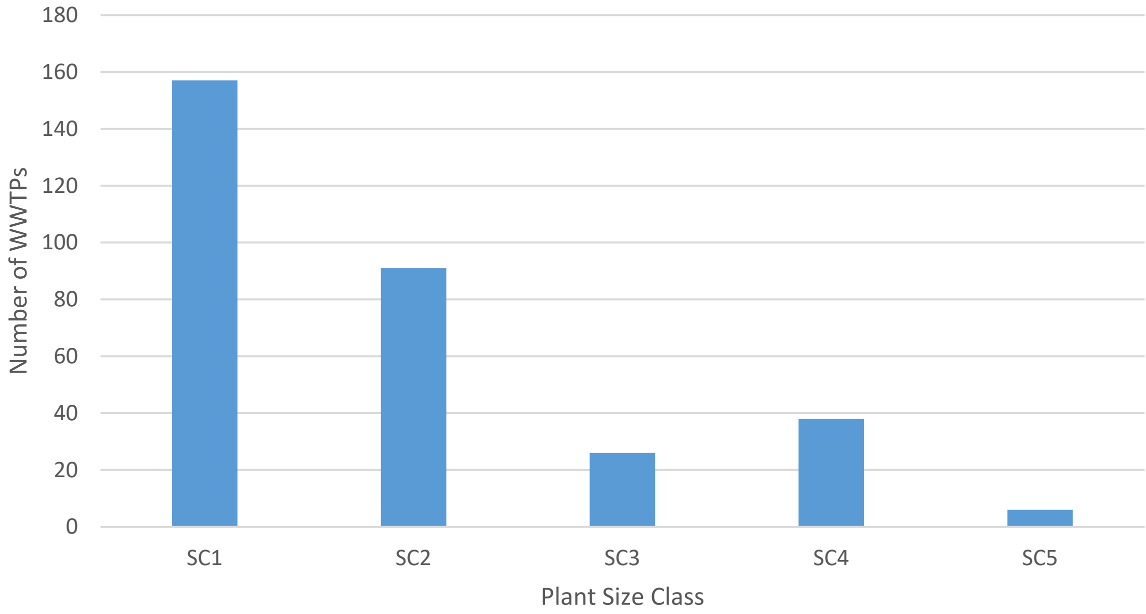


Figure 14: Number of WWTPs by size class

Table 6: Percentage of population serviced by WWTP size classes

Plant size class	Percentage of population serviced
SC1 (<1000 people)	1%
SC2 (1000 to 5000 people)	5%
SC3 (5000 to 10,000 people)	4%
SC4 (10,000 to 100,000 people)	34%
SC5 (>100,000 people)	54%

As depicted in Figure 14 and Table 6 above, the majority of WWTPs are SC1 and SC2 (248 out of 322), servicing populations of less than 5000 people. However, the serviced population by these two plant sizes only represent 6% of the total serviced population. The large and major plants (SC4 and SC5) only consist of 44 facilities, yet they service 88% of the total serviced population.

Wastewater volume treated by municipal WWTPs

The wastewater flow data in the database was summarised into regions, as depicted in Figure 15.

The estimated total wastewater flow (on average) for all of New Zealand (to municipal WWTPs) is about 1.5 Mm^3/day.

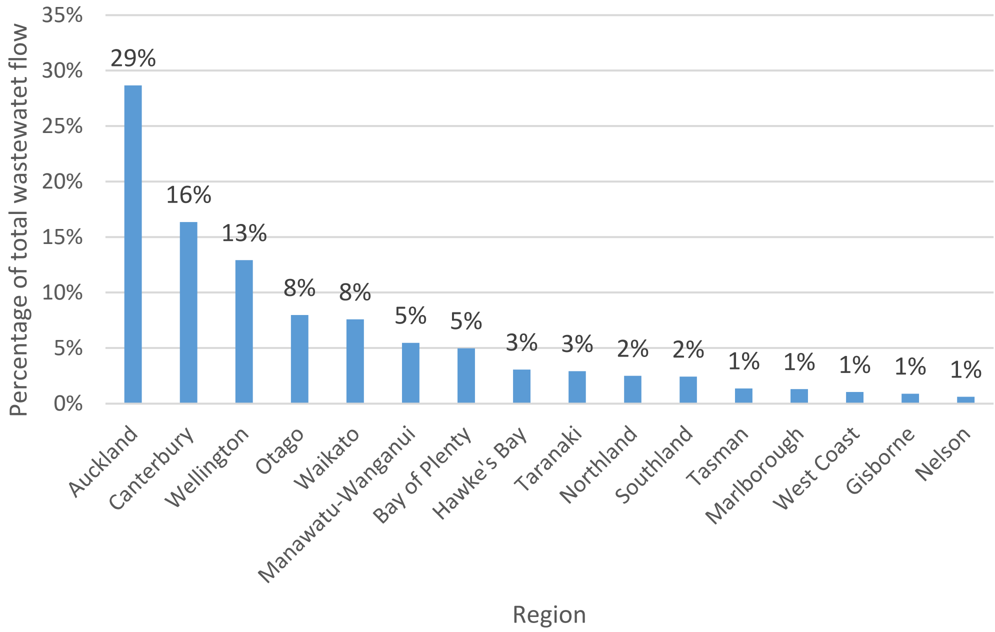


Figure 15 Wastewater flows by region

1.4.2 WWTPs by discharge and receiving environment

Figure 16 and Figure 17 summarise the number of WWTPs by discharge environment, and the total serviced population respectively.

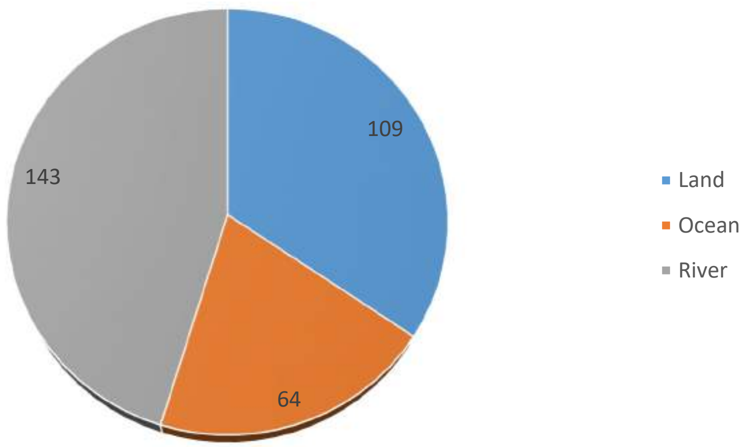


Figure 16: Number of WWTPs by discharge environment

As observed in Figure 16, the majority of WWTPs discharge treated effluent to a freshwater environment or to land. By volume (Figure 17) most of the serviced population is connected to a wastewater scheme discharging into the ocean or estuaries.

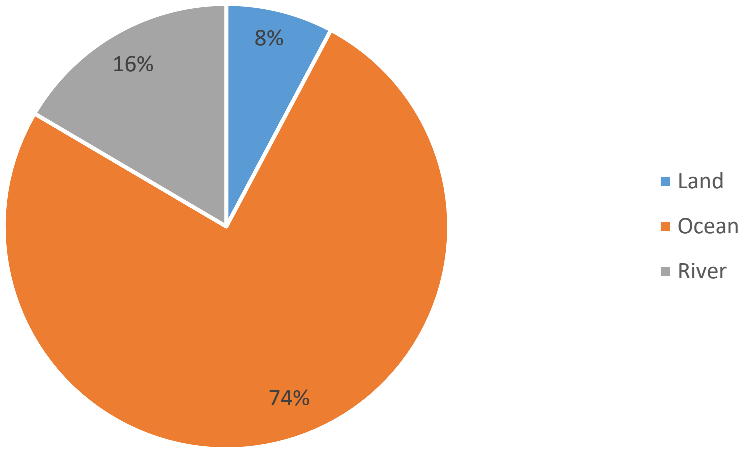


Figure 17: WWTP serviced population by discharge environment

This is attributed to the coastal locations of our largest population centres, including Auckland, Christchurch, Wellington and Tauranga. This is also attributed to the lack of reuse opportunities near the major cities. Refer to Chapter 5 for an in-depth synopsis of land treatment of final effluent and respective case studies.

1.5 Current technologies in wastewater treatment facilities

There are a wide variety of wastewater treatment technologies employed in New Zealand, as summarised in Table 7 below. Typical treatment processes are activated sludge processes, trickling filters, aerated lagoons, facultative ponds, wetlands and recirculating filters. This report adopts the treatment technology grouping based on the Energy Benchmarking studies completed for Water Services Association of Australia (WSAA), which has been used to benchmark energy efficiency for similar process configurations.

Table 7 WWTP technology overview

Treatment	WSAA Group	Classification	Examples	Number of Facilities	% by No.	% by Pop
Activated sludge (AS)	Type 1	*AS process with primary treatment, digesters and onsite co-generation*	*Mangere, Chapel Street*	*5**	*2%*	*49%*
	Type 2	*AS process with primary treatment, digesters and no onsite co-generation*	*Westport*	*1*	*0.3%*	*0.1%*
	Type 3	*AS process with no primary treatment nor anaerobic digesters*	*Moa Point, Shotover*	*51*	*16%*	*25%*
Trickling Filters	Type 4.1	*Trickling filters*	*Taupo*	*22*	*8%*	*11%*
	Type 4.2	*Trickling filters combined with activated sludge process*	*Tokoroa*	*4*		
Ponds and lagoons	Type 5.1	*Aerated lagoons and oxidation ponds with high intensity aeration*	*Blenheim*	*37*	*64%*	*15%*

Treatment	WSAA Group	Classification	Examples	Number of Facilities	% by No.	% by Pop
	Type 5.2	*Facultative ponds and wetlands*	*Huntly*	*168*		
Others	Type 6	*Recirculating filters*	*Whakamaru*	*17*	*5%*	*0%*
	Others	*Septic tanks, Imhoff Tanks, Worm farms*	*Oamaru Bay*	*16*	*5%*	*0%*

** Bromley WWTP is classified as a special case Type 1 because of onsite co-gen.*

As depicted in the above table, the majority of the WWTPs in New Zealand are pond-based systems. Pond based systems were the common treatment method constructed several decades ago because of their simple construction and operation. However, they do not achieve consistent nutrient removal compared to modern activated sludge processes (Type 1 to 3). For this reason, most of the treatment plants built in the last 20 years are primarily activated sludge processes.

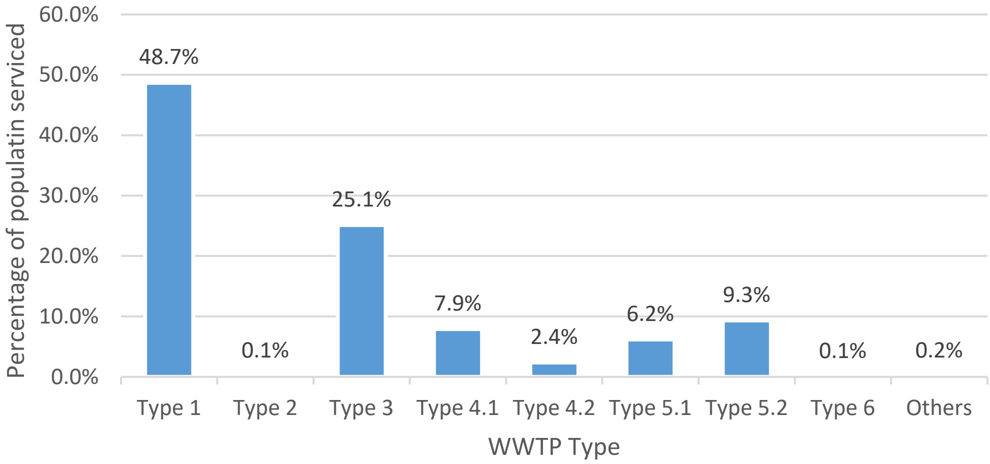


Figure 18 WWTP Type by serviced population

As seen in the above graph (Figure 18), whilst the majority of WWTPs in New Zealand are pond-based systems (Type 5.1 and 5.2), they only service approximately 17% of the total serviced population. Activated sludge processes (Type 1 to 3) are used to treat wastewater from three quarters of the total serviced population.

Compared with conventional pond based systems, Activated sludge processes can be configured to achieve a greater removal of nitrogen and phosphorus from wastewater and require a much smaller amount of land for the plant. There are a number of treatment plants achieving median total inorganic nitrogen limits of 5-10mg/L (as N) and median total phosphorus limits of 1 to 2mg/L (as P). On the other hand, pond-based systems cannot meet these stringent discharge standards easily and consistently.

Table 8 shows the typical effluent qualities achieved by different treatment types.

Table 8 Typical effluent quality following different treatment processes

Treatment Type	TSS (mg/L)	BOD5 (mg/L)	AmmN (mg/L)	TIN (mg/L)	TP (mg/L)	E. coli (cfu/100mL)
Facultative pond	*15-50*	*15-50*	*5-30*	*25-50*	*5-8*	10^3-10^4
Pond with tertiary filtration	*<5*	*<5*	*5-30*	*25-50*	*5-8*	10-10^2
Pond with media for nitrification	*15-50*	*15-50*	*5-10*	*25-40*	*5-8*	10^3-10^4
Trickling filters	*10-20*	*10-20*	*5-30*	*25-40*	*5-8*	*100-500**
Trickling filters with Activated sludge	*10-20*	*10-20*	*5-15*	*20-30*	*5-8*	*100-500**
Activated sludge	*10-20*	*10-20*	*5-15*	*25-30*	*4-8*	*100-500**
Activated sludge with tertiary treatment	*<5*	*<5*	*5-15*	*25-30*	*4-8*	*100-500**
Activated sludge with nutrient removal & tertiary treatment	*<5*	*<5*	*1-5*	*5-20*	*2*	*100-500**

** - Pathogen reduction achieved by UV disinfection*

Upgrading pond-based systems

Because of the large number of pond based treatment systems in the country, there have been a number of retrofit upgrades undertaken to improve the discharge quality. Some examples include:

- Aeration upgrade – this improves organic removal.
- In-pond media addition – this improves nitrification and achieves partial denitrification.
- Membrane tertiary filtration – this significantly reduces suspended solids, $cBOD_5$ and pathogens in the pond effluent.
- Conversion into activated sludge process – this is achieved by converting the existing pond (if the pond has sufficient water depth) into an activated sludge reactor or by constructing a much compacted concrete reactor adjacent to the existing pond(s), and repurpose the existing ponds as flow storage.

The two photos following are examples from Cromwell and Matamata ponds where additional aeration, in-pond media and tertiary membrane filtration were added.

Figure 19 Photos of enhanced pond-based systems: Cromwell (left), Matamata (right)

1.6 Emerging technologies in wastewater treatment

Several treatment technologies may emerge as potential upgrade options in New Zealand when the existing plants require an upgrade to increase capacity or improve performance. Table 9 below outlines several examples of these emerging treatment technologies.

Table 9 Emerging wastewater treatment technology examples

Technology examples	Description	Process drivers	Current status
Aerobic Granular Sludge (AGS) e.g. Nerada	Large granules are formed within the reactors to achieve simultaneous nitrogen and phosphorus removal. These granules are fast settling, requiring smaller reactor size and lower power consumption.	Process intensification	Full scale, quite a number of plants in operation overseas.
Membrane Aerated Biofilm Reactor (MABR)	Gas permeable membranes act as surface to facilitate attached growth media. Unlike conventional attached growth process, air is directed into the membranes to supply air/oxygen into the biofilm around the membrane surface while the bulk liquid remains anoxic. This approach significantly reduces power requirements and achieves compacted reactor volumes.	Process intensification Energy consumption reduction	Full scale, most plants under design overseas. Difficulty getting very low nitrogen values.
Mainstream Deammonification	In lieu of conventional nitrification and denitrification pathway, the biology will be based on Anaerobic ammonification (ANAMMOX) which requires significantly less oxygen (hence power), lower carbon requirements for nitrogen removal (i.e. more influent carbon can be diverted to anaerobic digestion). However, the ANAMMOX bacteria is very slow growing, particularly in mild temperature like New Zealand.	Novel process Energy consumption reduction	Some full scale set-up overseas
Gel Encapsulation	Microorganisms are encapsulated in gel	Process intensification	Limited to some industrial

Technology examples	Description	Process drivers	Current status
	beads/cubes. The micro-media is then dropped into bioreactors for maximising treatment performance. Compared to conventional activated sludge, which has only a small population of active microorganisms, this process will have significantly higher capacity per unit volume of bioreactor.		facilities overseas. Still unsure of reality of this process.
Waste to protein	The process uses purple phototrophic bacteria (PPB) to convert soluble wastewater constituents of organics, nitrogen, and phosphorus from high strength wastewater into protein rich biomass, potentially replace fishmeal in aquaculture industries.	Novel process, resource recovery. PPB uptake capacity.	Demonstration scale overseas
Algal bioreactors	The use of algae to uptake additional nitrogen and phosphorus and provide a biomass for use (e.g. High rate algal ponds, Petro process – ponds combined with trickling filter or activated sludge). Recent examples utilising micro and macro algae and anaerobic digestion of algal solids.	Low cost upgrade for nutrient removal	Full scale examples over the last 20 years. Some large plants in USA and Mediterranean. Western Treatment Plant in Melbourne (Petro)
High rate anaerobic treatment	Use of high rate lagoons, UASBs, or anaerobic membrane bioreactors to treat raw wastewater. Polishing with trickling filter, algal ponds or activated sludge. Also opportunity to recover nutrients from outlet of anaerobic.	Maximise energy recovery and offer a low cost treatment system.	Many examples in India and Brazil.
Physical / Chemical treatment	Use of chemical addition, fine screening, sieve filtration or membrane filtration to maximise removal of organics and send to anaerobic digesters.	Small footprint, low operating costs.	Some examples overseas. Significant research in this area.
Struvite recovery	This applies in treating centrate with magnesium hydroxide to form struvite (MAP)	Forming fertiliser products	Full scale plants in US

Wastewater treatment processes have traditionally been developed for removal of contaminants prior to releasing the treated wastewater into the environment. “Circular economy” thinking has become more prevalent and is changing how wastewater treatment is considered from a resource recovery perspective. A research and development focus on treatment technologies and methods to facilitate resource recovery from treating the wastewater, including carbon diversion is becoming more prevalent (refer Chapter 6).

1.7 Industrial wastewater treatment facilities

New Zealand manufactures and exports a range of products to overseas markets. The largest export earner is from dairy, egg and honey manufacturing, earning approximately 28% of the total export trade (Workman, May 28, 2020). This is followed by the meat industry (14%) and wood processing (9%). Wastewater generated from these manufacturing facilities are often treated onsite and/or discharged into local council's wastewater systems as trade wastes. Because of the vast quantity and diverse spectrum of manufacturing facilities in New Zealand, this section provides a high-level overview only of on-site wastewater treatment from these industrial discharges.

Refer to Chapter 2 for a detailed description of trade waste management.

1.7.1 Dairy industry and milk process plants

New Zealand produces approximately 3% of the global milk production, of which 95% of product is exported. The dairy sector provides direct employment to 38,000 people.

Exports from the dairy industry have been valued to approximately $16.7 billion (DCANZ, n.d.), and the top five export-earning products are whole milk powder, butter, cheese, infant formula and skim milk powder.

Fonterra is our largest dairy producer, and they own and operate 30 factories across New Zealand. The majority of these have onsite wastewater treatment facilities to treat the wastewater from the manufacturing process. Other major dairy companies include Tatua Dairy, Open Country Dairy, Westland Milk, Synlait, Oceania Dairy and Yashili. A more detailed account of dairy wastewater plants is included in Chapter 2.

The wastewater characteristics from each factory is different due to the dairy products that each factory produces. In general terms, dairy processing wastewater contains dilute milk, spill milk products and cleaning solutions. The waste stream usually has elevated organic levels (measured as COD, and $cBOD_5$), fat and grease (FOG), nitrogen and phosphorus and variable pH (by the cleaning chemicals).

Common onsite treatment processes include screens and dissolved air flotation (DAF) before the treated wastewater is irrigated on land. Often pond based systems are used as further treatment. Some dairy producers also have anaerobic treatment systems and recover the biogas for reuse. If a higher pre-treatment/discharge standard is required, a biological treatment system (ponds, trickling filters or activated sludge) will be used, such as Lichfield and Pahiatua (Daly & Beuger, 2016). As advised in Fonterra's Sustainability Report 2019, the factory produces approximately 61.3 Mm^3 of factory wastewater per year.

The factory domestic wastewater is usually treated by a small separate system.

1.7.2 Meat industry and abattoirs

Process wastewater from abattoirs is another major source of industrial wastewater. The wastewater characteristics are very different to those in the dairy wastewater. Affco, Alliance, Greenlea and Silverferns Farms are the major red meat processing companies in New Zealand. Tegel, Inghams, Brinks, Turks and Waitoa are known companies own and operate poultry processing facilities.

Typically, the waste stream is heavily loaded with suspended solids, fat, blood and manure, resulting in a very high strength wastewater with elevated levels of suspends solids and organics; with very high nitrogen and phosphorus concentrations. Typical onsite wastewater treatment processes include milliscreens, save-alls, dissolved air flotation, anaerobic biological treatment (ponds) and aerobic biological treatment. Milliscreens and DAF are commonly used to remove solids and protein/organics in the wastewater.

Some of the meat works and poultry processing facilities discharge the wastewater to local council's wastewater systems. Some facilities have their own discharge permits to release the treated wastewater to the nearby receiving environment (land or water).

1.7.3 Other industries

In addition to dairy and meat industries, there are other industries in the country, including petrol chemical, food processing, wool scouring, pulp and paper and others. The pulp and paper sector produces large volumes of wastewater with high suspended solids and organics. Treatment processes usually entail, screening, primary clarification and biological treatment using a combination of anaerobic and aerobic systems. Most of these plants in New Zealand are pond-based systems due to their rural location. There are numerous of these industrial facilities in all of the regions. There is no centralised database to provide a breakdown of all of these onsite treatment types (if any) and associated volumes of wastewater.

1.8 Combined domestic and industrial

Several WWTPs receive significant discharges from the nearby industrial facilities within the township; examples include Whanganui, Morrinsville, Fielding and Blenheim. In these facilities, there are specific provisions to manage the effect of treating a higher percentage of trade waste than other municipal wastewater treatment plants around the country.

1.8.1 Case Study – Morrinsville WWTP

The Morrinsville township has a population close to 8,000 people and is located in close proximity to a number of industrial sites. The Morrinsville WWTP receives trade waste from Fonterra's Morrinsville site, Greenlea Premier Meats and smaller discharges from IXOM and Evonik Peroxide.

The current average flow to the treatment plant is approximately 5,800 m^3/day, of which approximately 25% originates from the industrial sources.

The existing treatment process comprises of inlet works (screens and grit removal), a Sequencing Batch Reactor (SBR) lagoon, tertiary filters and UV disinfection, as shown in Figure 21 and Figure 20. The final effluent is discharged into the Totara Gully, which is a tributary to the Piako River. The current resource consent requires the treatment process to produce a high quality effluent with low ammonia and nitrogen concentrations.

Figure 20: Morrinsville WWTP inlet works and decant pond

Figure 21: Morrinsville WWTP layout

The discharges from Fonterra and Greenlea represent 21% and 5% of COD loads, and 13% and 27% of total nitrogen loads to the Morrinsville WWTP respectively. Hence, monitoring and managing the trade waste loads are highly important to the plant operation and to maintain compliance with the discharge standards. An online UV photospectrometer monitors the levels of organic and nitrogen in the incoming wastewater around the inlet works.

From the online data, the Matamata Piako District Council (MPDC) operators adjust the SBR setpoints to optimise the wastewater treatment, as well as querying the industrial dischargers for abnormal levels of trade wastes contaminants. MPDC has demonstrated the potential of smarter usage of process data collected from the field instruments to optimise the wastewater treatment processes, especially when the treatment plant performance is affected by flows and loads of the trade waste.

1.9 Onsite wastewater systems overview

1.9.1 Background

In New Zealand, approximately 21% of the population is not connected to a reticulated sewer system (Water New Zealand, 2019). The majority of these people are living in rural areas where water services are not provided by the local council. In such situations, buildings have to be serviced by an on-site wastewater management system (OWMS) that treats all the household wastewater flows. For these OWMS, the treated wastewater effluent is discharged to a land application area on the property.

As stated above, OWMS are mostly located in rural areas. Therefore, the distribution of OWMS amongst the councils differs depending on the amount of the population living within urban areas in a district. Table 10 below shows the percentage of the population not connected to a wastewater network in each of the regions that participated in the Water New Zealand 2018/2019 National Performance Review. It can be seen that Hamilton City Council which has completely urban population has no OWMS while the Far North and Kaipara which have a high level of the population in rural areas have greater than 60% of their population using OWMS.

Table 10: OWMS usage by Territorial Authority (Water New Zealand, 2019)

Region	Territorial Authority	Percentage of the population not connected to a wastewater network
Northland	Far North	64%
	Kaipara	63%
	Whangarei	40%
Auckland	Auckland	6%
Waikato	Hauraki	44%
	Waipa	34%
	Taupo	29%
	Hamilton	0%
Bay of Plenty	Whakatane	39%
	Western Bay of Plenty	27%
	Rotorua	11%
	Tauranga	10%
Hawke's Bay	Hastings	29%
	Napier	0%
Manawatu-Whanganui	Ruapehu	43%
	Tararua	40%
	Manawatu	39%
	Whanganui	17%
	Palmerston North	2%
Taranaki	Stratford	42%
	New Plymouth	24%
Wellington	Masterton	22%
	Kapiti Coast	12%
	Wellington Water	9%
Marlborough	Marlborough	31%
Nelson	Nelson	0%
Tasman	Tasman	39%
Canterbury	Selwyn	38%
	Ashburton	38%
	Waimakariri	37%
	Timaru	37%
	Mackenzie	12%
	Christchurch	11%
Otago	Clutha	41%
	Waitaki	34%
	Queenstown-Lakes	24%
	Central Otago	21%
	Dunedin	18%
West Coast	Grey	26%
Southland	Gore	12%
	Invercargill	1%

Region	Territorial Authority	Percentage of the population not connected to a wastewater network
	Southland	0%
Overall New Zealand		**21%**

An OMWS is comprised of four components:

1. The wastewater source
2. The treatment plant
3. A dosing system
4. A land application system

Domestic wastewater sources generally come from houses, schools, offices, marae, camping grounds, country huts, and public toilets. Stormwater from roofs and paved areas should not enter the OWMS (Dakers, n.d.).

On-site WWTPs consist of a primary treatment step and increasingly also a secondary treatment step prior to land application.

Primary treatment is most commonly provided by septic tanks. These are single or multiple chamber tanks, usually fitted with an outlet filter, that are buried underground. Septic tanks installed for standard domestic wastewater sources are usually around 3000 litres in capacity.

Septic tanks act as a retention unit that allows for fats/grease/oil to be separated via floatation and solids by settling to the bottom of the tank. This separation allows for there to be a clear zone in the middle of the tank that is free of solids and is able to be discharged to land (Chen & Silyn Roberts, 2018). Over time, sludge and scum will accumulate in the tank, which will reduce effective operation. While the rate of sludge and scum accumulation will vary from source to source, septic tanks are recommended to be pumped out by a contractor every three years to remove sludge and scum (Bay of Plenty Regional Council, n.d.). Sludge at the bottom of the tank will also biodegrade slowly under the influence of anaerobic and facultative bacteria (Chen & Silyn Roberts, 2018). Discharge from septic tanks is usually via a percolation or drainage bed which is a network of buried perforated pipe in a porous bed of material to distribute the partially treated wastewater in a safe manner. The success of the percolation depends on the climatic conditions in the region and uptake of nutrients in the environment. In areas where the soil is clay or rocky, percolation tanks are not an acceptable way to disperse septic tank effluent and secondary treatment is required.

Secondary treatment systems are located after the septic tank and use microorganisms in an aerobic environment to further 'polish' the effluent. Secondary and advanced secondary treatment plants (commonly called package plants) usually involve a number of chambers incorporating components such as, aerators, activated biomass recirculation, contact media, sand and textile filters and occasionally specialised membranes (Dakers, n.d.). Secondary treatment systems produce effluent that is of a higher quality than that produced by septic tanks alone. This is demonstrated in Table 11 where the typical range of effluent produced by a septic tank is compared to an advanced secondary system.

Table 11 Typical range of on-site influent and effluent quality

Parameter (mg/l), (cfu/100ml)	Raw domestic wastewater (influent)	Septic tank effluent	Advanced system effluent (e.g. Aerated WWP)
BOD	210 – 400	120 – 180	15 – 50
SS	220 – 350	60 – 80	10 – 80
TN	45 – 100	45 – 60	20 – 45
NH_4	42 – 90	40 – 50	6 – 40
NO_3	0.5 – 2	0.5 – 20	10 – 35
TP	4 – 18	4 – 12	6 – 10
FC	$10^7 – 10^9$	$10^5 – 10^7$	$10^4 – 10^6$
E coli	$10^6 – 10^7$	$10^4 – 10^6$	$10^3 – 10^5$

Data source: (Treblico, et al., 2012)

The dosing system is the method by which effluent is transported from the treatment system to the land application system (LAS). Older septic tanks do not dose load to the LAS but simply overflow to the LAS when there is an inflow into the septic tank. This is called 'trickle loading'. Trickle loading is now generally discouraged for soakage fields due to the build-up of an anaerobic biofilm within the soakage field (Dakers, 2017). Modern OWMS use pump dosing or gravity dosing equipment (siphons and flouts) depending on the site.

The land application system (LAS) is the method used to discharge the treated wastewater to the land. There are a range of different LAS used in New Zealand including soakage trenches, sand beds, mounded systems, low pressure effluent distribution irrigation, and pressure compensating drip irrigation fields (Dakers, 2017). It is important that the correct type of LAS be used for the site specific conditions. Factors that need to be considered include the available land area and slopes, access, soil types and seasonal soil saturation risks, surface and subsurface drainage characteristics, depth to groundwater, risks to drinking water supplies (surface and subsurface), any site contamination issues, existing or proposed vegetation cover, existing or proposed land use, required setbacks from boundaries, development densities, flooding risks, proximity to protected and sensitive ecosystems (Dakers, n.d.)

1.9.2 Onsite system common failure issues

On-site wastewater failure is where inadequately treated wastewater from an OWMS is released to the environment, creating a risk to environment and public health. (Ministry for the Environment, 2008). Failure can cause unpleasant odours, ponding and a limitation to, or loss of wastewater treatment (Dakers, 2017).

To operate effectively, OWMS need to be designed, installed and operated correctly. The property owner/occupier needs to actively manage what goes into the system and ensure that regular servicing and maintenance is carried out.

Failure of OWMS in New Zealand is most commonly attributed to a lack of regular servicing and maintenance (Roberts & Smith, 2020). This is often due to the property owner not being aware of how to manage and maintain their system. In some cases the property owner is not even aware that they have an OWMS (Mulrine, 2014). Failure due to inadequate management is often due to the user disposing of unsuitable items or chemicals that cause blockages or harm the bacteria in the system. Inadequate maintenance such as not pumping out the tank when required is also a common cause of failure (Ministry for the Environment, 2008). Other causes of maintenance failure include inadequate servicing of pumps, aerators and filters (Dakers, 2017)

Poor design is also an issue that causes OWMS failures in New Zealand (Dakers, 2017). This often occurs at the site and soil assessment phase of the LAS design. Inadequate knowledge of the soil hydraulic capacity can result in the land application system being sited on an area that has poor soakage which causes effluent to pool on the surface. Similarly, siting of LAS on soils with very high soakage rates can result in effluent reaching ground and surface waters too quickly before the soil can renovate the effluent (Ministry for the Environment, 2008). Incorrect sizing of the land application field is another cause for failure that occurs. Changes in the water usage due to the introduction of technology such as washing machines means that some older LAS are too small to cope with modern flows.

Incorrect installation is another factor identified that commonly cause OWMS to fail. One example is when stormwater pipes or open drains are connected by accident or on purpose to the OWMS, which leads to overloading (Ministry for the Environment, 2008). Equipment such as drip lines should also be installed such that it is not in a position where it will likely to be damaged (Dakers, 2020). Treatment units also need to be installed in accordance with the manufacturer's specification.

Equipment will eventually come to the end of its expected lifespan and will start to deteriorate. Old septic tanks are susceptible to developing cracks which results in the discharge of untreated wastewater to the surrounding environment.

The below pie chart (Figure 22) shows the proportion of failure modes across a sample group of 36 failed OWMS (Dakers, 2020). It can be seen that design, site and soil assessments made up the majority of the failures in this sample group.

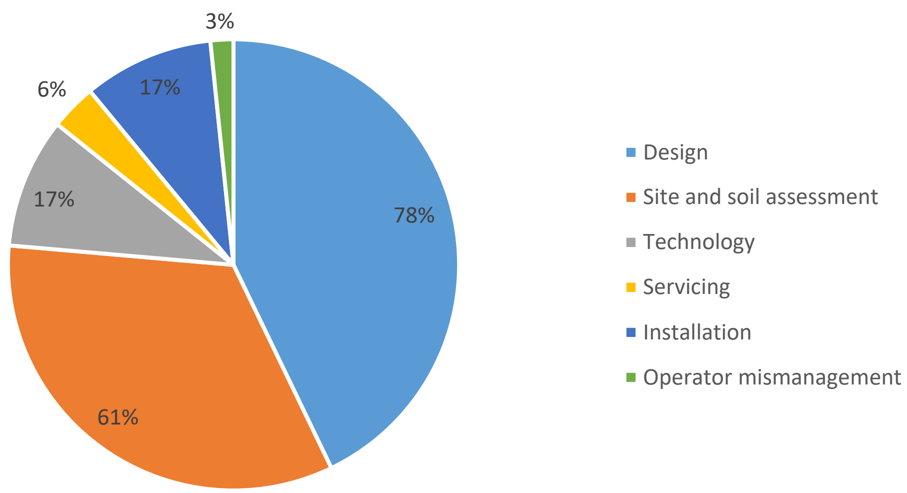


Figure 22: Failure mode proportions of OWMS (Dakers, 2020), note there are overlaps in failure mode, hence total exceeds 100%

Untreated or inadequately treated wastewater discharged from failed OWMS contain elevated levels of contaminants such as nitrate and phosphorus as well as pathogens, viruses and protozoa, that can cause harm to humans and the surrounding environment.

Disease can result from direct contact with the wastewater or the consumption of contaminated drinking water (Ministry for the Environment, 2008).

1.9.3 OSET programme

There is a wide range of on-site wastewater treatment systems for sale in New Zealand. Not all of these products have been able to live up to what the manufacturers/suppliers claim they are able to do.

In 2008, the On-site Effluent Treatment National Testing (OSET) Programme was established by Bay of Plenty Regional Council, Rotorua Lakes District Council, Water New Zealand, and the Small Wastewater and Natural Systems Group (Water New Zealand, n.d.). This programme developed a facility that can test and benchmark up to seven on-site domestic wastewater treatment units annually. The performance certification provided from this testing gives consumers confidence that the systems can work as advertised. However, there are no current regulations in place that require on-site wastewater treatment systems to pass this testing before it can be marketed and sold in New Zealand.

1.9.4 Regulation of onsite wastewater system

OWMS are regulated by the following pieces of legislation:

- The Building Act 2004 – covers the design and installation of OWMS
- The Health Act 1956 – has powers that can be invoked if the OWMS is a public health risk or nuisance
- The Resource Management Act 1991 – controls the environmental effects of discharges
- Local Government Act 2002 – local bylaws

OWMS discharges are regulated through section 15 of the Resource Management Act which states in effect that no person shall discharge on-site wastewater effluent to land or water unless the discharge is allowed by a rule in a Regional Plan or a resource consent. Regional Plan rules are therefore the main vehicle for managing on-site wastewater discharges. However, across the 16 regional councils and unitary authorities in New Zealand, there is a large amount of variation in the rules governing on-site wastewater discharges between the regions. This variation is demonstrated in the below Table 12 and Table 13.

Table 12: Regional Council consent status of domestic on-site systems in New Zealand (2007)

Permitted activity (existing and new systems)	Existing systems permitted, new systems require consent	Primary systems require consent, secondary systems permitted	New systems located in sensitive areas require consent
12 council	3 councils	1 council	5 councils

Date source: (Ministry for the Environment, 2008)

Table 13: Local government management requirements for on-site systems (2007)

Council requirement	Regional councils	Territorial authorities
Regular pump-outs (compulsory)	2 (only for sensitive areas)	3 (through bylaws)
Systems maintained according to manufacturer's specifications (recommended)	2 (only for secondary systems)	
Systems maintained on a regular basis (recommended)	9	
No formal maintenance and inspections requirements (unless consented)	3	71

Data source: (Ministry for the Environment, 2008)

1.10 Managing wastewater network overflows

1.10.1 Background

Wastewater networks convey wastewater to a WWTP. The complexity and scale of the networks operating in New Zealand vary across communities. Many networks include a combination of both old and new sections. While the majority of networks operate using gravity, there is a steady increase in the installation of pressurised systems being retrofitted to older areas of networks or being installed to service new developments. For most networks, the wastewater conveyed is from a combination of residential, commercial and industrial sources. In addition, water commonly enters networks from either infiltration of groundwater or inflow from stormwater/rainfall and via illegal stormwater connections.

Infiltration is water entering the collection system from locations along the collection network through service connections, defective pipes, pipe joints or damaged manhole walls (Figure 23). The surrounding groundwater table is affected by rain events and the percolation of water through the ground from rivers and other water bodies. The character of the ground surface, soil formation, and the rate and distribution of rain events determine the percolation rate and varies from area to area. Permanently high groundwater tables cause continuous leaks into the network, especially for aged and damaged parts of the pipe network.

Inflow is stormwater entering the collection system from incorrect connections or as part of the combined collection system or ponded water on manholes and pump stations lids (Figure 23). Inflow causes an almost immediate increase in wastewater flowrates.

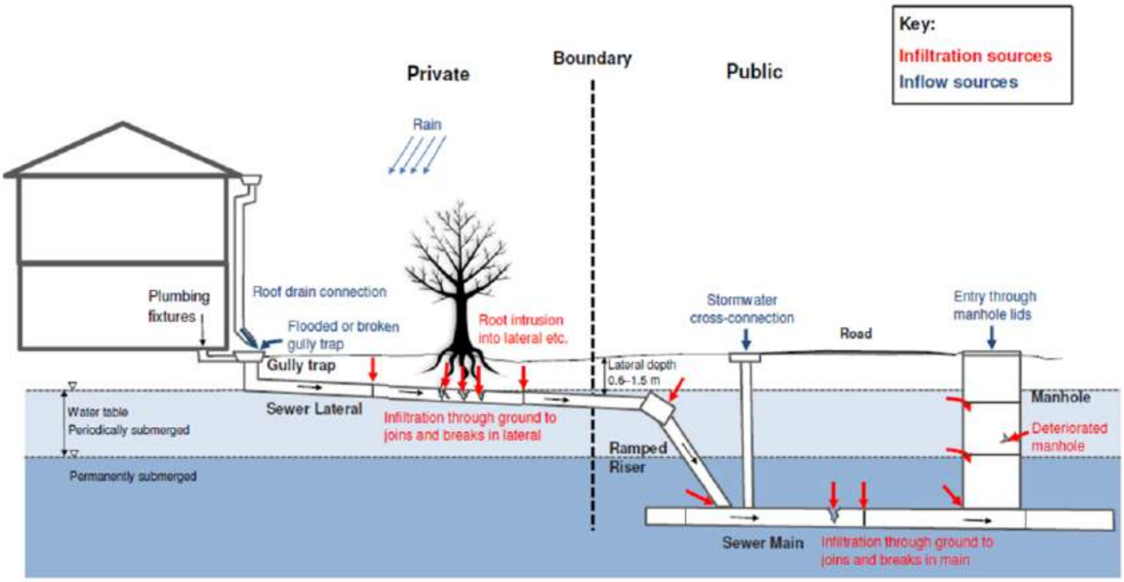


Figure 23: Schematic diagram of wastewater network infiltration and inflow sources adapted from Opotiki District Council (2019)

The load from inflow and infiltration often causes total inflows to exceed the capacity of the network; and for this reason many systems incorporate engineered overflow points.

In these circumstances, networks are designed to overflow to ensure that sewage does not back up and flood areas that would cause significant health risks, such as private homes or commercial premises, or cause wider environmental damage.

In some parts of New Zealand, wastewater networks are specifically designed to overflow to the stormwater system in rainfall events. In other situations, the wastewater and stormwater networks are combined and incorporate designed overflow points to receiving waters when it rains. Overflows from combined networks are called a combined sewer overflow (CSO's).

Combined systems are no longer constructed, and in cases where they exist, the network owners are working to eliminate them over time by separating the stormwater to a separate sewer system.

Wastewater networks are not designed for the discharge of dry weather flow, which is wastewater plus any groundwater infiltration within the system flowing in dry conditions. However, overflows of networks can occur due to various failures within a system such as a pump failing or more commonly system blockage. This type of overflow is a dry weather overflow.

Wastewater overflows are classified as per the definitions provided in Table 14.

Table 14: Wastewater overflow definitions

Wastewater overflow Type	Description
Dry weather overflow	Overflows from system failure, which normally would be either blockage or pump failure.
Combined sewer overflow	Overflows from combined stormwater and wastewater networks are combined sewer overflows. These combined systems are no longer constructed. However, some historic wastewater networks do overflow to the stormwater system in rainfall events or are design to convey combined stormwater and wastewater flows. Overflow points to either the coast or freshwater are included in these systems and designed to operate when it rains.
Uncontrolled wet weather overflow	Uncontrolled wet weather overflows are those that occur within a network in places that were not designed to overflow e.g. via manhole lids.
Controlled wet weather overflow	Controlled wet weather overflows in a network such that in rainfall events, where system capacity is exceeded, the overflow goes to a designated location – often a stream or river.

The rate and frequency of overflows from wastewater networks varies across New Zealand. In many municipalities' network owners are operating systems that were constructed more than 50 years ago and are managing associated issues with degradation (causing infiltration) and lack of capacity to deal with population growth.

1.10.2 Water New Zealand Performance Benchmarking

Water New Zealand (Water NZ) co-ordinates a voluntary National Performance Review (NPR) through an annual benchmarking exercise that covers drinking water, wastewater and stormwater service delivery. The NPR is undertaken "*to provide water service managers and stakeholders with comparable data of drinking water, wastewater, and stormwater service delivery across New Zealand*" (Water New Zealand, 2019). The latest available report (for the period of 2018 to 2019[2]) included data from 44 councils or council-controlled organisations. The participants preside over 91% of the New Zealand population.

[2] Data source for the 2018/19 NPR: wwww.waternz.org.nz/NationalPerformanceReview

The NPR report distinguishes between dry-and wet-weather wastewater overflows. Dry-weather overflows occur due to either pipe blockages or system failures. Wet-weather overflows occur during rainfall events. The location of the overflow can be gully traps, manholes, pump stations, engineered overflow points, waterways or the sea. The NPR data for the 2018/2019 period[3] are summarised below (Table 15).

Table 15: Total wastewater overflows for the 2017/2018 data period

Overflow type	Frequency
Dry-weather overflows	1164
Wet-weather overflows from combined networks	343
Wet-weather overflows from wastewater networks	744
Total Wastewater overflows	2251

According to the NPR report, network blockages were the main cause of the dry-weather overflows during the recorded period Figure 24.

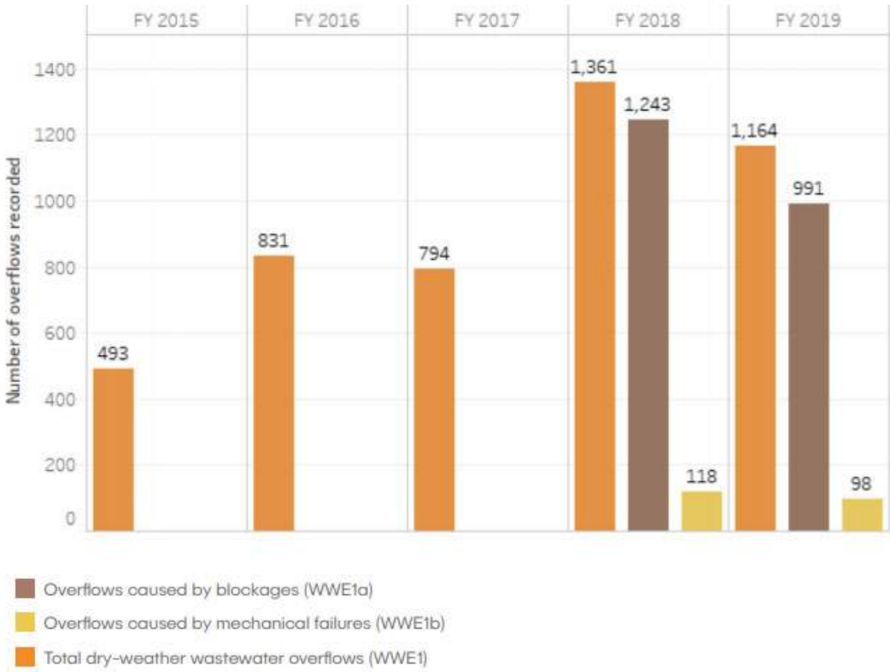


Figure 24: Dry weather overflows adapted from Water NZ (2020)

The report notes that in 2018-19 more than 1,000 wastewater overflows were wet weather events. Increases in the number of wet-weather overflows for the periods from 2016-17 and 2017-18 (Figure 25) were due to some parts of New Zealand experiencing more extreme rainfall events, while 2018-19 was generally a year of normal or below normal rainfall.

[3] Data source: https://www.waternz.org.nz/wastewateroverflows

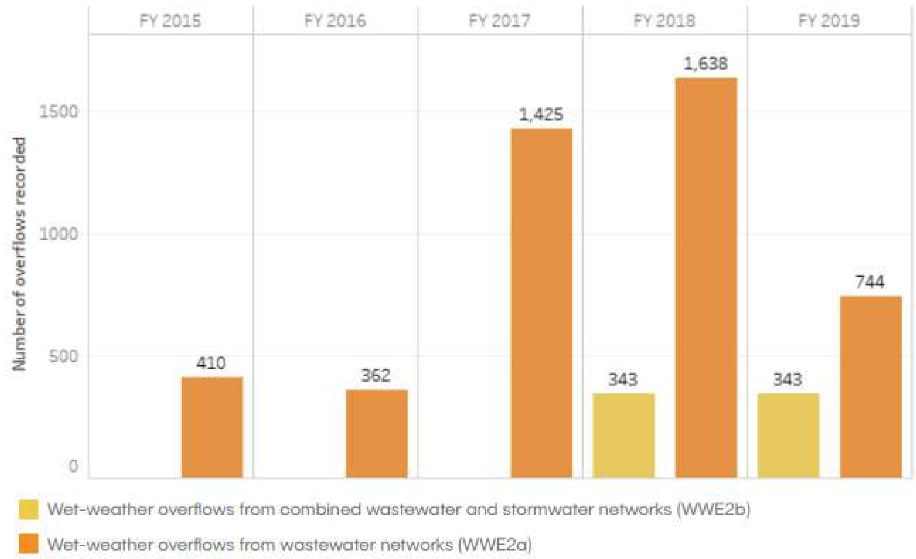


Figure 25: Wet weather overflows adapted from Water NZ (2020)

Tracking of overflows occurs through a combination of hydraulic models, monitoring and verbal reports from either staff or the public. The NPR identified that not all participants have a specific system target in relation to overflows; and where these are in place there is significant variability. There is a strong correlation between improved overflow recording methods and the number of wet-weather overflows reported. With a quarter of participants relying on verbal reports (Table 16) this indicates wet-weather overflows may have occurred more frequently than reported.

Table 16: NPR participants approaches to overflow recording

Overflow recording approach	Number of participants
Overflows recorded through verbal reports	37
Overflows recorded through SCADA monitoring	24
Overflows calculated through hydraulic models	15
Overflows calculated through calibrated hydraulic models	11
Unspecified	3

In reporting on wastewater overflow data quality, the NPR auditor (AECOM) commented that: "*We believe that the industry in general has poor information/knowledge of the performance of the wastewater and combined sewer networks during wet weather, which causes problems in getting good quality, consistent answers to questions on wet weather overflows from the wastewater network, wet weather overflows from combined stormwater and wastewater networks, sewage design standards and average calculated wet weather overflow frequency* (Water New Zealand, 2019)

1.10.3 DIA Study 2019

In addition to the NPR, GHD and Boffa Miskell completed a study for DIA on the regulation, controls and extent of wastewater overflows in New Zealand in 2019. (GHD, Unpublished)

The study investigated the condition, performance and consenting status of wastewater networks in New Zealand using the following sources:

- Water NZ NPR (2017/18)
- Data collected from councils about their networks, including information about frequency of overflows, knowledge about condition of networks, hydraulic modelling in place - 2019

The study also sought to improve the understanding of the regulation frameworks in place to manage the effects of wastewater network overflows and the cost associated with significantly decreasing the frequency of wet weather overflows.

Key findings and conclusions from the unpublished report included:

- There are no common definitions of what constitutes an overflow event nationally, with many councils employing different ways of counting overflows.
- The study highlighted that councils have varying degrees of knowledge of their wastewater networks including where their overflows occur (uncontrolled) and what events trigger them.
- Moreover, of the 34 councils that participated in this report, only nineteen indicated they have monitoring arrangements in place for overflows. For this subset, the levels of coverage and sophistication varied widely. The majority relied on telemetered systems for pump stations and reporting from the public for overflows elsewhere in the network. Only two participants identified that they had any form of electronic monitoring located at constructed overflow points.
- The minority of councils have conducted network modelling.
- In terms of reducing overflow occurrences, it is clear that many councils are on a journey of continual improvement, and a few councils are working towards a set target of overflow reductions.
- It is evident that there is considerable variability across New Zealand in relation to the regulation of wastewater overflows. Significantly, there is a lack of alignment between Regional Plan rules and the reality of wastewater overflows in some regions where they are prohibited.
- Current monitoring practices, knowledge of networks, and the wide range of approaches to regulation of wastewater overflows mean that under current settings it would not be possible to benchmark regions or engage in basic performance improvement metrics to drive better performance. Consistency in approach across all these areas would lead to considerable benefits.
- The summation of the information received is that there is a wide variation in council positions on budget planning for wastewater overflow reduction.
- There are a number of councils that do not currently hold sufficient detailed knowledge of their networks to predict where overflows currently occur and to develop options and associated cost estimates to meet a specific overflow target.

The report concluded that given the multiple ways in which a network can overflow, and the openness of the system complete elimination of wastewater overflows from networks is likely an unrealistic expectation.

However, for many communities, with better knowledge of networks, and upgrades to infrastructure, the frequency of wastewater overflows could be lowered significantly while safeguarding health and the environment. Alongside this, community expectations about overflows are changing, and many communities now express a preference for little or no discharge of sewage into freshwater, land or beaches. For Māori, there is widespread abhorrence of discharge of sewage to water, both for cultural and spiritual reasons, alongside the risks posed to mahinga kai.

1.10.4 Current wastewater overflow practice in New Zealand

The current practice to reduce the impact of wastewater overflows includes more flexibility in pump station design, treatment of wet weather flow in the wastewater network and specific wet weather flow treatment at treatment plants. Two case studies below highlight some of these current practices.

Case Study – Whangarei Wet Weather management practice

Whangarei District Council (WDC) constructed a multi-purpose pump station at Hatea. The pump station site is low-lying, adjacent to Hatea River, and in close proximity to a park reserve. During wet weather events, the flow to the pump station is significantly higher (>250 L/s) than the original pump capacity of 120 L/s, which caused overflows into the nearby river approximately 6 to 10 times per year on average.

Figure 26 Hatea pump station structure

In an effort to reduce overflow in the wastewater network, WDC replaced the original pump station with multi-purposes infrastructure, including a pump station, a flow storage tank and a storm flow treatment unit prior to discharge. The new pump station is a multi-storey structure comprising of UV, switchboards and a chemical storage room in the ground floor. The valve gallery in the first basement floor is accessible from the ground floor via a staircase. The pump wet well and a 1000 m^3 storage tank are located directly below the valve gallery floor.

During wet weather flows, when the incoming flow exceeds the wet well level storage and pump capacity, storm wastewater is diverted into the storage tank. A fine screen is placed upstream of the storage tank to retain coarse solids within the wet well.

If the wet weather flow continues and the storage tank level is rising, the UV units will begin a warm-up sequence and will start treating the storm wastewater prior to discharge into the Hatea River. Since the new pump station became operational in 2012 the number of overflows (treated storm wastewater) has reduced to 2 times per year.

Figure 27 Hatea pump station internal (left) and UV (right)

In addition to the construction of offload sites such as the example above, WDC also has a parallel treatment train at the Whangarei WWTP to specifically handle the high flows from the wet weather events. The current dry weather flow is below 21,000 m³/day and the extreme wet weather flows can reach up to 140,000 m³/day. This is the reason for the parallel treatment train. This comprises screening, partial primary and secondary treatment prior to UV disinfection. Discharge is to Limeburners Creek.

Figure 28 Whangarei WWTP peak flow UV system

Case Study – Taupo urban sewer risk identification and prioritisation

Taupo District Council (TDC) commissioned GHD to develop a Pipe Spatial Analysis Tool that assists TDC to understand and prioritise risks associated with their underground pipes based on a range of attributes. A portal was created to apply geospatial analysis with multi-criteria analysis. The portal enables different users in TDC to identify and visualise potential high risk pipes under a specific set of criteria.

The analysis has taken a range of environmental and non-environmental factors into account. This includes flooding, geology, fault lines, streams, asset age, pipe materials and interaction with other infrastructure (e.g. buildings, roads and utility services).

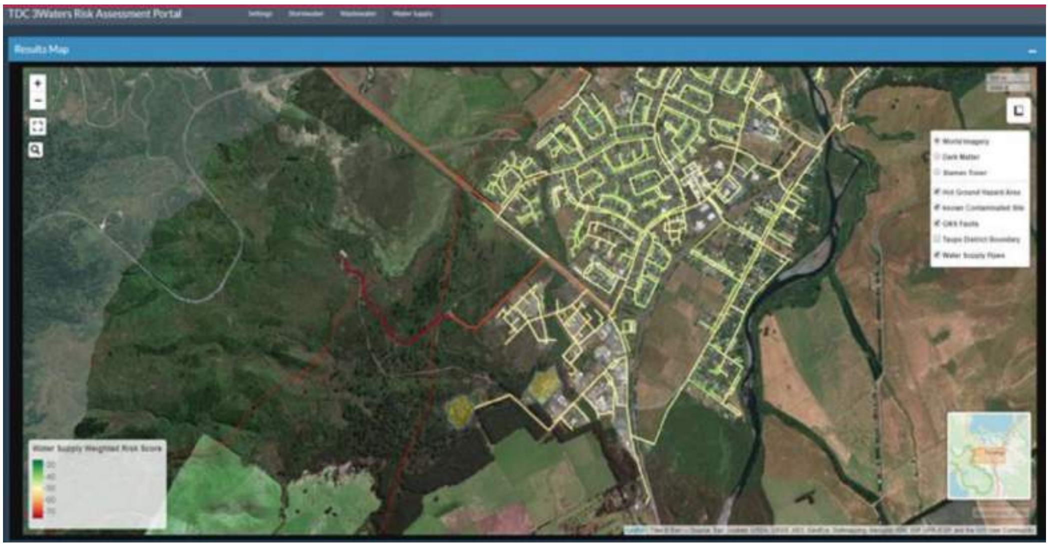


Figure 29 Taupo underground 3 Waters pipe GIS portal

By adjusting the weighting of the criteria, TDC engineers and managers can appreciate the risk sensitivity through an easy to understand visual output.

Moreover, this tool will be utilised for future asset renewal and upgrade planning. The TDC team will increase the database over time for operational/performance criteria, e.g. the number of calls for service and the respective spatial location.

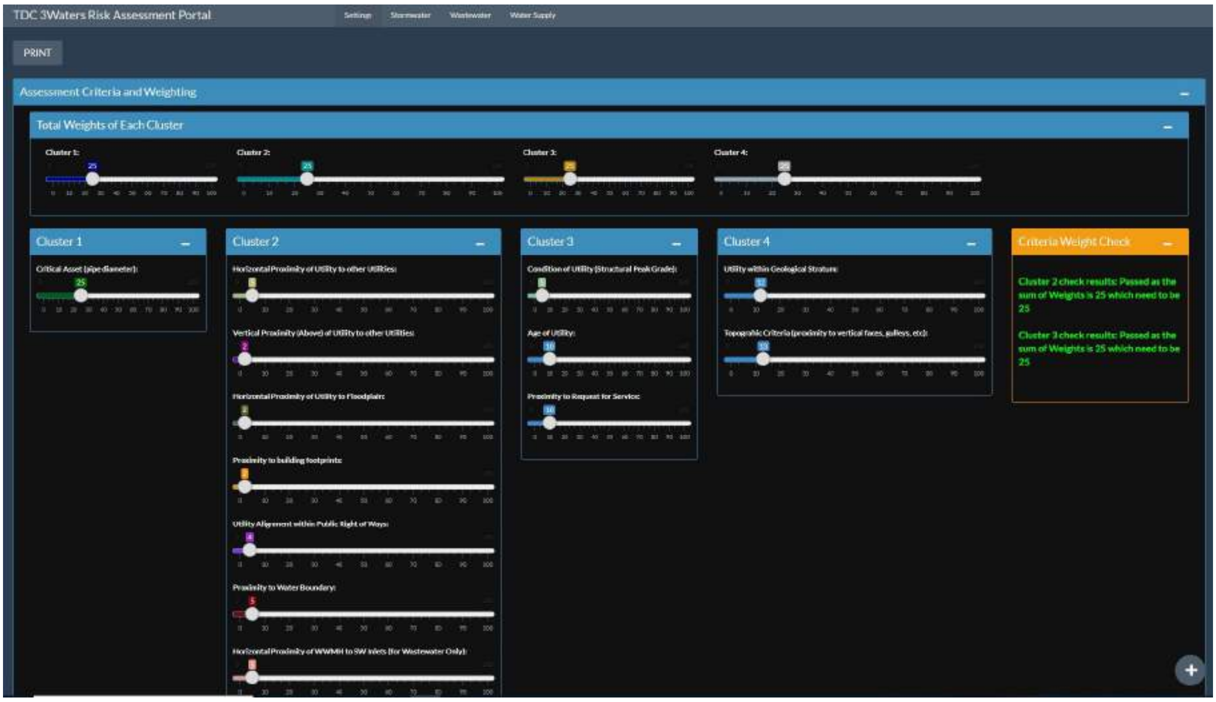


Figure 30 Criteria weighting adjustment

1.10.5 Emerging practices for managing wastewater network overflows

There are a range of emerging practises relating to wastewater overflow reduction. These fall into the following categories:

- Increased community education
- Network optimisation

- Real time controls

The following sections provide a brief overview of these practises.

1.10.6 Community education

Councils are increasingly focussing on community education as a measure to reduce overflows.

As highlighted in Section 1.2.2, dry weather blockages are caused by disposal of unsuitable items by members of the community and industries. Many local councils have adopted a community education program to inform the public members not to dispose of items which could cause blockages in their sewer laterals or the public wastewater network. Below is an example published by Hamilton City Council.

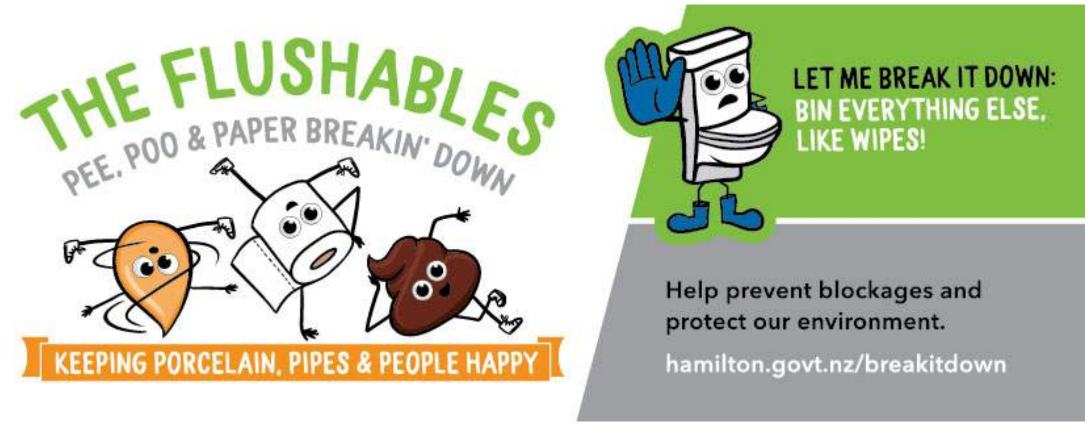


Figure 31 Example wet wipe outreach poster (Source: Hamilton City Council)

1.10.7 Wastewater network optimisation

Network optimisation, through developed of hydraulic models accurately representing wastewater networks is another tool. Table 17 presents an example of the data required for a network optimisation approach in the elimination of wastewater overflows.

Table 17: Example of a Smart Data Infrastructure approach – elimination of wastewater overflows

Cause of overflow	Potential intervention	Data requirements for network optimization
Rainfall-derived Infiltration and Overflow (I/I) Undersized pipes *(Wet weather overflows)*	• Pipe replacement • I/I mitigation measures	• Level and flow measurements • Sewer and land characteristics • Cost of potential solutions
Grease, debris, and sedimentation build up *(Dry weather overflows)*	• Improved operating cleaning and maintenance procedures • Pipe replacement • Flushing systems	• Level, velocity, and flow measurements • Camera Inspection • Cost of potential solutions
Pipe breaks, leaking manholes and offset joints *(Dry weather overflows)*	• Repairs • Pipe replacement	• Flow measurement • Camera inspections • Smoke Testing • Cost of potential solutions

1.10.8 Smart data infrastructure

Smart data infrastructure is the combination of emerging and advancing technology to enhance the collection, storage and/or analysis of water-related data. The United States Environmental Protection Agency has produced a [4]document relating to Smart Data Infrastructure for wet weather control and decision support with the focus of the document on how councils can implement these systems using advances in technology. The document also describes how advanced monitoring data can support councils with wet weather control and decision-making in real time.

Smart data infrastructure can inform operational decisions that ultimately improve the efficiency, reliability, and lifespan of physical assets (pipes, pumps, reservoirs, valves) by:

- Maximising existing infrastructure and optimising operations and responses to be proactive, not reactive
- Providing savings in capital and operational cost
- Improving asset management and understanding of collection and treatment system performance
- Improving long-term control plan implementation, modification and development
- Meeting regulatory requirements
- Prioritising critical assets and future capital planning
- Providing the ability to better optimise collection system storage capacity to reduce peak flows and the occurrence of overflows
- Enabling effective customer service and enhancing public notification

The two key focus areas for implementation are the optimisation of existing networks and the use of Real Time Control (RTC).

1.10.9 Real Time Control (RTC)

RTC is a system that dynamically adjusts facility operations in response to online (live) measurements in the field to maintain and meet operational objectives using both dry and wet weather conditions. For optimal use of RTC the wastewater system is over designed to provide a factor of safety. This extra network capacity provides short-term storage when rain falls unevenly across the collection system and varying runoff lag times that introduce stormwater into the system apply.

RTC presents opportunities to optimise full system capacity for both existing and proposed facilities.

[4] EPA 830-B-17-004

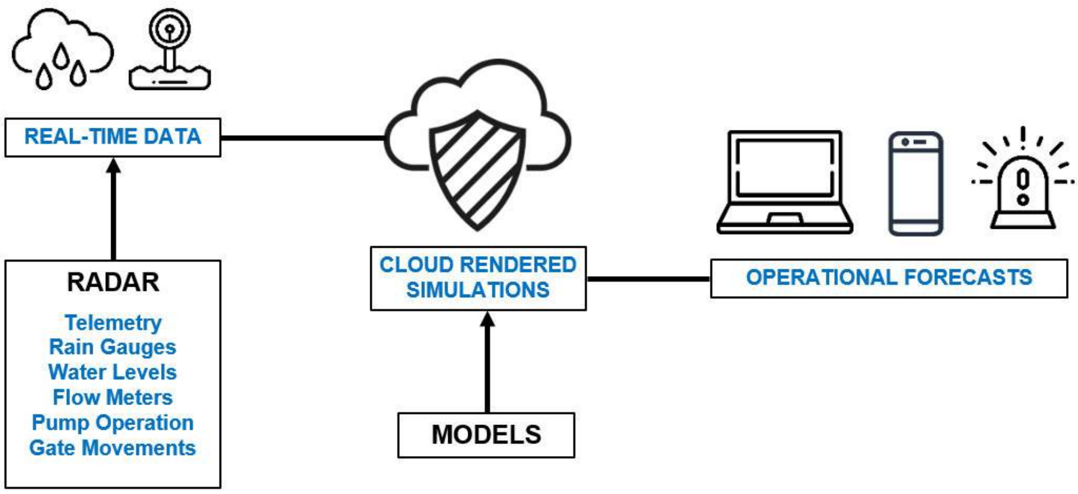


Figure 32: Schematic of RTC system process

A well-designed RTC system can address a number of different operational goals at different times. Examples of operational goals include

- Reducing or eliminating sewer backups and street flooding
- Reducing or eliminating wastewater network and combined sewer network overflows
- Managing/reducing energy consumption
- Avoiding excessive sediment deposition in the sewers
- Managing flows during a planned (anticipated) system disturbance (e.g.major construction)
- Managing flows during an unplanned (not anticipated) system disturbance, such as major equipment failure or security-related incidents
- Managing the rate of flow arriving at the WWTP

Recent examples of RTC control use includes the Buffalo Sewer Authority CSO control (GHD , March 2019)

1.11 Biosolids and byproducts management

1.11.1 Biosolids

Primary and secondary biological wastewater treatment processes produce solids from the biological treatment processes. Sources of solids generated from treatment processes are:

- Lagoon solids removed intermittently
- Raw primary sludge from primary settling tanks
- Humus sludge sloughed from trickling filters
- Waste activated sludge from secondary processes
- Solids from tertiary treatment (e.g. filtration of secondary effluent)

All of these are biosolids. Out of 318 active WWTPs in the country, there are 83 based on either activated sludge or trickling filters, as described in Table 7.

Biosolids disposal and reuse requires management and stabilisation of contaminants.

1.11.2 Biosolids Guidelines

The 2003 “Guidelines for the Safe Application of Biosolids to land” is the go-to information source in terms of biosolids grading and practice for land application. Under this 2003 guideline, there are two stabilisation and two contaminant classification grades. This guideline will be replaced by “Guidelines for Beneficial Reuse of Organic Materials on Productive Land”, currently being finalised after consultation (Water New Zealand, 2019 Consultant Draft).

The proposed new guideline has broadened its scope to cover a range of organic-rich materials including household organic waste, pulp and paper waste etc. It also has a simpler grading system for contaminants than the previous 2003 guideline.

The proposed new guideline contains two volume:

- **Volume 1 Guide** – this document describes the “how to” of reuse application of organic materials, including the revised grading system, risk management, sampling and monitoring, transportation, storage and land application practices.
- **Volume 2 Technical Manual** – this volume is a supporting technical document to Volume 1, explaining the derivation of limits and explanatory notes of the regulatory framework and recommendations.

The proposed new guideline has simplified the grading of biosolids as in Table 18.

Table 18 Proposed new organic waste grades

Type/Grades	Stabilisation Grade	Contaminant Grade
A1	Grade A	Compliant
B1	Grade B	Compliant
A2	Grade A	Non-Compliant
B2	Grade B	Non-Compliant

Stabilisation Grade refers to a substantial reduction or removal of pathogens and vector-attracting compounds (e.g. unstable organics and odour) in biosolids and organic wastes. Stabilisation Grade A typically involves thermophilic anaerobic digestion, a thermal process (e.g. drying at elevated temperature), thermal treatment, or high pH process (e.g. lime addition/stabilisation). Mesophilic anaerobic digestion and aerobic digestion comply with Stabilisation Grade B. A non-classified grade is when biosolids do not meet Stabilisation Grade B.

For the product verification phase, Grade A biosolids must meet the following pathogen quality criteria:

- E. coli <100 MPN/g
- Campylobacter <1/25 g
- Salmonella <2 MPN/g
- Human adenovirus <1 PFU/0.25 g
- Helminth ova <1/4 g

Routine monitoring of biosolids stabilisation is via the vector attraction reduction (VAR) measurements (for both Grade A and B) and E. coli (Grade A only).

Contaminant Grade refers to whether biosolids and/or organic waste contain metal and organic contaminants above the proposed guideline limits. Similar to the Stabilisation Grade, an intensive sampling program is required during the 3 month product verification phase, followed by a reduced testing frequency during the routine sampling phase.

The grades of the biosolids will dictate the recommended control for specific land reuse application. Examples of land use include:

- Food crops that can be consumed by human unpeeled or uncooked
- Public amenities, sport fields, public parks, golf courses, playgrounds and land reclamation
- Fodder crops, orchards
- Pasture, turf farming, non-edible crops
- Forest, trees or bush scrubland.

The proposed guideline has recommended a number of management plans to manage the risks associated with biosolids quality assurance and land application.

1.11.3 Quantities of biosolids in New Zealand

On behalf of WaterNZ, Rob Tinholt from Watercare undertook a survey of 16 utilities relating to biosolids processing and disposal (Tinholt, 2019). The survey covered 23 WWTPs each with a connected population of over 25,000 people, in order to understand the volume, treatment and disposal/reuse routes of biosolids.

The survey identified that the selected group of WWTPs generated approximately 300,000 wet tonnes of biosolids per year, with a typical dry solids content of 18% (i.e. 82% moisture). Only four facilities employ thermal drying to achieve 90% or higher dry solids (i.e. 10% moisture). The annual cost of processing, transport and disposal of biosolids is in the order of $40M.

Figure 33 (Sankey diagram) shows the biosolids in weight percentage treated by different treatment steps and disposal routes.

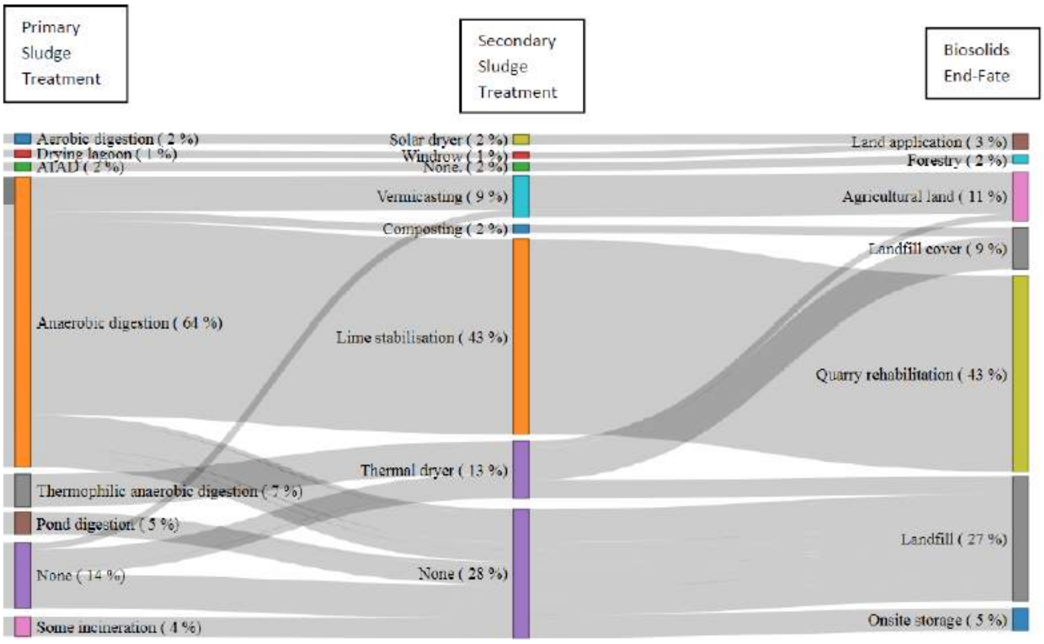


Figure 33 Biosolids treatment and disposal routes in New Zealand from 23 of the largest treatment plants (Tinholt, 2019)

The above diagram shows anaerobic digestion processes (mesophilic and thermophilic) produce the largest quantities of biomass, being approximately 71% by mass. There are 16 WWTPs in New Zealand that have anaerobic sludge digesters on site.

The Mangere WWTP employs lime stabilisation to further stabilise/treat the biosolids prior to quarry rehabilitation in the Puketutu Island. Other forms of sludge digestion (e.g. aerobic digestion and ATAD) process a much smaller quantity of biosolids.

Vermicomposting is used in a number of locations including Taupo, Rotorua and the Western Bay of Plenty district. These locations have good access to forestry and pulp and paper products, providing the required high carbon feed source necessary for vermicast. Vermicomposting is a recognised stabilisation method to achieve Grade A in the proposed guideline.

The survey also identified that undigested sludge represents 14% of the total biosolids surveyed, and all of this goes to landfill. Excluding quarry rehabilitation reuse in the Puketuhu Island and landfill day-cover, only 16% of biosolids are beneficially reused. This percentage is much lower than countries such as Australia, the UK and the USA.

There are several facilities in New Zealand with sludge drying. Examples include Pines WWTP (solar drying), Bromley and New Plymouth (thermal drying). Sludge drying will increase the stabilisation to Grade A, but there is a high-energy cost associated with thermal drying.

Several perceived barriers limiting biosolids reuse in New Zealand include:

- Biosolids is generally viewed as a low value and high volume process
- Low landfill levy ($10/tonne vs $100 to 140/tonne overseas)
- Limited practice of co-composting with green waste
- Lack of secondary sludge treatment to lift pathogen protection from Grade B to Grade A, reducing odour and handling, or reducing metal/organic contaminants;
- Strong focus of managing biosolids as a “disposal” problem or “operation compliance”, instead of through the lens of circular economy or product/resource recovery
- Perceived risk of applying biosolids to productive land

Figure 34 below reproduces the photos for a soil remediation case study in West Coast, in Rob Tinholt's Water NZ presentation 2019.

Figure 34 West Coast case study before soil remediation (left) and after biosolids applied (right) (Tinholt, 2019)

1.11.4 Emerging trends and issues related to Biosolids management

Several emerging trends will affect biosolids management in New Zealand, and some ideas came from the interview with Rob Tinholt:

- **Zero Waste Vision** – the zero waste vision across New Zealand will limit disposing sludge to landfills. A landfill levy hike of $60 has been proposed. Alternative routes including biosolids reuse will have to be examined more thoroughly (Tinholt, 2020).
- **Growing interest in non-chemical fertiliser** – there has been growing interest in reducing or eliminating the use of manufactured fertilisers, because of environmental and social concerns. Nitrogen based fertilisers are manufactured using the Haber Bosch process reacting hydrogen from natural gas with nitrogen from air under high pressure and temperature. Phosphorus based fertilisers mainly come from processing phosphate rock which is depleting globally. Soil conditioning and nutrient-rich properties of biosolids may result in a large uptake of applying well-treated biosolids to land (Tinholt, 2020).
- **Increase in biosolids volume** – the combination of population growth and more stringent discharge limits are likely to result in conversion of existing treatment ponds to high-rate activated sludge processes (GHD and Boffa Miskell, 2018). These new upgraded WWTPs plants will generate more biosolids, requiring appropriate management and reuse. As biosolids management becomes more expensive and challenging, this may drive changes including improved treatment processes.
- **Water Regulatory Reforms and consolidation of facilities** – The proposed reform may result in consolidation and agglomeration of water services providers across New Zealand. The consolidation of water services providers is intended to create centres of skilled water professionals and may also lead to establishment of regional treatment and/or biosolids facilities. While some of these facilities may service only a relatively small regional population in the order of 10,000 to 30,000, they can still present potential opportunities for more sustainable biosolids management practices.
- **Intensification of sludge digestion** – Process intensification of sludge digestion is a significant driver resulting in more optimised sludge digestion configurations and performance including sludge hydrolysis via thermal or ultrasound, recuperative thickening and others. The processes not only increase the digester process capacity, but also improve volatile solids destruction, biogas yield and stabilisation from the anaerobic processes.

- **Carbon diversion to sludge digestion** – As wastewater treatment is increasingly being viewed as a resource recovery facility; more carbon may be diverted into the sludge stream for energy and materials recovery. This will also lead to a larger quantity of biosolids.
- **CECs and PFAS** – As explained in Section 1.12.3, the public have expressed concerns over emerging contaminants including PFAS. There is a significant knowledge gap in identification and understanding of the health impact of individual compounds. Australian and New Zealand Biosolids Partnership (ANZBP) has commissioned a review to understand PFOS and PFOA (perfluorooctanoic acid) in biosolids (ANZBP, 2017). The study entailed a survey of 13 wastewater treatment facilities with 100 samples tested, of which 17 biosolids samples were below non-detectable limits. The study concluded, "*PFOS and PFOA are generally presented in biosolids at detectable levels in Australia*" and "*PFOA was significantly lower than the Health Investigation Levels suggested by the Australian Government Department of Health*". The study recommended a PFOS limit in biosolids for unrestricted use and agriculture use to be 0.3 and 4.2 mg/kg respectively.

Sludge incineration is common in northern Europe and large metropolitan cities. There are other thermal processes such as gasification, lower temperature liquefaction and others. A more novel biosolids process is to produce Biochar, a carbon enriched by-product from drying and pyrolysis of dewatered biosolids. Figure 35 is re-produced from a GHD presentation to a US-based municipality. Both sludge incineration, thermal processes and Biochar technology are viewed as less viable for future biosolids management in New Zealand because of a lack of expertise and similar processes in the Australasia region, and smaller population bases.

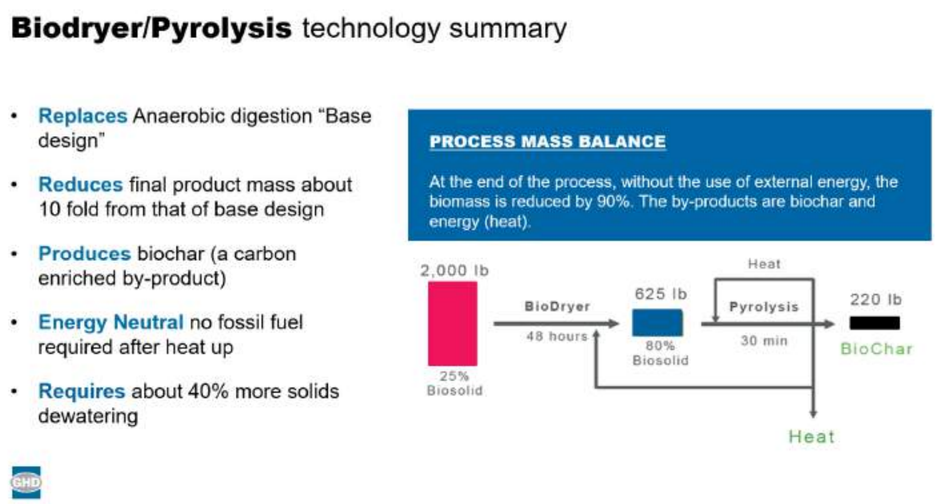


Figure 35 Biochar technology overview (GHD, 2019)

1.11.5 Biogas

Biogas from wastewater treatment

Anaerobic treatment generates biogas as a by-product to the degradable organic waste. Biogas typically comprises 60-65% methane, with a balance of carbon dioxide, moisture and a number of gaseous impurities. Anaerobic reactors are common in treating high strength organic wastes (e.g. dairy or food waste) and in sludge digestion.

Anaerobic ponds in municipal WWTPs are often uncovered; and biogas is not captured and able to escape to the atmosphere through the surface crust of the ponds.

There are about 16 treatment facilities with anaerobic digesters and co-generation that reuse biogas (Calibre, 2018). Biogas from the anaerobic digestion process is used for hot water heating, or power generation via co-generation engines. Excess biogas is flared off through a gas flaring system.

Co-generation engines often require impurities in the biogas to be removed to prolong the engine turbine. Removal of biogas contaminants is therefore highly important. Typical examples include:

- Water/moisture – Removal of water is often via a gas dehumidifier to create a dry biogas
- Hydrogen sulphide – Removal of H_2S in biogas is often via water and caustic scrubbers, activated carbon filters and iron sponge scrubbers
- Siloxanes – Removal of siloxanes is often cooling, and includes an adsorption process with media made of activated carbon or activated alumina

Figure 36: Biogas co-generation engine (left) and Biogas flare (right)

Methods to improve biogas production

Below are two common practices to boost biogas production from anaerobic digestion (Solley, et al., 2018):

1. Optimisation of digestion mixing and pre-thickening, this reduces dead zones and extends retention time inside the digesters.
2. Co-digestion of food and organic waste which has a higher energy value (biodegradable organic content), example is Palmerston North WWTP
3. Improve digestability of the feed sludge into the digesters, an example process is thermal hydrolysis (THP), Oxley Creek WWTP in Brisbane (Figure 37)

In 2016, Watercare set an energy neutral target for the Mangere and Rosedale WWTPs by 2025 (EECA, 2016). A THP upgrade is currently under design for Rosedale WWTP, which will not only significantly increase biogas production, but also create additional digester capacity and drier more stable biosolids for offsite disposal.

Figure 37 Oxley Creek WWTP thermal hydrolysis plant

Alternative biogas uses

In addition to producing biogas from anaerobic digestion or anaerobic processes, there are a number of alternatives, including:

- **Upgrade of biogas to bio-methane (**a renewable natural gas) - biogas is refined and purified into methane by separating carbon dioxide through a membrane process (IEA, March 2020)
- **Hazer process** – this process converts biogas into hydrogen gas and graphite. Water Corporation in Western Australian (Renew Economy, 2020) recently provided funding to develop this technology into a demonstration pilot facility with a target production of 100 tonne per year of hydrogen gas and 380 tonne per year of graphite.

1.12 Contaminants of Emerging Concern

Contaminants of Emerging Concern (CECs) are chemicals and other substances that have recently been 'discovered' in natural water bodies, can potentially cause adverse ecological and human health impacts and are not currently regulated by environmental law (U.S. Environmental Pretection Agency, 2008).

CECs are not necessarily new chemicals. They are often pollutants that have been in the environment for some time and their presence and significance is only now being investigated. Endocrine disrupting chemicals, microplastics and per- and poly-fluoroalkyl substances (PFAS) are three types of CECs that have received widespread public interest recently both overseas and in New Zealand.

1.12.1 Endocrine disrupting chemicals

Endocrine disrupting chemicals (EDCs) are natural and synthetic chemicals that interfere with the endocrine (hormone) system of animals. At high enough concentrations, EDCs can produce unwanted effects on development, behaviour, fertility and normal metabolic function (Scognamiglio, et al., 2016). Scientific research of EDCs has been undertaken for the last 20 years and has led to a better understanding of some of these chemicals.

Some of the well-known EDCs and their effects on humans are shown below in Figure 38.

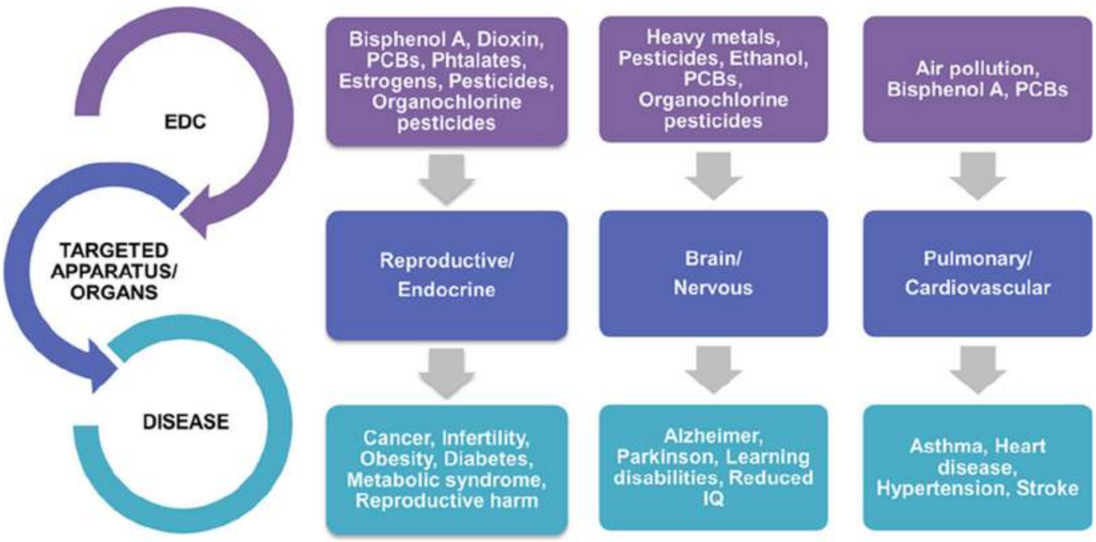


Figure 38: Endocrine disrupting chemical effects (Scognamiglio, et al., 2016)

Some research has been done on how to effectively remove EDCs from wastewater. For instance, research has been completed on quantifying removal of estrogens (a type of EDCs) in wastewater treatment processes. The natural and synthetic estrogen estrone (E1), 17β-estradiol (E2) and 17α-ethinylestradiol (EE2) are endocrine disruptors found in wastewater that can produce estrogenic effects such as the feminisation of fish when discharged to an aquatic environment (Koh, et al., 2008). Studies of estrogens at WWTPs have found that secondary treatment processes are effective at reducing estrogen concentrations. Microorganisms present in these processes consume the estrogens as a carbon source (Koh, et al., 2008). Activated sludge processes have demonstrated high estrogen removal rates for E1, E2 and EE2 at 61%, 86% and 85% respectively (Baronti, et al., 2000).

A minimum sludge retention time of at least 10 to 12.5 days is suggested as the period required for the growth of organisms that decompose E2 and E1 (Koh, et al., 2008). MBR plants have shown estrogen removal rates of greater than 90% in MBRs with nitrification and denitrification

(Joss, et al., 2004). Estrogen removal by trickling filter processes have been found to be less consistent.

New forms of wastewater treatment such as Advanced Oxidation Processes (AOPs) may also provide solutions to the EDC problem. AOPs rely on the action of hydroxyl radicals, which are highly reactive species, to oxidize recalcitrant and non-biodegradable pollutants. EDC degradation yields have reported to be high (80 – 90%) but the technology has issues with the formation of toxic by-products and high operating costs (Cesaro & Belgiorno, 2016)

1.12.2 Microplastics

Microplastics are defined as any plastic that has a particle size of less than 5 mm (Cole, et al., 2013). The small size of microplastics allows them to be ingested by marine biota and cause harmful effects such as obstruction of feeding appendages, limitation of food intake, and the release of harmful toxins (Cole, et al., 2013).

Effluent discharge from WWTPs is one way in which microplastics make their way to the environment. Studies has been conducted to quantify removal of WWTP contributions to release of microplastic to the aquatic environment, and it has been concluded to be a very minor source because of treatment effectiveness (Conley, et al., 2019).

Microplastic sources in wastewater come from a range of primary and secondary sources. Primary microplastics are plastic particles or fragments that are already 5 mm or less before entering the environment. Sources in wastewater include manufactured plastic microbeads, pellets and fragments used in cleaning agents, personal care products and industrial applications (Okoffo, et al., 2019). Secondary microplastics are created by the breakdown of larger plastic products by physical destruction or UV degradation (Simon, et al., 2018). Secondary microplastic sources include polymer fibres from synthetic turf, the washing of synthetic textiles, discharge from fibre manufacture, and plastic household items. A single garment can produce thousands of microfibers per wash (Okoffo, et al., 2019).

While WWTPs are not specifically designed to remove microplastics, research has shown that conventional treatment technologies will reduce the amount of microplastics in the wastewater. This is primarily achieved by capturing the microplastics in preliminary treatment and the sludge stream (Okoffo, et al., 2019). The primary treatment processes of skimming and settling have been shown to remove 70% to 98% of plastic fragments in the influent (Murphy, et al., 2016) (Talvitie, et al., 2017) (Okoffo, et al., 2019). Secondary treatment has been shown to further reduce plastics to less than 20% of the concentration in the raw wastewater (Murphy, et al., 2016) (Talvitie, et al., 2017) and tertiary treatment (filtration) to less than 2% (Murphy, et al., 2016) (Okoffo, et al., 2019). Overall, up to 99% of the microplastics entering a plant can be captured in the screenings, grit and sludge streams.

Whilst the wastewater treatment process is effectively capturing microplastics, it is only a minor source relative to other routes. Reducing or a complete stop on the use of microplastics will significantly minimise the risk and quantities of microplastics to the aquatic environment.

1.12.3 PFAS and PFOS

PFAS (per- and poly-fluoroalkyl substances) are a large group of manmade chemicals which have been used in many types of manufacturing since the 1940s and in firefighting foams since the 1960s. PFOS (perfluorooctane sulfonic acid) is a member of the PFAS family of chemicals (Environmental Protection Agency, 2019). PFOS was used in manufacturing processes, usually to make products resistant to water, grease or stains (e.g. in carpets, clothing, cookware). PFOS is now classified as a persistent organic pollutant (POP) under the Stockholm convention. POPs are stable compounds that do not readily break down through biological or chemical processes. As a result, PFOS persists for a long time in the environment and in the human body which can cause potential effects on health (Environmental Protection Agency, 2019). Health effects include interference with hormones, increased cholesterol, weakened immune system and increased risk of some cancers.

In 2016, USEPA published a guideline PFOA and PFOS limit of 70 ng/L (as combined) for drinking water. Alaska has adopted the same limit for surface water discharge in 2018 (Hertle, 2019).

From various studies, PFAS have been found in fire training facilities, electroplaters, pulp and paper industry sites. In addition to the specific facilities mentioned above, the presence of PFAS in household cleaning products means that domestic wastewater is likely to be the most significant source of PFAS compounds entering WWTPs in terms of mass loadings (Rumsby, 2018). The combination of very low concentrations of PFAS in wastewater (measured in part per trillions) and the nature of PFAS removal in conventional wastewater treatment processes means that research effort has focussed on alternative treatment methods.

Alternative treatment methods that receive higher interest include granular activated carbon (GAC), reverse osmosis-nanofiltration (RO/NF), anion exchange (AIX) and thermal treatment (Hertle, 2019). Each alternative treatment technology comes with their own advantages and challenges. For instance, the activated carbon adsorption process is relatively inexpensive to implement and achieves over 90% removal of PFOS and PFOA, however it is not effective at removing short chain PFAS and the activated carbon is susceptible to blinding by other organics (Marquez, 2018). On the other hand, ion exchange is relatively effective for removal of PFOS, but less efficient in short chain PFAS removal. Also it requires larger system size and specific waste management of resin. It was also found that wastewater pre-treatment may be required to prolong the life of the media (Marquez, 2018).

There have been several treatability investigations in Australia to investigate PFOS and PFAS removal from wastewater lagoons, pond effluent and electrochemical AOPs (Hertle, 2019). Generally speaking conventional treatment processes have limited success in removing PFAS, thus PFAS can be present in treated discharges and biosolids.

1.12.4 Addressing concerns from the community

As more information is circulated in the media, community concerns about CECs in the environment have grown. The wide use of social media can lead to misinformation or inaccurate information, which in turn can shake public confidence in the water services providers. In addition, the general public may have the mindset of "*Hear first, trust first, hear last, trust last*".

For these reasons, communication strategies recommended for water service providers and crown institutes to adopt is "*to become and stay as the GO-TO source for public information*" on these matters (McGrill, 2020). The purpose of these proactive communications is to demonstrate transparency, knowledge, appreciation of customer's concerns and current research/investigations to address unknowns and future developments.

Regulation of emerging contaminants may come in time, with those causing the biggest effects being prioritised, but initially it is more likely that use will be restricted or banned (e.g. microbeads are now banned). Regional councils have the ability to regulate contaminants reaching the discharge environment through the resource consent process, but first there has to be a proven detrimental effect, and a way to detect the contaminant without it being a high financial burden on a council in order for the consent condition to be applied in a sustainable manner.

1.13 Regulation and management of the wastewater sector

1.13.1 Overview

While there are some exceptions, municipal WWTPs in New Zealand are most often operated and managed by territorial local authorities or council-controlled organisations owned by territorial local authorities. The construction, operation, maintenance and upgrade of WWTPs is, in most cases, funded through council rates or wastewater charges. These WWTPs require a number of resource consents from regional councils to authorise their operation.

Regional councils and unitary authorities are the consenting authorities for WWTPs. Thus, both the regulator and the consent holder are local government bodies. In the case of unitary authorities, the same organisation is both the regulator and the consent holder.

The legislative framework that applies to the environmental performance of WWTPs is covered in Chapter 3 in detail and summarised below.

1.13.2 Municipal wastewater provisions in Regional Plans

Regional Plans (including, proposed and operative regional plans) generally contain objectives, policies and rules that control the discharge of wastewater containing contaminants to freshwater bodies, land or coastal waters. However, there is significant variability across all Regional Plans in terms of specific requirements that relate to wastewater. This was explored in detail in the report completed in 2019 for the DIA (GHD and Boffa Miskell 2019). For this study it was found that all the regional planning documents reviewed contain objectives, policies and rules that control the discharge of wastewater containing contaminants to freshwater bodies, land or coastal waters. Five council regional planning documents (Auckland, Taranaki, Manawatu-Whanganui, Wellington and Canterbury) contain provisions specifically addressing the discharge from municipal WWTPs.

Resource consents are required for the discharge of treated wastewater from WWTPs in all regions.

1.13.3 Resource consents

Resource consent durations for WWTPs can vary from as little as 2 years and up to 35 years.

The study completed by GHD and DIA in 2019 found that nearly a quarter of WWTPs (comprising 73 plants) are currently operating on expired consents, with the average time operating on an expired consent being four years. Another key finding was that consent conditions, monitoring, reporting, compliance grading systems and enforcement vary considerably between regions and even between WWTPs in the same region.

A recent study completed by GHD and Boffa Miskell for [5]MfE explored consent conditions in more detail and involved the preparation of a database that collates characteristics of consent conditions for a representative sample of municipal WWTPs in New Zealand.

A strong theme from review of the database is one of inconsistency in terms of monitoring parameters, reporting, the use of compliance limits and lack of Iwi/cultural considerations and monitoring The sample included WWTPs serving both large and small population sizes, and included WWTPs that discharge to land, freshwater and coastal waters. 38 WWTPs were included in the database.

[5] Review of WWTP consent conditions, 2020

1.13.4 Local Government Act

The Local Government Act 2002 requires that all councils provide annual reporting on the performance of their wastewater systems. The reporting covers key performance metrics including compliance with resource consents, number of wastewater overflows and any public health incidents.

1.13.5 Funding arrangement

For the majority of New Zealand's population, wastewater collection and treatment that is serviced by Councils (i.e. not onsite septic tank systems) is funded through general rates payments. The Auckland region is the exception where wastewater collection and treatment is funded via payments to Watercare and there is a household use related charge.

CHAPTER 2
TRADE WASTE

2. Chapter 2 Trade Waste

Chapter Purpose: To provide a detailed description of the trade waste regime in New Zealand, including an assessment of its relative effectiveness in reducing the volume and concentration of contaminants in wastewaters entering municipal wastewater networks, and identification of opportunities to improve contaminant source control practices.

2.1 Introduction to trade waste

This Chapter covers a detailed review of the trade waste regime, including:

- Evolution of the trade waste regime, legislation and regulation
- How and why trade waste is managed, including roles and responsibilities
- Summary of industries managing their own waste
- Discussion on regime effectiveness in reducing contaminants entering municipal wastewater systems
- Findings of interviews from across a range of situations, including individual councils, and organisations that manage trade waste across multiple councils
- Identification of opportunities for the trade waste regime

2.1.1 What is trade waste

Trade waste is defined in NZS 9201.23:2004 (model trade waste bylaw) as "*any liquid, with or without matter in suspension or solution, that is or may be discharged from a Trade Premises to the Wastewater Authority's (WWA) Sewerage System in the course of any trade or industrial process or operation, or in the course of any activity or operation of a like nature; and may include Condensing or Cooling Waters; Stormwater which cannot be practically separated, or Domestic Sewage*."

In New Zealand there are three treatment and discharge "pathways" for industrial wastewater which are broadly described below:

1. **Co-treated:** Industries which discharge to municipal systems, are mixed with the municipal wastewater and treated to one common standard. This is the most common and primary focus of this Chapter.
2. **Mixed Model:** Industries which discharge to municipal systems for separate treatment, usually to a lesser standard and then combined with the municipal wastewater for discharge. These are discussed in section 2.2.5
3. **Standalone:** Industries which have standalone wastewater treatment and discharge resource consents and fall outside the "Water sector" and hence the scope of the water sector reform. These are discussed in Section 2.2.6

Trade waste can come from a large variety of sources and industries, with their own unique characteristics depending on the processes that produce them, and as such the discharges require management and control.

2.2 The trade waste regime in New Zealand

2.2.1 Evolution of trade waste management

Figure 39 provides a summary of the timeline of significant changes in government and legislation in New Zealand which has moulded the management and control of trade waste over time. These changes are discussed in further detail below.

Figure 39 Timeline of the evolution of trade waste control and regulation

The environmental impact of trade waste discharges was investigated as far back as the 1940s, when a nationwide survey was undertaken to understand water pollution across New Zealand, and the extent of pollution in waterways was found to be significant.

Once the Water Pollution Act was passed in 1953, this paved the way for the formation of the Pollution Advisory Council which was responsible for the development of the first model trade waste bylaws.

Further enforcement and control functions were enabled with the passing of the Water and Soil Conservation Act in 1967, and the 1972 creation of the Water Resources Council[6].

Significant changes in local government came with the local government reforms from 1987 to 1989[7], consolidating hundreds of single-purpose bodies into 86 territorial authorities and

[6] Source: Christine Dann, 'Sewage, water and waste', Te Ara - the Encyclopedia of New Zealand, http://www.TeAra.govt.nz/en/sewage-water-and-waste/print (accessed 9 June 2020)
[7] Source https://www.parliament.nz/en/pb/research-papers/document/00PLLawC51141/local-government-amalgamation

regional councils. Running in parallel with the local government reforms, environmental legislation reforms resulted in the Resource Management Act 1991 (RMA).

The Resource Management Act 1991 sets out how to manage the environment in New Zealand[8]. Regional councils are responsible for establishment of regional policies, rules and plans which provide regulation of treated wastewater discharges to the environment. Sustainable management principles within the RMA has meant local government has had to consider the effects of activities on the environment. The focus on impacts of treated wastewater discharges on the environment means territorial authorities must control inputs into the sewer networks, and what is received at the WWTP, in order to reliably meet the WWTP environmental discharge limits.

The first New Zealand Standard model trade waste bylaw (NZS 9201.23) was released in 1995 as an interim measure due to reviews and rewriting of the Local Government Act at the time. By this time, some trade waste bylaws and control measures were already in place across the country. Other territorial authorities controlled trade waste by the use of individual agreements. The purpose of the model trade waste bylaw is summarised in Figure 40.

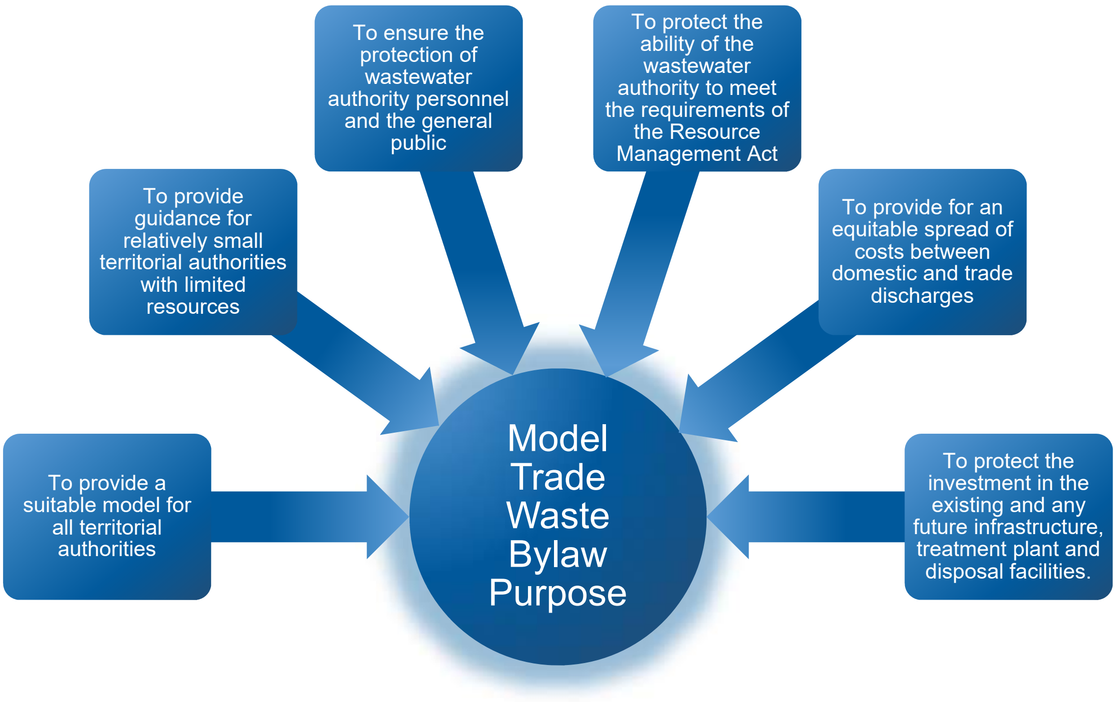


Figure 40 Purpose of the model trade waste bylaw

[8] Source https://www.mfe.govt.nz/rma/about-rma

The full standard was published in 1999, with the understanding it would need updating to cover any changes brought about by government reform of the water and wastewater industry. According to the standard, most territorial authorities had bylaws in place covering trade waste, but these needed to be brought up to date with legislation changes with the enactment of the Building Act and the RMA in 1991. The Building Act has since been updated again in 2004.

The Local Government Act enacted in 2002 allows for making of trade waste bylaws by territorial authorities (TA) ((s146 (a) (iii)), and sets out the processes required to make a bylaw (Part 8). It also requires that any trade waste bylaw is sent to the Ministry of Health for comment (s148 (1)), and the TA publicly notify the intention to make the bylaw (s148 (2)). Consultation with the community and involvement of Māori/local tangata whenua in providing comment when trade waste bylaws are reviewed is also provided for under Part 6. With its implementation, it also required local government to start managing their assets and develop asset management plans. This in turn put more emphasis on territorial authorities managing trade wastes in their areas in order to protect their assets.

The model trade waste bylaw was updated in 2005, and key changes such as the charging calculations, consideration of disposal routes, inclusion of management plans, and the ability to cancel the right to discharge all have implications for reductions of contaminants in trade waste discharges.

The LGA required that all TA bylaws be reviewed by 30 June 2008, and as such the trade waste bylaws are now on their second or third iteration due to the requirement to review bylaws every five years.

2.2.2 Responsibilities under New Zealand legislation

Figure 41 summarises current legislation and who has responsibilities relating to trade waste control and regulation.

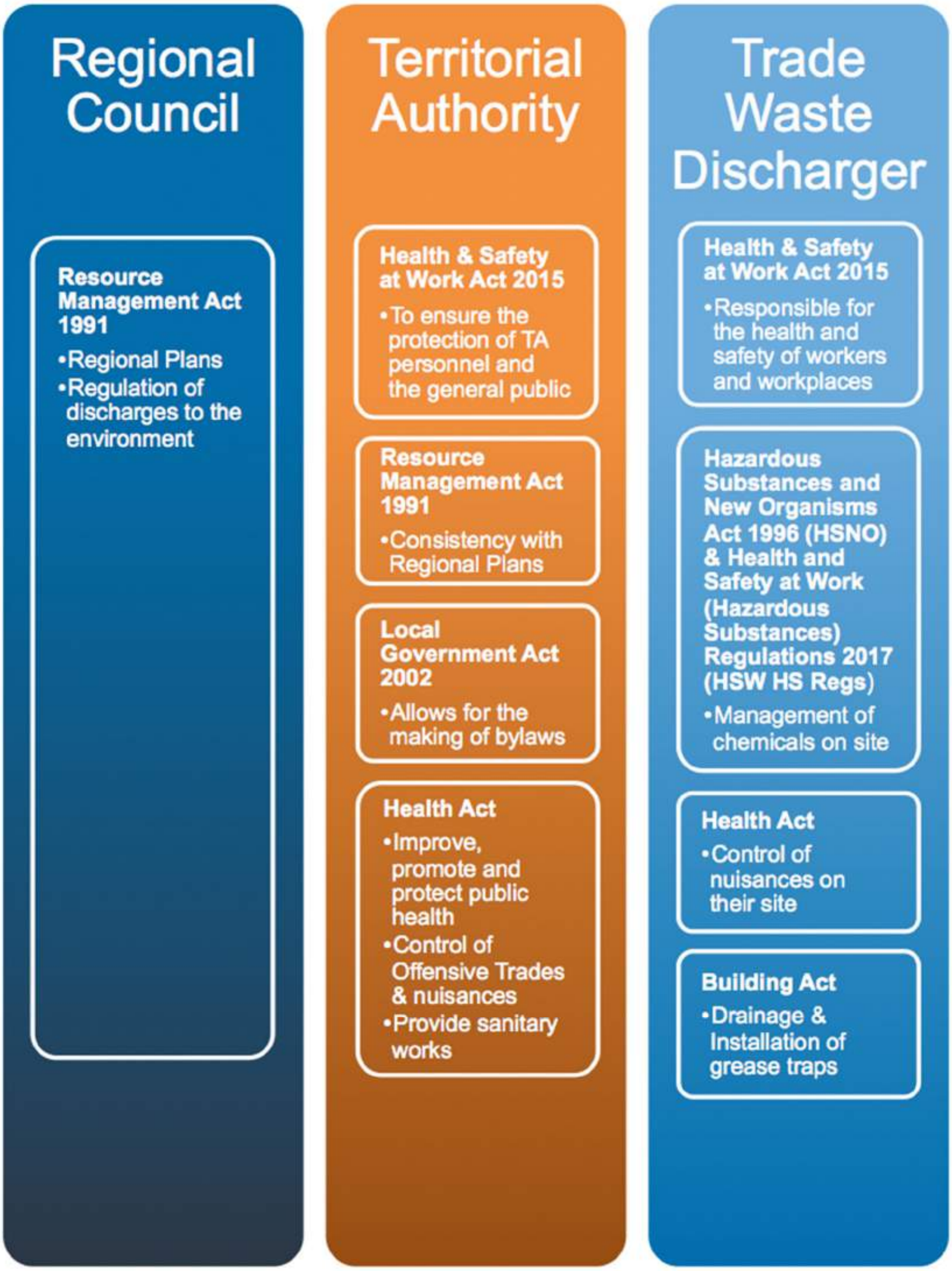


Figure 41 Responsibilities under New Zealand legislation relating to trade waste

The legislation, guidelines and other inputs into the development of an individual traders' conditions of discharge are summarised in Figure 42. These are driven from central, regional and local government and are collectively used to develop local trade waste regimes.

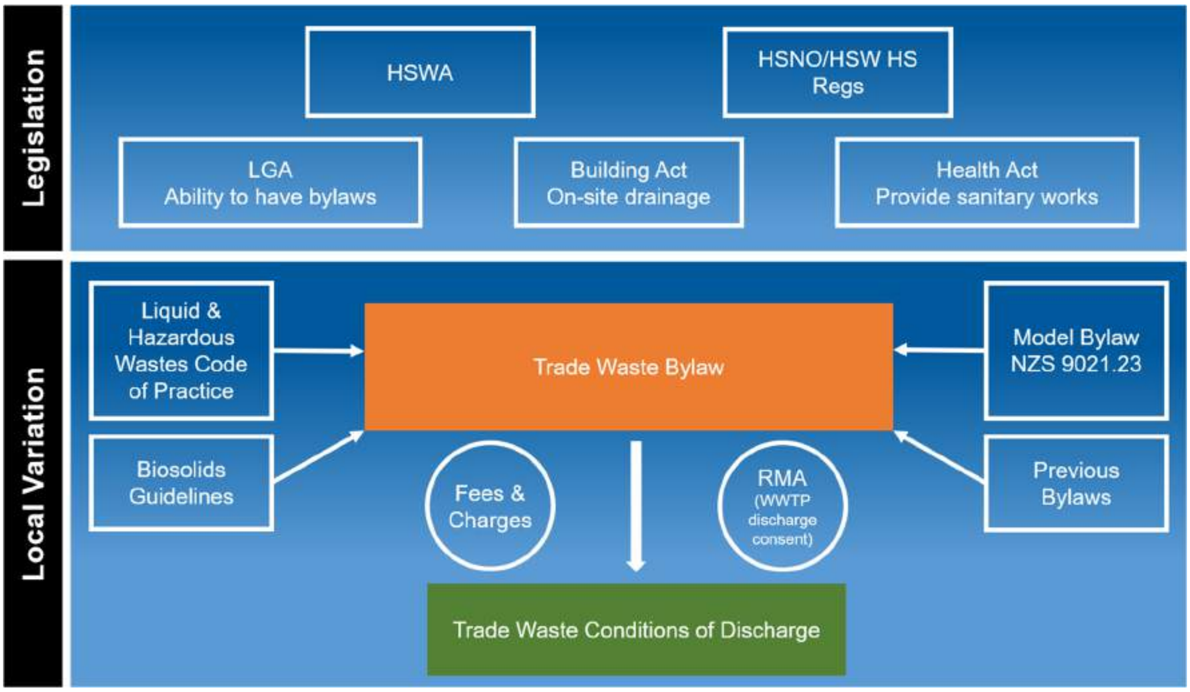


Figure 42 Inputs into development of trade waste conditions

2.2.3 Categories of trade waste

Trade waste discharging to sewer for treatment at the municipal WWTP is categorised in the model bylaw into three categories as shown in Table 19. Generally speaking, territorial authorities tend to follow these categories, although registration or consenting of industries in the permitted category is very much dependent on the local trade waste bylaw in force. Individual trade waste bylaws define the characteristics that apply in each of the categories, and are based on local conditions. These may be area specific within a WWA area.

Table 19 Trade waste categories (source: NZS 9201:Part 23:2004)

Category	Description	Examples of sources or substances
Permitted	Standard conditions applied	Small restaurants Laundries Educational facilities Retail butcheries Bakeries
Conditional	Has a significant risk of producing a waste which may be unacceptable, for which specific conditions may be applied	Dentists Dry cleaners Landfills Food and beverage processing Meat processing Tankered waste

Category	Description	Examples of sources or substances
Prohibited	Not acceptable for discharge in their current form, or could cause issues either immediately or in the course of time. May be sufficiently treated to allow discharge as a Conditional trade waste, otherwise must find another disposal route.	Radioactive waste Asbestos Substances which could be explosive or flammable Health care wastes

2.2.1 Why is management required?

Most contaminants in trade waste can be removed or reduced through biological processes, or through adsorption/absorption processes. However, any contaminants that are not readily treatable will pass through the municipal WWTP, and ultimately enter the receiving environment, if not adequately controlled at source.

All municipal WWTPs must have a resource consent which places controls and limits on the discharge. These are issued by the regional council, under the RMA. This is discussed in Chapter 3. Of note however, is that the consent conditions placed on each treatment plant discharge will be unique and specific for the receiving environment it is discharging to. It is based on a determination of effects, and hence can result in a wide range of treatment levels. Those plants discharging to sensitive environments will need a much higher level of treatment and can be much more sensitive to the impacts of trade waste discharges on the plant performance. Specific trade waste contaminants are not picked up through the resource consent process, as these are not currently a driver for setting discharge consents from the WWTPs. The mechanisms are also not currently in place to identify and control any specific contaminants from trade waste which pass through the WWTP treatment process and end up in the environment. The effects on the receiving environment is the driver for the discharge consent.

Trade waste does not only impact the WWTP as discussed below.

Organisational drivers

Drivers within the TAs include cost recovery, the need to protect assets, control nuisances, implementation of the trade waste bylaw, energy efficiency and sustainability, waste minimisation, and meeting the conditions of their own discharge consents at the WWTPs.

Sewer network

The interaction of the trade waste with its environment starts as soon as it leaves the process it was produced in. It will interact with other waste streams from the same site on the way to the sewer, with the materials it comes in contact with, and once it joins the main sewer, with other waste streams and materials within the sewer network. Gravity sewers, pump rising mains and pump stations can all be damaged by the chemical reactions in the waste streams. By understanding the nature of the waste and controlling and managing the individual waste streams within permissible levels, the issues can be kept to a minimum.

Tankered waste

Trade waste can also be tankered to the WWTP from sources such as septic tank emptying, and grease trap cleaning. Other waste types are normally treated in specialist facilities (not generally provided by territorial authorities). The responsibility for the tankered waste should have a formal transfer from the generator to the transporter, although the ownership may still lie with the generator[9].

In the case of septage, while these tend to be small volumes (typically 1-20 m^3), they are high-strength wastes, and depending on the number of tankers discharging at the WWTP, and the size of the WWTP, can have a significant impact on the performance of the treatment processes due to “shock loading” (high strength wastewater coming through the WWTP in slugs). Generally speaking, best practice is to provide a septage reception facility, to balance the flows from the tankers (spread the load into the WWTP by slowing the flow rate down), and some also have screening, as septage has a high rag loading (gross solids such as sanitary products, wet wipes, etc removed by screens). For the purpose of this report, we do not consider septage to be a true trade waste, as it is predominantly from unreticulated domestic sources. It is entirely appropriate that septage is treated at the municipal facility.

Treatment

Once the mixed waste stream arrives at the WWTP, in sufficient quantities (or due to a lack of dilution with domestic waste), or with its unique characteristics, it can impact on the vulnerable bacteria which forms the backbone of wastewater treatment in the biological processes at the WWTP. It can have a direct toxic effect on the bacteria, can cause issues such as peak loading which exceeds treatment capacity, or can coat instrumentation with contaminants, which then affects the performance of the instruments which monitor or control processes. The chemical composition of the waste streams can also impact on the performance of the processes within the WWTP, whether they be physical, chemical or biological.

The treatability of the individual contaminants in trade waste will vary according to their form, and to the treatment processes used in the WWTP. Pre-treatment, required due to consent conditions, can reduce a contaminant to consent limits, but can make the remaining portion more difficult to treat at the WWTP.

More passive systems such as oxidation ponds will have less ability to treat contaminants than WWTPs that have multiple treatment steps targeting key contaminants. The treatment processes selected will be driven by the consent conditions imposed on the WWTP discharge (discussed in Chapter 3). The lower the discharge consent conditions, the higher the treatment requirements, often with increases in complexity, depending on the site.

Given that combined domestic and trade waste needs to be treated to the discharge consent conditions, a good understanding of the incoming flows and therefore the nature and quantity of trade waste (the more variable portion) is required in order to design and build processes that will treat down to consent limits or better. Every WWTP has its own unique cocktail or fingerprint of wastewater coming into the site to treat, and this changes in nature over time as businesses come and go. But, as shown in Figure 44 - Figure 47, trade waste generally constitutes a small proportion of the incoming flows into at WWTP, and only some of these cause impacts on the treatment processes at the WWTP, and these are the ones that require management and control.

Variability

Trade waste can be highly variable in its discharge regime –production can be batched, with an associated batch discharge, or vary widely during cleaning operations, dependent on the product being produced at the time or the seasonality of the raw materials. Generally speaking, trade waste is not monitored based on its true fluctuations, rather on a more averaged approach. Normal practice is for limits (maximums) to be set which the WWTP can cope with,

[9] Liquid and Hazardous Wastes Code of Practice 2012

very often with headroom, so traders can stay compliant with their discharge consent conditions.

The impact of the high variability and the peaks of contaminants is not always clear at the WWTP, due to the nature of the monitoring of the processes, and also with end-of-pipe discharge monitoring generally being at a point in time, rather than continuous.

Disposal routes

The ultimate disposal routes for the liquid and solids streams from the WWTP can be impacted by the contaminants originating from trade waste. Contaminants such as pharmaceuticals, pesticides, hydrocarbons and heavy metals can prevent the liquid or waste streams being utilised for land application, reuse or further processing into value-added products. In New Zealand it is not uncommon for large primary industry processing plants to treat their own waste and apply the liquid and/or solids streams to land (discussed further in S2.2.5). For companies such as Fonterra, inclusion of a domestic waste would potentially prohibit the use of these waste streams on land used for dairy grazing.

2.2.2 How trade waste is managed

Categorisation

In order to discharge trade waste, a business contacts its local TA to understand if its trade would be categorised as permitted, conditional or prohibited. Not all TAs require businesses to register permitted trade waste. Typically permitted trade waste has small volumes (<5 m^3 per day), with low concentrations of contaminants. Figure 43 shows relative proportions of trade waste by category – these will vary from TA to TA, and depending on their use of categories. The six councils who provided the data varied significantly in proportions for each of the categories – one of the councils had a significant majority of permitted, while another had 75 per cent conditional. The data (Figure 43) is shown as a total of all six councils.

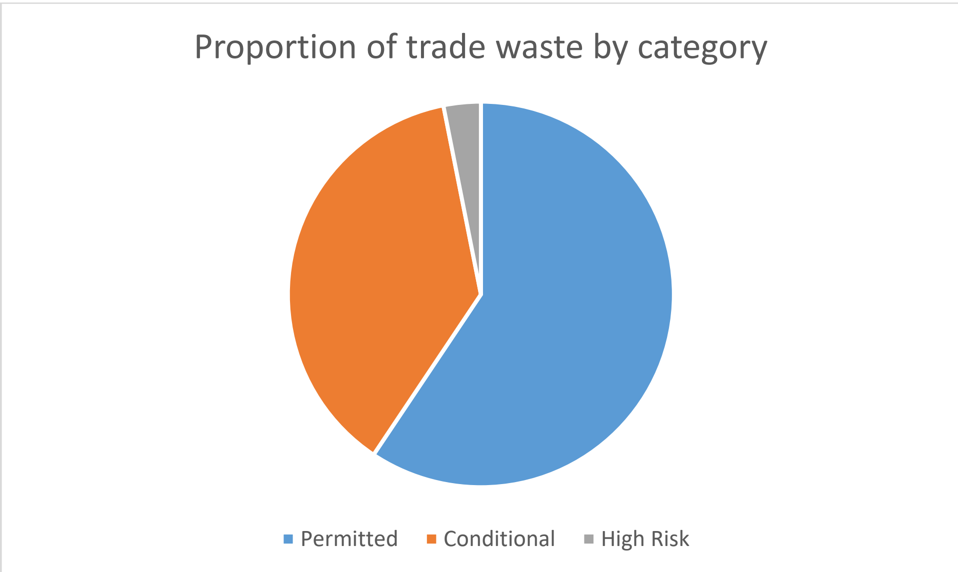


Figure 43 Approximate proportions of trade waste by category (total for 6 councils)

Trade wastes which fit into the conditional category must apply for a trade waste discharge consent from the TA. The TA will impose conditions in the consent to discharge which typically limit concentrations or loads of parameters which exceed those found in Schedule 1A of NZS 9201.23:2004 (equivalent found in TA trade waste bylaws with local customisation), and instantaneous and total daily flows. Contaminants in the trade waste tend to be controlled by conditions which are typical for the industry type (see Table 21 below), and through characterisation of the particular trade waste being discharged, and may require some pre-treatment or balancing on site prior to discharging to sewer in order to meet the conditions.

Monitoring

Trade waste dischargers are monitored on a routine basis for charging purposes, and (quite often less frequently) to monitor compliance against consent conditions. The frequency of monitoring will depend on the TA, and generally takes into account the risk associated with the trade waste from each discharger (potential to exceed the conditions of their consent and scale /nature of discharge), resourcing to do the monitoring, and sensitivity of the treatment processes at the WWTP. The discharger pays for the cost of monitoring, and in fact may be required to self-monitor (undertake the monitoring themselves) and provide data to the TA. Very often, flow is based on water consumption records rather than actual measured discharge flows or volumes. The monitoring data administration and use varies from TA to TA.

Larger businesses often have their own on-site monitoring if they are undertaking pre-treatment or treatment of their own waste prior to discharge in order to control the treatment process. The data is often shared with the TA to provide evidence of compliance.

Where dischargers exceed their trade waste consents, TAs (depending on the management and control of trade waste by each TA) can increase sampling frequencies until the discharger is compliant with their consent conditions. This has a number of implications for the discharger which are discussed in 2.3.1 below.

Charging

Charging for trade waste evolved through the revisions of the model trade waste bylaw (NZS 9201.23) and trade waste bylaws - originally very prescriptive with onerous monitoring - and is now set by each TA. Generally speaking, charges per unit flow are used, and charges per unit for parameters such as BOD or COD, nitrogen and phosphorus can also be adopted, dependent on the treatment processes and the discharge consent at the WWTP.

Territorial authorities can only charge for cost recovery under the LGA, and charges for trade waste must not subsidise the cost to treat domestic waste. This means that anything that is charged for needs to be quantified for cost to treat. If there is no direct cost to treat, or a knock-on effect of receiving the trade waste cannot be quantified, then there is no charging mechanism for it. Key contaminants which may be causing an impact can be monitored though, and can be limited through consent conditions.

Development and capital contributions can also be charged (under the LGA). These are charged on a proportional basis of the industry flow/load for a WWTP vs the municipal load, and pay for the cost of any upgrades required at the WWTP due to industrial loads, and can be used to reserve future capacity by individual businesses.

Table 20 summarises the types of fees and charges currently used by TAs in New Zealand.

Table 20 Summary of fees and charges for trade waste activities

Charge	Description	Charged by
Rates	General rate for property	Annual fee as percentage of capital value of property
Volume	Amount of flow discharged as a total volume	m^3 discharged May be a proportion of water use if not measured at discharge point

Charge	Description	Charged by
Strength	Concentration of target contaminants such as BOD, nitrogen, phosphorus, arsenic	kg
Annual fixed charge	Covers administration of consent, such as annual audits, provision of trade waste services in district	Lump sum or per m^3
Development contribution	TW portion of capital cost of upgrade to sewer network or WWTP	Percentage of capital cost of upgrade
Infrastructure growth charge (Watercare)	Applies to new discharges, or WW discharges increase by >209 m^3/year, to fund upgrades required due to the impact of growth on the WW system	Lump sum based on location
Sampling and analysis	Cost to take sample (manual/autosampler), transport to laboratory and analyse	Cost recovery Some are lump sum per sampling event
Site visits	Cost of resource time and mileage to meet with trader, provide assistance and advice, discuss non-compliances, follow-ups	Lump sum per visit
Ad hoc advice	Provision of advice on request from trader, support for issue resolution, improvement options	Per hour
Damage/cleanup costs	Costs for resolution of issues shown to have been caused by action of discharger	Cost recovery
Incentive rebate	Rebate when a discharge has a beneficial effect on the treatment processes, and as such reduces the TA's cost to treat	Rebate per unit e.g. kg BOD

2.2.3 Scale of trade waste in New Zealand

Figure 4 to Figure 7 below show the volume of trade waste, compared to the total discharge, entering selected WWTPs across New Zealand. This shows that the proportion of trade waste being discharged to municipal WWTPs is highly variable, and entirely location dependent. [10]

The data did not show trends in sizes of WWTPs and trade waste inputs per se, but shows that trade waste inputs are highly variable and entirely location dependent. The volumes discharged to the municipal system are not always indicative of the amount of industry in the area, as some businesses may have other means of disposing of their waste. Generally speaking, trade waste is only a high proportion of incoming flows in a small number of WWTPs across New Zealand.

[10] Data sourced from WaterNZ WWTP 2018-2019 database using available data supplied. Data was not available for every WWTP in New Zealand, and it has been assumed that values of "zero" indicate no trade waste flows, rather than no data available. It is also not clear if the dataset includes the small volumes that arise from permitted traders, as this will also vary from TA to TA.

Trade waste, although it may be a low proportion of the flow, can have big impacts on treatment performance at WWTPs depending on the nature of the contaminants in the discharges. Equally, high trade waste proportions coming into WWTPs may not have a significant impact – but again, this is contaminant-dependent. Assessing a trade waste application prior to discharge to the municipal system will help characterise the proposed discharge and allow the opportunity to assess the ability of the WWTP to receive and effectively treat the contaminants prior to commencement of the discharge. TAs may also take the opportunity during WWTP upgrades to develop the WWTP in order to allow particular trade waste discharges to be received without impacting on the overall treatment performance of the WWTP.

Some locations in New Zealand have separate trade waste conveyance systems to the WWTP. These flows are kept separate to the municipal treatment through the WWTP, and are not treated further, but are combined for discharge – these are usually found where there is an ocean discharge. These are discussed further in Section 2.2.6.

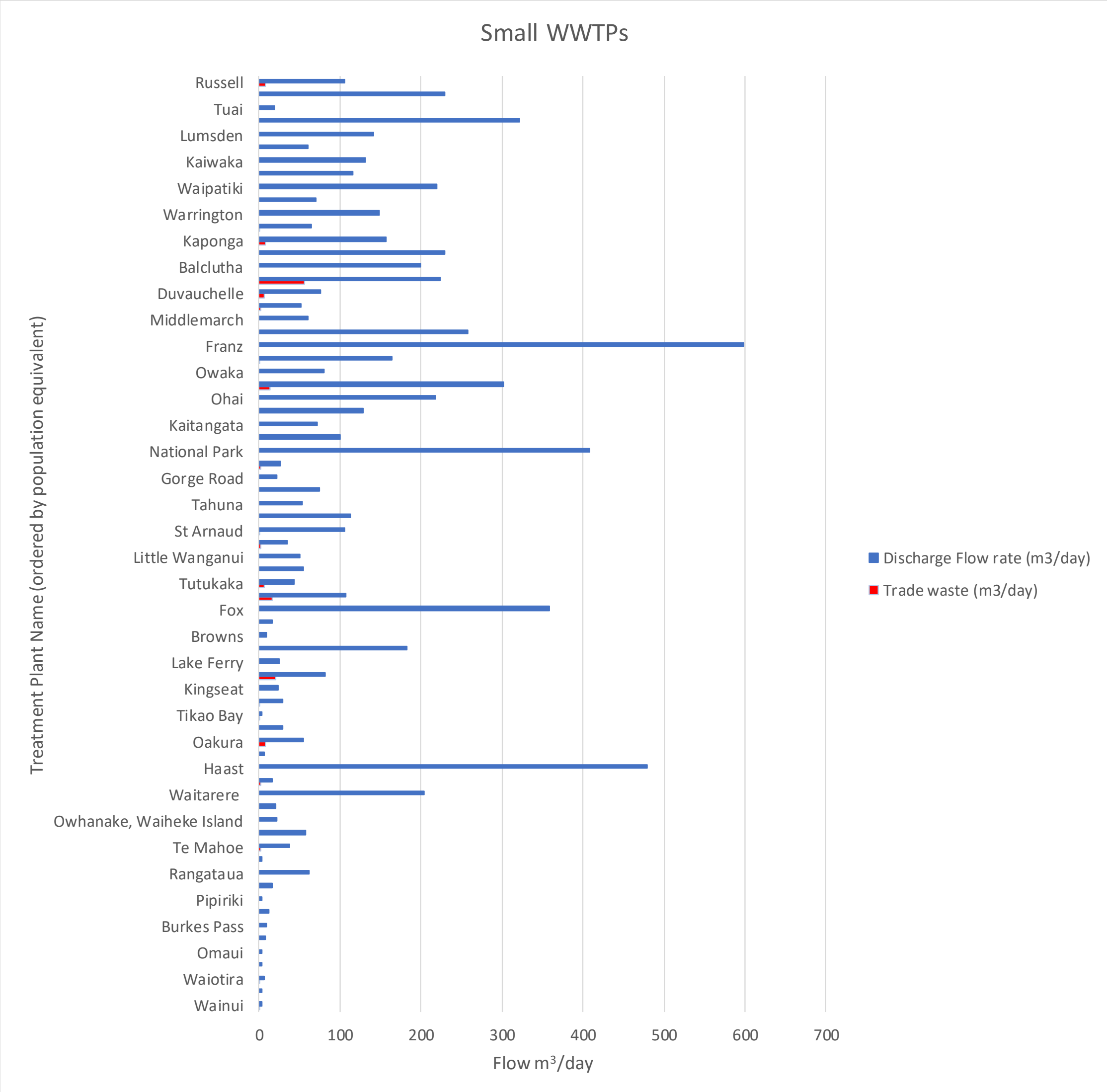


Figure 44 Small WWTP trade waste daily flow vs overall daily flow

As shown in Figure 44, trade waste input to WWTPs smaller than 500 people are one third or less of the incoming flows. The majority of small WWTPs have little or no trade waste input – only 21 plants in the dataset receive trade waste.

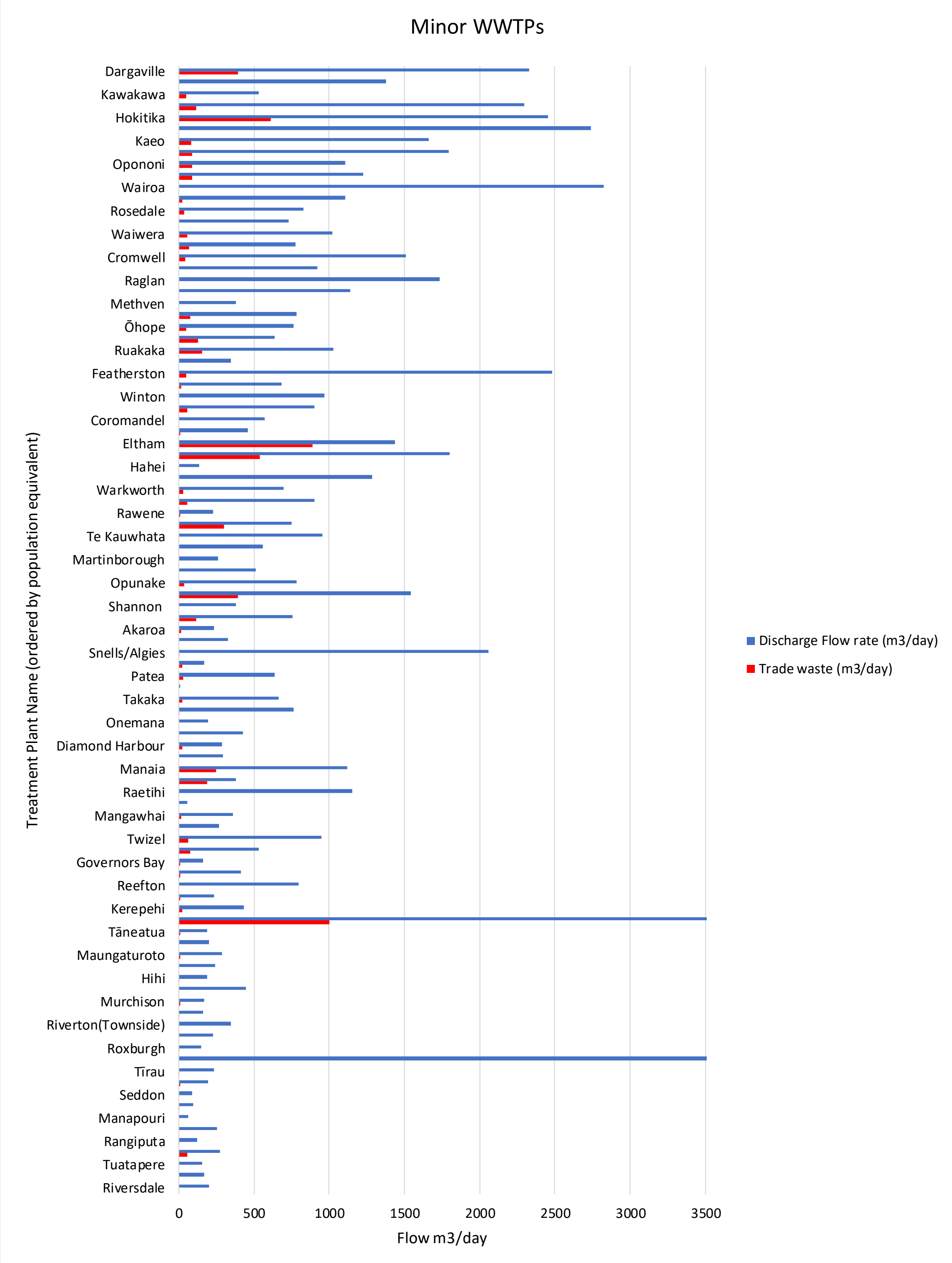


Figure 45 Minor WWTP trade waste daily flow vs overall daily flow

Minor WWTPs tend to have a higher trade waste input than small WWTPs, with larger numbers of WWTPs having a trade waste input - 57 of 97 plants in the dataset receive trade waste.

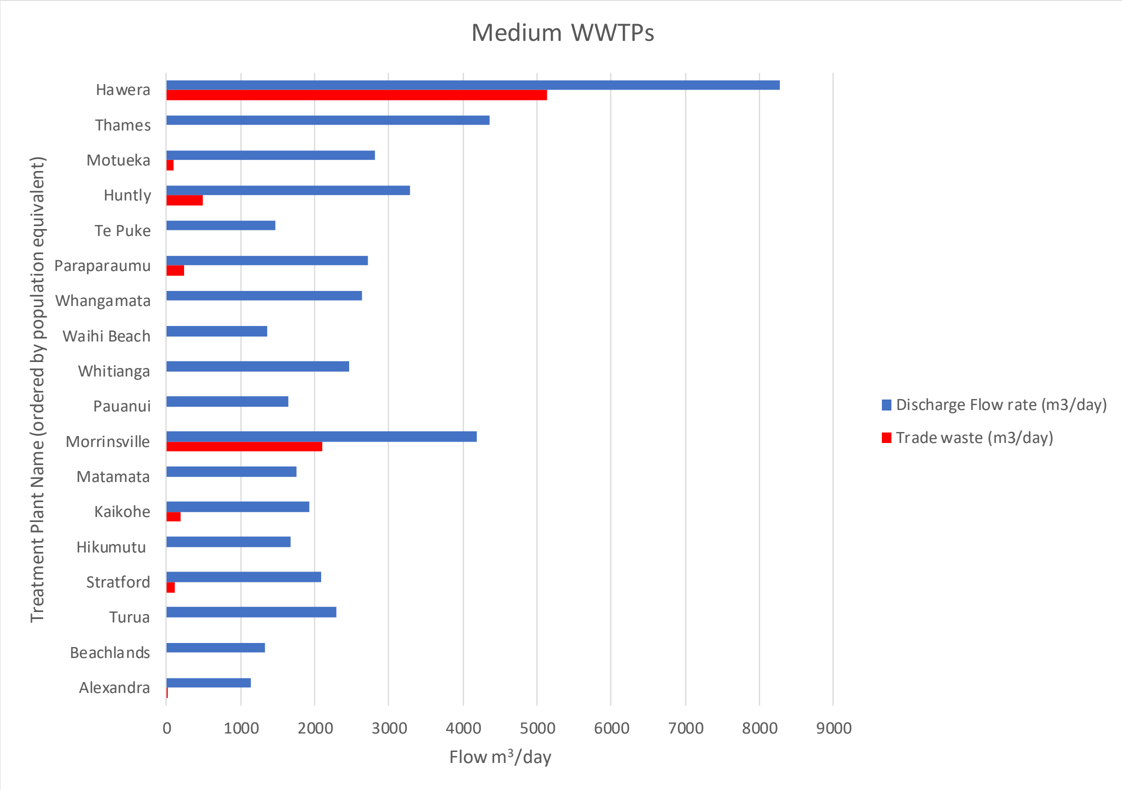


Figure 46 Medium WWTP trade waste daily flow vs overall daily flow

A number of the WWTPs in the medium-sized WWTP dataset are coastal towns, with high seasonal loading from visitors. The proportion of trade waste coming into the sites is highly variable as shown in Figure 46 above.

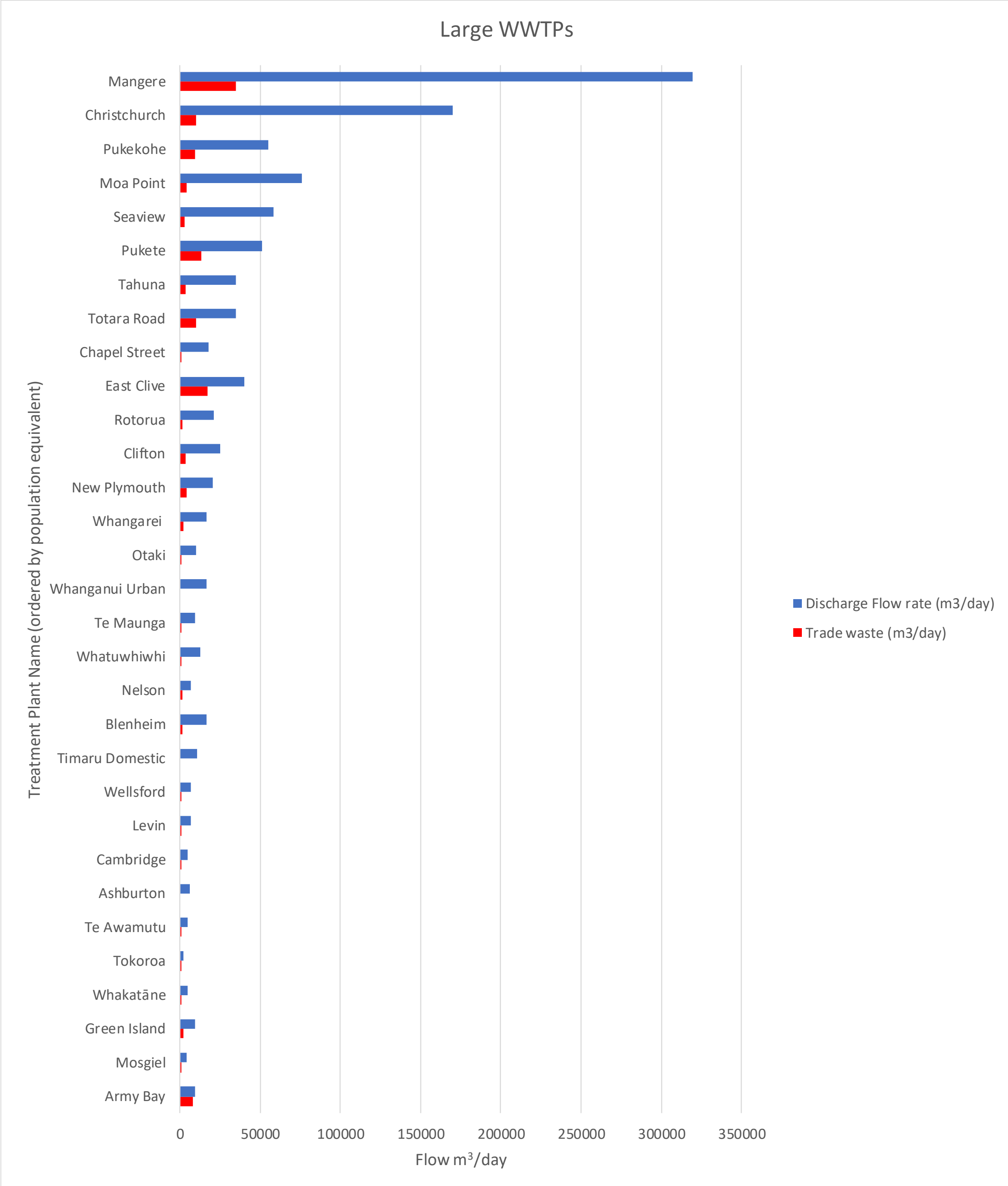


Figure 47 Large WWTP trade waste daily flow vs overall daily flow

Only three of the WWTPs in the large category do not receive trade waste, although the majority only receive a small proportion of trade waste in the incoming flows.

2.2.4 Typical industry data

Trade waste discharge regimes are very much dependent on the scale of a business, whereas contaminants tend to be more typical by industry type - Table 21 summarises these. The New Zealand Trade and Industrial Waters Forum (NZTIWF) is working towards collating information on industry types, key contaminants in their discharges, and options for management and (pre-) treatment of these in order to help their members understand industry trade wastes.

Table 21 Typical contaminants by industry

Industry type	Typical contaminants
Septage	High strength, septic, FOG
Meat processing/abattoir	High nitrogen, FOG, blood
Food and beverage manufacturing	High BOD, FOG, high nitrates, pH issues
Takeaways, cafes, restaurants, supermarkets	pH issues, FOG
Vehicle wash Stock truck wash/sale yards	Hydrocarbons, heavy metals, inert solids High BOD, high nitrogen
Laundry	Detergents
Electroplating	Heavy metals, acid
Pharmaceuticals, hospitals, vets	Pharmaceuticals, chemicals
Dairy	FOG, pH issues, high nitrates
Landfill leachate	Heavy metals, high nitrogen/low BOD
Chemical industries	Inhibitory chemicals
Concrete manufacturers	pH issues, TSS, alkalinity (beneficial)
Hairdressers	Hair, surfactants
Dentists	Mercury

Interviews were undertaken with a number of TAs, and generally, while new trade waste discharges may have a suite of analyses undertaken initially to characterise the waste, routine monitoring will tend to be for charging purposes more than for monitoring of all parameters where there are consent conditions (these are analysed for less frequently).

2.2.5 Mixed model treatment and discharge

There are several locations in New Zealand where a mixed model for industrial treatment has been applied. By mixed model we mean locations where industrial wastes have been separated and conveyed to the municipal treatment plant but undertake a separate treatment process to the domestic waste stream. A common feature of these facilities is that the separated industrial wastes are treated to a lower (easier) standard than the domestic waste and then combined with the domestic for discharge via a long sea outfall to the marine environment. Consequently, they require much less capital investment and incur significantly lower ongoing operational costs than if they were treated to domestic levels. Mixed model systems have been implemented in Hastings, Napier, Gisborne, Taranaki, Timaru and Dunedin. Notably all of these locations discharge to the marine environment via long sea outfalls.

In order to establish and consent a mixed model system, consideration is given to the assessment of the effects of the discharge on the specific receiving environment as well as recognising the different views of stakeholders, particularly Māori, and environmental scientists about the relative acceptability of the different waste streams that discharge from the outfall. This includes consideration of the cultural acceptability of non-human wastes, the lower public health risks of many industrial wastes (i.e. pathogenic and viral risks), and the economic impact of the extremely high cost of treating the industrial wastes to an equivalent standard to domestic.

The prevalence of mixed model systems in New Zealand is a direct reflection of the effects-based focus of the RMA and the absence of national marine discharge standards, often seen in other countries.

Application of the same end of pipe treatment standards to all municipal and industrial marine discharges would require significant capital investment and result in a step change in the energy consumption of the WWTPs and the quantum of biosolids produced. It is anticipated that until such time as there is more widespread acceptance of the beneficial use of municipal or industrial biosolids, that most of this material would be disposed to landfills. The increased capital investment, and ongoing power and biosolids disposal operational costs would be significant.

2.2.6 Standalone industries treating and discharging direct to the environment

There are many industries which produce trade waste but do not discharge to municipal wastewater treatment systems. Often these industries are located outside urban reticulated areas and hence it is not viable to discharge to the municipal system, or the scale of the discharge is such that it is more economic to self-manage, treat and dispose of their own wastes. These "standalone" industries fall outside the water sector per se and hence potentially outside the remit of water sector reform. However, they are still required to apply for discharge resource consents with consent durations, discharge limits and conditions placed on the discharge and applicant as seen for the municipal plants. The technical work and consenting costs can be on par with municipal resource consenting costs as the discharge consent process is subject to the same resource management planning framework as municipal consents.

Standalone industrial wastewater treatment standards can vary significantly based on the receiving environment (i.e. land discharge versus direct to water, and consenting authority). Many industries discharge to land (irrigate) where it is technically and economically viable and/or beneficial for the land use.

Discharges to marine environments typically require a lesser level of treatment than municipal. This is often due to the lower public health risk associated with the discharge and the high level of dilution achieved when discharging from long sea outfalls which are prevalent in New Zealand. For those industries discharging to freshwater, treated wastewater standards for recently consented or renewed consents are typically on par with municipal treatment standards.

Our observation is that standalone treatment systems are very common in dairy manufacturing and to a lesser degree meat processing. Many of these sites discharge preferentially to land when it is technically and economically feasible but may have a secondary consented discharge to water for periods when land application is not suitable.

There are a small number of industries which produce, treat and discharge very high volumes of wastewater. For example the Oji Fibre solutions plant in Kinleith is consented to treat and discharge up to [11]165 MLD and the Wairakei geothermal power plant is consented to treat and discharge 13 m^3/s of cooling water per [12]day. Both of these plants have bespoke wastewater treatment systems to comply with the individual requirements of their discharge consents. In the case of the Wairakei bioreactor, the high volume, low hydrogen sulphide concentration

[11] https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/waikato-scoping-report-appendices-19-22.pdf
[12] https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=10835095

wastewater resulted in a high mass load to the receiving environment. This led to the development of a world first treatment solution for the unique wastewater.

Wineries tend to be located remotely and are considered more likely to have stand-alone discharge consents given the high costs of conveyance to a municipal facility. In addition, the seasonality of the waste, particularly at harvest can make winery waste particularly difficult to manage if using biological systems. Large winery processing sites located within or close to urban centres are considered more likely to discharge to the municipal facility. An example of this is the Blenheim WWTP which has designed the municipal treatment plant to cope with the large seasonal increase in load associated with the harvest.

There is no central database of standalone industrial wastewater discharges in New Zealand and hence the number and magnitude of discharges to the environment from industry is unknown, nor is data readily available on the number or type of industry discharging to each receiving environment type. In order to fully understand the extent and nature of industrial discharges to the environment, a comprehensive review of resource consent databases held by each regional council would be required.

2.3 Regime effectiveness in reducing the volume and concentration of contaminants in wastewaters entering municipal wastewater networks

2.3.1 Benefits and barriers to effectiveness

Currently there are no direct drivers requiring control of trade waste discharges in New Zealand, only enablers. The model bylaw (NZS 9201.23) provides a framework for TAs to use in order to develop their own trade waste bylaws, but it is up to the individual TA to implement, manage, monitor and control trade waste. This varies widely across the country - even though nearly all of the bylaws reviewed closely follow the model bylaw - as found during the interviews conducted with a variety of councils across the country. The key findings are summarised in Table 22 and discussed further below, and also in section 2.4.

Table 22 Summary of benefits, barriers and enablers to effectiveness of the current regime

Enabler	Benefit	Barrier
Cleaner production Waste minimization Management plans in Model Bylaw	Cost for dischargers	Resources for monitoring
Industry certification	Wastewater system	Lack of penalties
		Cost for dischargers
		Cost of water
		Cost to discharge
		Lack of drivers for waste to resource

Enabler – Cleaner production, waste minimisation, management plans in model Bylaw

The model bylaw is an enabler for improvement in trade waste discharges, by covering the topics of "cleaner production", waste minimisation, and including the use of management plans. The purpose of the document includes:

"*(h) To ensure Trade Waste dischargers consider, and where appropriate and practicable implement, waste minimisation and Cleaner Production techniques to reducing the quantity and improve the quality of their Trade Waste discharges*."

According to the model bylaw, cleaner production provides an opportunity for industry to improve their operations with the benefit of reduced wastage, system control/understanding and reduced impact on the environment. Consideration should be given to the following areas:

- Use of more efficient processes
- Use of less raw materials
- Use of less toxic chemicals
- Efficient use of materials
- Housekeeping

The topic of waste minimisation for trade waste dischargers according to the model bylaw should address the reduction of solid, liquid and gas wastes. Consideration should be given to reduce, reuse, recycle and recover materials.

It should be noted that while the model bylaw encourages the philosophies of cleaner production and waste minimisation, and the use of management plans, it is entirely up to individual TAs to include these in their trade waste bylaws, to utilise management plans as a framework for businesses to control the trade waste discharges from their premises, and for industry to want to a) comply, and b) improve their discharges.

Barrier – Lack of drivers for waste to resource

Within industry, there is no mechanism, driver or enabler for maximising utilisation of wastes as a resource, including collaborative utilisation of waste streams, particularly given the scale of industry in New Zealand. Larger companies look for opportunities, but smaller ones may not have the resources.

Enabler – Industry certification

Trade waste dischargers through their own industries may have drivers to comply with consents and improve their operations. An example of industry certification is the Leather Working Group Gold Standard. The Leather Working Group objective (from their website) is to develop/maintain a protocol that assesses the environmental compliance and performance capabilities of leather manufacturers and promotes sustainable environmental practices.

Businesses who export product can be particularly vigilant with regards to compliance, and where businesses are operating under accreditation such as ISO:14001, they have more than just their trade waste consent conditions to comply with in regard to the discharges. Failure to demonstrate compliance can result in the removal of the Gold standard or ISO certification from the Trader with immediate market and hence economic impacts.

Benefit and barrier – Cost for dischargers

Cost is always a driver for any business. In theory, the higher the unit rate for a business to discharge, the more incentive there is for a business is to reduce their discharges, but as summarised in Table 23, there are barriers to this happening in reality. Conversely, there are also benefits in reducing discharges, and opportunities to do so which may not be immediately apparent.

Table 23 Cost impacts for businesses

Cost	Description	Control/enabler
Cost to discharge	The more there is, and the stronger it is (if this is included in their charges), the more it costs them to discharge it	TA fees and charges Cleaner production and waste minimisation in model bylaw
Cost of lost product	If something is spilled on the floor, it is sent to waste, and is no longer earning money for them – very often the business does not realise the value of what is going to waste	Cleaner production in model bylaw
Cost of non-compliance	Frequency of monitoring increased due to non-compliance results in additional charges. Charges increase due to higher strength discharge or higher volume and are charged on a unit-rate basis.	Waste minimisation in model bylaw Conditions to discharge TA fees and charges
Cost of water	More water means higher costs (water purchase and more to discharge) Water reduction can also lead to increase in strength and therefore limit exceedance	Water audits by TA Cleaner production in model bylaw
On-site treatment cost	Businesses work with short payback periods Treatment not core business Space is a premium	Conditions of consent Technology improvements Operational improvements

The economic value of a business to the local community also needs to be considered. Some trade waste regimes have been allowed to go ahead or continue due to the number of local jobs involved, and the flow on benefit to the community. This does not always benefit the receiving WWTP or allow for adequate recovery of the costs to convey, treat and dispose.

Benefit – Wastewater system

While the discussion above considers point source control, the impact of trade wastes mixing and reacting can cause significant issues in the sewer network. In some cases, pretreatment processes adopted by the discharger to meet their trade waste consent can perversely impact on the treatability of the residual wastewater at the municipal plant. An example of this is stripping out soluble contaminants with coagulant or flocculant, leaving the inorganic/inert fractions in the discharge, which are harder to treat. Every WWTP has its own unique wastewater characteristics and patterns and this can change in nature over time as businesses come and go.

Trade waste can be highly variable in its discharge regime – flows and concentrations are affected during cleaning operations, and dependent on the product being produced at the time. Generally speaking, trade waste is not monitored or controlled based on its fluctuations, rather on a much more averaged approach with maximum limits and with little visibility of its true nature. The impact of the high variability and the peaks of contaminants is not always clear at the WWTP, due to the nature of the monitoring of the processes, and also with end-of-pipe discharge monitoring generally being at a point in time, rather than continuous.

By having a robust and well-embedded control and management regime for trade waste, and a much greater understanding of the individual trade wastes, the sewer network and WWTP can be controlled and managed to a higher degree. Resulting also in improved statutory compliance and identification of opportunities for improvement.

It should also be noted that particular types of contaminants can be of benefit in treatment processes at the WWTP. The carbon to nitrogen to phosphorus ratios are important in biological treatment and individual discharge wastes can have high carbon content which can be actually be of benefit in particular treatment processes. Some TAs adjust their charging regimes for individual traders to acknowledge the benefit of their discharge containing contaminants utilised in the treatment process at the WWTP.

Barrier – Resources for monitoring

Monitoring of trade waste discharges against consent conditions by TAs varies from one end of the spectrum to the other. In some TAs, management and control of trade waste discharges is very mature, having been in place for many years, with a good handle on what is happening across the board, and relationships between TA officers and traders being well established. Whereas in other TAs, sample data from monitoring of trade waste discharges is recorded, but not monitored (other than for charging purposes) or actioned, responsibilities of officers are unclear, and resources are limited. Understanding of trade waste, its management, and the knock-on effects to treatment performance at the WWTP vary hugely across TAs and is often down to the passion and/or experience of an individual, rather than organisational maturity.

Resources to fully investigate impacts of trade waste on WWTP treatment performance and optimisation are generally not available (funding, skills), and as such trade waste discharges have minimal monitoring. WWTP designs tend to allow for trade waste bylaw allowable limits (or trade waste consented limits) in order to protect WWTP discharge compliance. The assumptions made around trade waste discharges may not allow for the actual worst case and/or peaks.

Handling of trade waste data varies widely too – anything from a variety of resource-intensive spreadsheets that are manually inputted into, through to customised databases that automatically upload sample results and flow data, and alert trade waste officers to non-conformances.

Data management systems, experienced and adequate provision of resources for the control and management of trade waste by territorial authorities heavily influences the success of individual trade waste regimes and the ability to identify and action opportunities for improvement.

Barrier – Accuracy and availability of data

Trade waste flow and load data is often a small data set, and usually for a moment in time, or averaged across an extended period (e.g. monthly or quarterly water meter readings used as proxy for discharge flows). A picture of the true nature of the discharge is seldom available, and therefore the impact on the sewer system and the WWTP tends to be unknown, or at the very least not visible or obvious. Data is used for charging purposes, but data for monitoring purposes in order to understand impact is limited. There is often a disconnect between resources involved with trade waste, and WWTP operational staff (silo working), so linkages are often not made between treatment performance issues and trade waste discharges.

Barrier – Lack of penalties

Under the LGA (Part 8), enforcement for non-compliant discharges can only be done through the judicial system. The effort required in order to get a trade waste discharger to court will often put a TA off going to court, along with the cost of doing so. As such, councils have to rely on techniques such as following management plans and good relationships to encourage traders to comply with their discharge conditions.

TAs do have the ability to suspend or cancel the consent or right to discharge if they have written it into their bylaw. The implications of stopping a discharge, and therefore very often stopping production due to the scale of the volumes involved (which couldn't be tankered, or wouldn't be accepted for discharge directly at the WWTP from a tanker), means that the decision is often made to allow the non-compliant discharge to continue.

Barrier – Cost of water and cost to discharge

Water in New Zealand is relatively cheap. Several of the councils interviewed as part of this work made the comment that the cost to discharge is cheap too. This does not encourage dischargers to reduce their flows and loads discharged.

Increased biosolids production associated with industrial loads can also carry a high and often un-appreciated operational cost for TAs which is not always captured in the cost to treat.

Other considerations

In other parts of the world, external factors such as scarcity of resource (water, nutrients, climate change effects), tighter environmental standards, and size providing sufficient scale have driven the need to tightly monitor, control and understand both the incoming sources, and the treatment processes within WWTPs. New Zealand has yet to see such factors, and to incur sufficient economic impact to drivers for change, and therefore source control does not have the same focus as it has in other parts of the world.

Emerging contaminants

As discussed in Chapter 1, emerging contaminants are also becoming more topical across the world, and while the population is becoming more aware of these, visibility of the impact of these, treatment technology and regulation will continue to lag behind as the knowledge base evolves.

The question also has to be who decides that a contaminant is of concern, and what is the mechanism to identify them? How does that then feed into any sort of regulation? While that can be done locally in New Zealand, it really needs a world-wide approach because of the mobility of raw and processed goods across borders.

In reality, industry will not change without some sort of regulatory driver, whether that be on the control of the production, use or disposal of the contaminant.

Climate change response (Zero Carbon) Amendment Act 2019

The Climate Change Response (Zero Carbon) Amendment Act was enacted in November 2019. The Act provides a framework for the development of climate change policies which contribute to the Paris Agreement (to limit the global average temperature increase to 1.5° Celsius above pre-industrial levels) and allow New Zealand to prepare for, and adapt to, the effects of climate change.

Key changes in the Act are:

- New domestic greenhouse gas emissions reduction targets for 2030 and 2050.
- A system of emissions budgets to act as stepping stones towards the long-term target.
- Requirements for the Government to develop and implement policies for climate change adaptation and mitigation.
- Establishment of a new, independent Climate Change Commission to provide expert advice and monitor progress towards long-term goals.

This legislation will likely affect how TAs operate and maintain their services and also how they implement capital works.

This is discussed further in Chapter 6.

2.4 Case studies

Interviews were undertaken with a broad range of councils from across New Zealand, from large urban councils, to medium and small rural councils and with plants discharging across a range of receiving environments. The size of WWTPs receiving trade waste varied, along with the proportion of trade waste received at them. The councils were selected to demonstrate a variety of situations found across the country.

Table 24 Summary of trade waste case studies

Case Study	Council size	Discharge environment	Combined/separate industrial
Case study 1 (CS1)	Small rural	Streams and rivers	Combined
Case study 2 (CS2)	Medium urban	Ocean	Combined
Case study 3 (CS3)	Medium rural	Estuarine	Combined Separate Seasonal industrial treatment
Case study 4 (CS4)	Small rural	Streams and rivers	Combined
Case study 5 (CS5)	Medium urban	Ocean	Combined separate

A supplier of wastewater monitoring equipment, and the New Zealand Trade and Industrial Waters Forum (NZTIWF) were also interviewed. Their feedback is found throughout this Chapter.

While the councils interviewed all had second or third generation trade waste bylaws (the majority closely following the model bylaw), the control and management of trade waste varied significantly. Through the interview process, it became clear there were a number of common success factors with respect to management and control of trade waste in each of the councils. These success factors are broadly categorised by the following:

- Resources – passion, experience, monitoring and collaboration
- Relationships – regular and routine visits, sharing of knowledge, communication of issues
- Use of Management Plans (or equivalent) – framework for management and control

A number of barriers to and challenges for effective trade waste control were also identified:

- Cost to discharge
- Cost to treat
- Lack of penalties
- Adequate resourcing
- Politics
- Fly tipping
- Lack of waste outlets

These are discussed in more detail below.

2.4.1 Success factors – Resources

The degree of implementation of the trade waste bylaws for control and management of key contaminants in trade waste is entirely dependent on the councils' resources.

Passion of individuals

Where trade waste officers are very active and drive the management and monitoring of trade waste in their district, this is a key factor in the success of the control of trade waste, and improvements over time.

Experience of individuals

Experienced trade waste officers build up their knowledge base over time of industry types and key contaminants of concern for each of them. This makes the consenting process more seamless, and there is good support for dischargers who have any issues. Experienced trade waste officers will pick up on issues sooner (and indeed those who have made the effort to get to know the individual premises), and can help support with resolving issues more quickly, to lessen the impact of the non-compliance on the sewer network and the WWTP.

Some of the councils had trade waste officers had only been in the role a year or so, and others had been in the industry for decades.

NZTIWF encourages mentoring between experienced trade waste officers and those that want to learn more. By establishing contacts through industry bodies such as NZTIWF, trade waste officers can share their knowledge and support each other with trade waste problems across the country.

Monitoring of compliance

Systems in use across the councils varied from manually inputted spreadsheets, to databases that captured monitoring and charging data, and highlighted non-conformances.

Automated data management systems mean the trade waste officers can focus on the trends and non-compliances, rather than the management of the data – thereby providing the opportunity to drive improvement in trade waste discharges.

The monitoring still requires input from the trade waste officers, to see the non-conformances, act on them, and continue to pursue them until the issue causing the non-conformance is resolved. This of course relies on the passion and experience of the trade waste officer, and the ability to get the trader to address the problem. While the trade waste bylaws cover the do's and don'ts for trade waste, the how is still down to the trade waste team.

Collaboration

Provision of technical support – one of the councils interviewed provides an engineering service to its industrial customers. The team give advice, identify opportunities for improvement, and provide support with mechanical issues to keep the industrial customers running smoothly. The industrial customers are big employers in the district, and as such are influential in the local economy, not only as employers.

Another of the councils talked about the provision of a water audit service to support industrial customers with water efficiency, and to identify opportunities to reduce water use.

2.4.2 Success factors - Relationships

All the councils interviewed raised the fact that relationships are clearly key in the success of the control and management of trade waste. Where the trade waste team regularly and routinely visit trade waste premises (particularly where councils undertake the sampling), this creates the opportunities to:

- Walk through the site and identify any changes or issues
- Identify issues early
- Talk to operators and managers during business as usual times
- Educate traders on the impact of their waste streams on the sewer network, and treatment performance at the WWTP

One of the councils talked about an open invitation for trade waste customers to visit the WWTP they discharge to.

The nature of the relationship also means that:

- The traders are more likely to inform council they have had an incident issue and the waste stream is on its way to the WWTP.
- Conversations around non-compliance are easier, as the relationships already exist, the trade waste team know the site well, and are in a position to support them through issue resolution.
- Open and honest conversations minimise impacts of issues, with them being identified and resolved more quickly, if there is a good relationship between the trade waste team and the discharger.
- Trade waste customers are more likely to seek advice on how to resolve an issue or make improvements. They often don't have contacts in their own industry to provide the support for problem solving.

2.4.3 Success factor - Use of Management Plans as a tool for management and control

One of the councils did not require management plans from its trade waste customers, some had copies which were not utilised, and others used them as a tool to work with their trade waste customers. Where the councils did not request or use them, this tended to be in the small councils with low resourcing.

Where councils utilise management plans as a means for industrial customers to manage and control their activities:

- These were reviewed by council at the time of application to discharge trade waste to make sure they were appropriate for the type of operation the trade waste customer has
- They were used as a tool for traders to keep their trade waste under control – in theory, as long as they follow their Management Plan, they should be compliant
- They were used by the trade waste officers to audit a trade waste customer's activities
- They were used when a trade waste customer was non-compliant – follow the management plan (which has the appropriate processes, monitoring and controls required for the operation), and they should come back into compliance.

2.4.4 Barriers and challenges

Cost to discharge is discussed in Table 23 above.

Cost to treat

The cost to treat is often disconnected from the impact of the trade waste on the treatment processes, and the cost to treat is not always fully recovered, due to inappropriate charging formulas, or lack of data to inform fees and charges calculations. The councils interviewed fed back that the true cost to treat is not on-charged to the trade waste customers, or there was a lack of visibility to establish if the cost to treat was covered.

Adequate resourcing

Sometimes a function of the scale of a council, the trade waste officer(s) often have other responsibilities and/or multiple functions. Cost to treat or annual trade waste charges should cover the costs for the team, but if trade waste is not seen to be a significant activity for the council, then resourcing will be kept to a minimum. The councils interviewed for this Chapter had 0.5-3 FTEs in their teams dealing with trade waste, although many had more than solely trade waste responsibilities.

All of the councils interviewed were of the opinion that they were under-resourced.

Political Influence

This came up in a number of ways:

- Pressure to accept a trade waste because of the economic contribution to the community
- Pressure to not stop a non-compliant discharge because of the business impact and knock-on effects to the community if this was a big employer, and because of the potential impact of public relations
- Setting of fees and charges could be influenced by political pressures

Lack of penalties

All of the councils interviewed raised the point that there is no ability to fine or impose penalties for non-compliances, other than through the mechanisms discussed in 2.3.1.

Tankered waste

The data and information around wastes which are tankered into WWTPs for treatment is not currently well managed. Mandatory systems in the Liquid and Hazardous Wastes Code of Practice are not user-friendly for either liquid waste operators or the territorial authorities, and are a barrier to easy access to information and data. As such, data is not readily available, and tankered waste is often under-charged due to limitations and difficulties with the system in use.

Fly tipping

Fly tipping into wastewater networks was raised as an issue that happens regularly for all of the councils interviewed. This could be due to a spill from a trade waste customer that has not been reported, or by a member of the public dumping hazardous waste in the sewer network.

Lack of waste outlets

The lack of waste facilities to accept prohibited waste types was raised by one the councils interviewed. The DIY mechanic who changes the oil in his vehicle at home, the bottles of weed spray in the garage where the label has fallen off, the prohibited substances that were banned years ago don't have readily-accessible outlets in all areas across New Zealand.

2.4.5 Other organisations

Interviews were also undertaken with organisations that monitor, manage and control trade waste on behalf of multiple councils. These are minority examples in New Zealand, and demonstrate the methods which are shown to be effective where trade waste services are consolidated.

The functions of each organisation are summarised in Table 25 below.

Table 25 Summary of consolidated services functions

Case Study (CS)	CS6	CS7	CS8
Description	Council-owned company which manages assets on behalf of several councils	CCO which owns and manages assets on behalf of council	Collection of councils who have joined together to share resources
Number of councils involved	Five District and city	One City	Three District and city
Bylaw owner	Each council All similar	Council	Each council All similar
Responsibility	Provision of consistency (consents, technical approach to issues), resources or advise to councils	Own and operate assets, control and manage trade waste	Control and management of trade waste for councils
Trade waste monitoring	Trader self-monitoring	Trader self-monitoring	Trader self-monitoring
Trade waste enforcement	Each council	Organisation	Initial: Organisation Prosecution: Each council
Charging regime	Flow and load	Volumetric only	Flow and load
Resourcing levels	2 FTEs + council TW teams	8 FTEs 4 compliance advisors Investigation specialist Technician	6 FTEs
Benefits of regime	Standardisation of approach Additional resource availability Compare, contrast and leverage the collective experience for the benefit of all	All resources can provide support across all areas, although there's area ownership for BAU Businesses can be encouraged to base their operation at another location within the TAs area where the WW system can accept the trade waste (due to	Efficiencies Standardisation of bylaws and consistency of service across the three councils Size of resource pool greater than total of what each council would have had

Case Study (CS)	CS6	CS7	CS8
		large geographical area)	
Of note	Use of Non-conformance notice when dischargers exceed consent conditions	Very clear requirement to notify of issues or spills Very concise bylaw Consent conditions to enable network management eg in heavy rain	Use of penalty charging where consent conditions are breached – increase of unit rate charged as non-compliance worsens (only for very large traders) Workshopping of TW application with council WW team prior to approval to discharge
Challenges	High numbers of food premises Large industrial customers have left over time, lack of load causes treatment issues	Grease traps are not registered or monitored. As such, these are often not emptied until blockages are investigated Sheer numbers of businesses No visibility of true load because of charging regime being flow only	Gradual growth of a trader may not trigger development contributions

2.5 Overall summary of the effectiveness of the trade waste regime

The mechanisms within the trade waste regime in New Zealand exist to enable control of the volume and concentration of contaminants entering municipal wastewater networks, and indeed also the reduction of them, but there is a lack of focussed drivers. However, in most cases, the applied trade waste regime does not prioritise reducing the volume and quantity of contaminants discharging to municipal sewers below the limits stipulated in the trade waste consent. Provided the traders comply with their consented conditions of discharge, TAs will generally only take the opportunity to reduce limits when consents are renewed and if it aligns with a reduction in the municipal WWTP consented performance.

The following summarises key facets that support effective trade waste contaminant reduction:

Territorial Authorities

The model bylaw provides a good framework for territorial authorities to use to set their bylaws, with guidance on how to manage trade waste. It is entirely up to each TA to monitor, manage and control trade waste in their district according to the bylaw they have enacted. The degree to which TAs actively manage and control trade waste appears to boil down to three factors:

1. The passion and experience of TA officers with trade waste responsibilities or management responsibilities

2. The level of resourcing for trade waste activities
3. The requirements of the WWTP in effect driven through the discharge resource consent.

Management Plans in the model bylaw provide a basis for dischargers to develop a plan to control (and potentially reduce) the contaminants in and volumes of their trade waste, but active management by both the TA and the business is required to give them any value.

Industry

Schemes such as ISO 140001 accreditation, and Leather Working Group Gold Standard are voluntary (although some markets drive the need for the accreditations), and encourage behaviours leading to less contaminants in discharge streams.

Trade waste charges are highly variable across the country, and as such, are often not a driver to improve the level of contaminants in waste streams, or to reduce volumes. Smaller businesses often find it is cheaper to discharge non-compliant trade waste than to invest in treatment to reduce the flows and loads.

There is an absence of penalties for non-compliant trade waste. Enforcement under the LGA has to be undertaken through the judicial system, and territorial authorities have to prove nuisance, impacts and/or damage to the wastewater system. Fines can be up to NZ$ 200,000.

Pseudo penalties can take the form of increased sampling frequencies during non-compliant periods, and as such costs for increased monitoring, and higher strength wastes result in additional charges to the business.

The model bylaw (and also the majority of bylaws reviewed for this report) allows TAs the right to suspend or cancel a consent to discharge. Escalation internally within a TA is often a blocker when the decision is made to allow a discharge to continue for political reasons.

2.6 Opportunities to improve contaminant source control practices

Based on feedback from the interviews with TAs, and consideration of the current trade waste regime, a number of opportunities have been identified. A summary of these is outlined in Figure 48, with further discussion below.

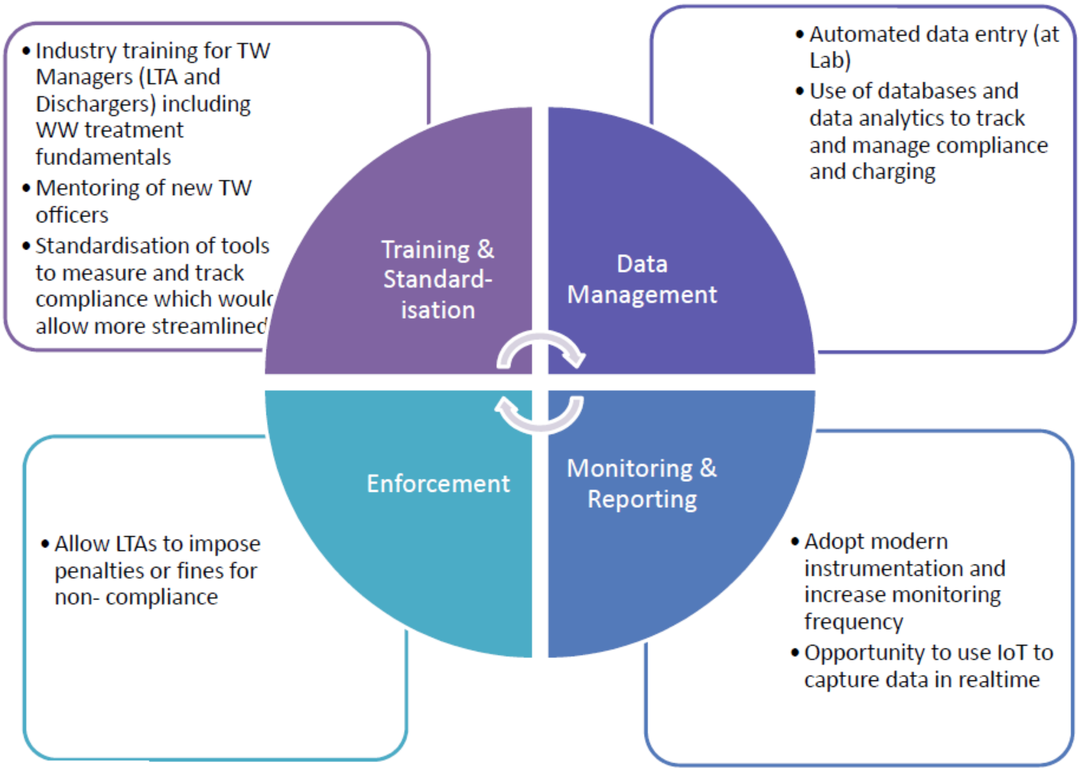


Figure 48 Summary of opportunities to improve contaminant source control

Training - Territorial Authority

Industry training for those managing trade waste within TAs should include an understanding of industry (production, drivers, markets, waste streams), trade waste bylaws (management, control, enforcement of trade waste), wastewater treatment processes (a very good understanding of their local WWTPs) as a minimum. Efforts have been made by NZTIWF to implement a national standard, but funding was never secured to enable this.

Training - Industry

Trade waste dischargers should have a good understanding of the wastes they produce, and how processes should be controlled in order to minimise the wastes that are generated. They should also have a good understanding of any on-site treatment they have of their wastes, in order to monitor and control it. There does not appear to be a body which provides this training to allow a standardised approach.

Training should be provided to the dischargers themselves on the treatment processes at their local WWTP, so they understand the impact of their waste streams. This can be provided by the TA, or by a more high-level approach on education about municipal wastewater treatment in general, for example through virtual learning. This could be a multi-purpose educational package, of use in schools as well.

An understanding of the environment(s) they impact on due to the nature of their business and discharges would be also beneficial, so they are more likely to protect it.

Resources/tools

TA resourcing needs to be adequate in order to manage and control trade waste.

Development of a tool which territorial authorities can use for real costs to be assessed – cost to treat and cost to discharge.

Use of modern data systems to remove the manual data entry and analysis aspect to gain better visibility on performance and hence allow space to focus on enforcement and education.

Monitoring

Improvement of flow monitoring on discharges.

The wider use of consent conditions and monitoring to understand the full fingerprint of a discharger's trade waste and its true load and variability. Realtime monitoring could assist with this.

Policy change

Policy changes from allowing territorial authorities to have a trade waste bylaw to shift to making them manage and control trade waste in their district. Currently legislation gives the TAs the ability to have a bylaw, but nothing is currently in place that means they actually have to control and manage trade waste.

Reporting

Compulsory reporting of trade waste compliance and data to a national body – one of the early model bylaws had a reporting aspect in it, but it didn't stipulate who it had to report to (only to be made public).

Waste transfer data

User-friendly waste transfer system for recording information regarding wastes which are tankered, the transferral of them, and the information provided at the discharge point by the liquid waste company.

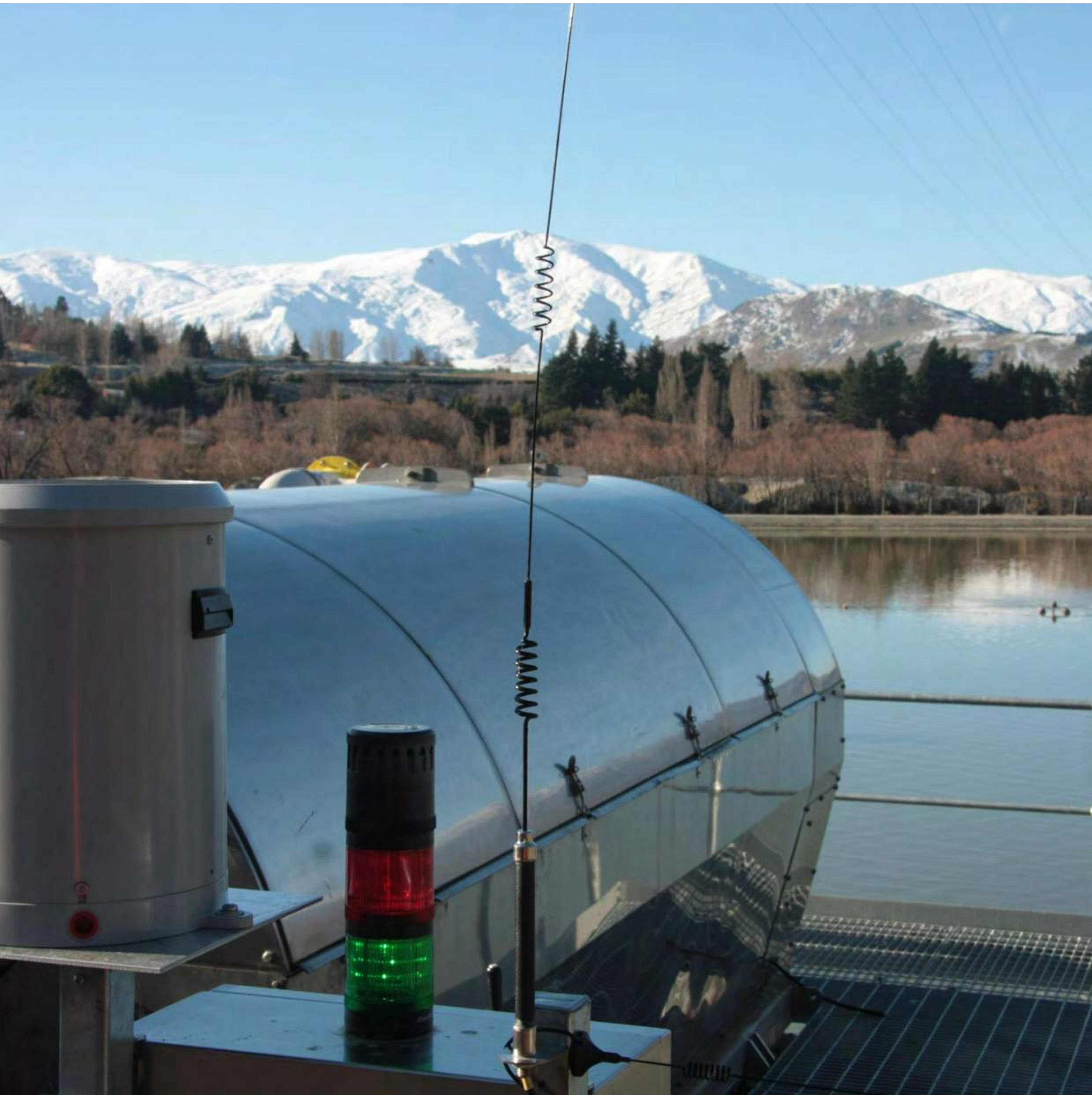
Penalties

The ability to impose penalties should be allowed for.

The value of water

New Zealanders need to understand the true value of water - as a resource, as an ecosystem, and as a life force. With the impacts of climate change (more weather extremes, rising sea levels) becoming more apparent, higher water allocations/demand, and with the effects of pollution, the need to understand the impact of our activities on water is becoming more important.

CHAPTER 3
ENVIRONMENTAL PERFORMANCE



3. Chapter 3: Environmental Performance

Chapter Purpose : A description of the key factors influencing the environmental performance of wastewater treatment plants and networks, including an overview of key cost drivers of different wastewater treatment processes and their relative effectiveness in reducing contaminants in wastewater prior to discharge (eg, BOD, TSS, bacteria, nutrients)

3.1 Introduction

This Chapter provides an overview of the key factors influencing the environmental performance of wastewater treatment plants and networks, these include:

- Legislative framework governing environmental performance in New Zealand;
- Differing wastewater treatment processes, their effectiveness in reducing contaminants in raw wastewater and the inherent costs of these processes; and
- The sensitivity of the receiving environment to adverse environmental effects.

It should be noted that this Chapter covers environmental performance primarily from a western science perspective. Iwi perspectives are discussed in more detail in Chapter 4.

3.2 Legislative framework

A key factor governing the environmental performance of WWTPs is New Zealand's legislative framework. The following section provides a high-level overview of the legislative framework governing wastewater discharges in New Zealand. A comparison is also made to environmental legislation in other jurisdictions.

3.2.1 Resource Management Act 1991

The primary legislation for environmental management in New Zealand is the Resource Management Act 1991 (RMA) which covers the use, development and protection of land, fresh water, air and the coastal marine area. The purpose of the RMA is to promote the sustainable management of natural and physical resources, and this purpose is supported at a national level through a number of principles (ss6-8) that must be recognised or provided for ("matters of national importance"), must have regard to ("other matters") or must take into account (the principles of the Treaty of Waitangi). From this national direction, the RMA sets out a hierarchy of policies and plans that are to be prepared at a national, regional and district level and this is set out in the following sections.

The discharge of municipal wastewater requires resource consent in New Zealand. Very small discharges of treated wastewater, such as those from on-site wastewater systems, are generally permitted activities (up to a certain size, typically < 1.5 m^3/d) and do not require consent. The nature of the rules governing discharges varies between regions.

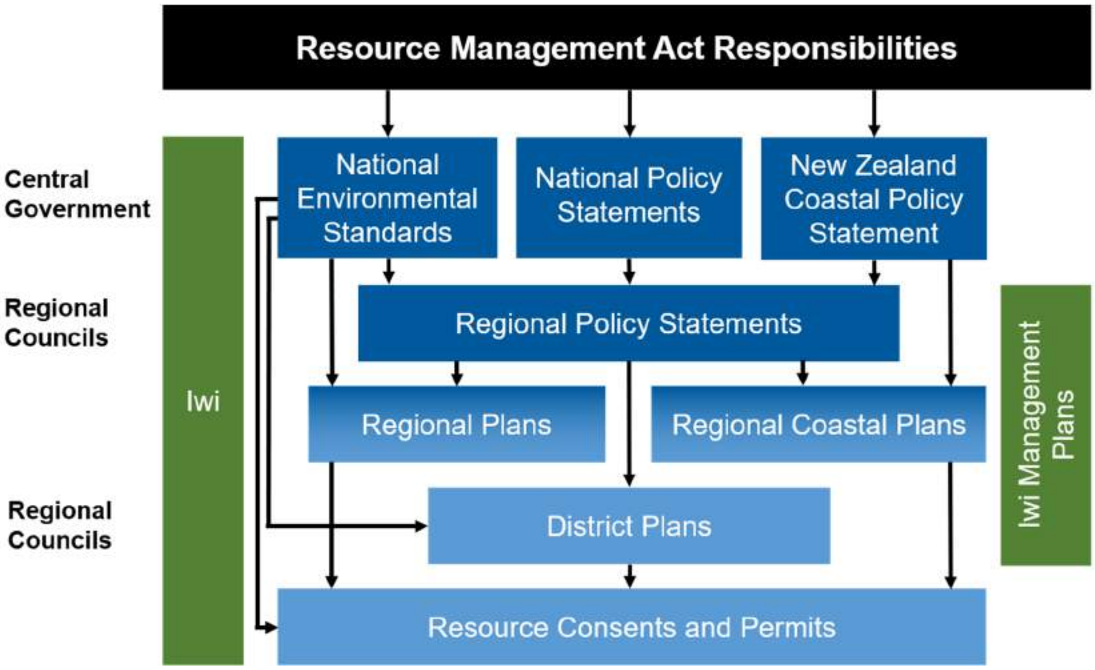


Figure 49: Responsibilities under the Resource Management Act

3.2.2 National direction

The RMA provides for national policy statements (NPS) and national environmental standards (NES) that can be developed, which enables the adoption of consistent policy, standards or regulations to be implemented at regional and/or district levels.

New Zealand Coastal Policy Statement

The New Zealand Coastal Policy Statement 2010 (NZCPS) is the only mandatory national policy statement to be prepared under the RMA. It contains policies relating to the use, development and protection of the coastal environment. The NZCPS must be given effect to by lower order policy documents (e.g. regional policy statement or plans, and district plans). When considering an application for resource consent under s104 of the RMA (e.g. application for discharge of treated wastewater to the coastal environment or structures within the coastal environment), the consent authority must have regard to the relevant provisions of the NZCPS. This includes consideration of whether the project is consistent with or contrary to the policy (and justification as to why not and if this is acceptable in the context).

Some policies require adverse effects to be avoided (e.g. policy 11a), and it is not acceptable for these effects to be mitigated or remedied. Other policies also require ‘significant’ adverse effects to be avoided, and other, ‘lesser’ effects to be avoided, remedied or mitigated (e.g. policy 13(1)(b)). In respect of the above, during design of wastewater infrastructure it is important that the appropriate environmental assessments are undertaken to determine if there are any effects identified that need to be avoided, which may result in design changes (e.g. location, type of structure or standard of water quality discharge).

National Policy Statements

National Policy Statements (NPS) are generally prepared to address a nationally relevant issue, in which regional and district councils are required to implement (generally in a nationally consistent manner). Of key relevance, the NPS for Freshwater Management 2014 (NPS FM), amended 2017, sets out objectives and policies for freshwater management and provides direction to regional councils as to how to manage freshwater. This includes each council developing objectives and values for each defined “freshwater management unit” (which may be a defined catchment, waterbody or series of waterbodies) in their region through consultation with local Iwi and the community. From these objectives, council will develop water quality measures ("attributes") and water quality and quantity limits in order to meet the objectives and values over time. Some attributes (e.g. ammonia, periphyton) have a national 'bottom line' to be achieved[13]. The provisions will be incorporated into the relevant regional plan. This NPS FM is currently being updated and will be replaced by a new version to be gazetted in 2020 which expands the values and attributes to give effect to (amongst other changes). The NPS FM is relevant to those projects seeking to take and use water as well as discharge into water. In relation to wastewater collection, treatment and discharge facilities, if the water quality (attribute) standards of the NPS FM are higher than that currently required within regional plans, implementation of the NPS FM will generally steer environmental performance towards enhanced treatment in order to meet these standards.

National Environmental Standards

National environmental standards set out national regulations that must be enforced by each regional or district council. Of key relevance are:

- NES for sources of drinking water (NES DW), sets requirements to protect sources of human drinking water (e.g. lake, river or groundwater that supplies a community with drinking water) from becoming contaminated. The NES DW is being reviewed at present. This may be of relevance in relation to a wastewater discharge point upstream of an abstraction source and may require additional levels of treatment so that the water meets the appropriate standards for drinking water.
- NES for assessing and managing contaminants in soil to protect human health (NES CS), sets out consent requirements to be sought for defined activities (e.g. soil disturbance, change in land use) proposed to be undertaken on a "piece of land" (which includes an activity or industry on the Hazardous Activities and Industries List (HAIL)[14] - this includes wastewater treatment). The NES CS aims to appropriately remediate the land or contain the contaminants so that the land is safe for human use thereby seeking an enhanced level of environmental performance with respect to the use of the HAIL site.
- Current national policy direction such as the NZCPS and NPS FM should be considered when developing new national direction instruments, to check for consistency and seek to avoid conflicting policies. An example of relevance to the wastewater sector (and as noted above with respect to the NPS FM), the NPS FM sets out compulsory national bottom lines for certain (listed) attributes from which freshwater objectives must be set (at a minimum). As such development of new policy that may impact on these bottom lines will need careful consideration and testing.

3.2.3 Regional Policy Statement and Regional Plans

As per s59 of the RMA, regional councils (and unitary authorities) are required to prepare a regional policy statement (RPS) that sets out an overview of resource management issues, policies and methods to achieve integrated management of the natural and physical resources of the region. The RPS is given effect to through regional plans which must also give effect to national policy. Regional plans cover issues within the function of the regional council, including objectives, policies, methods and rules relating to (of key relevance to wastewater) soil

[13] These are included in Appendix 2 of the NPS which can be found at https://www.mfe.govt.nz/sites/default/files/media/Fresh%20water/nps-freshwater-ameneded-2017_0.pdf

[14] Refer to https://www.mfe.govt.nz/sites/default/files/hazards/contaminated-land/is-land-contaminated/hazardous-activities-industries-list.pdf for the HAIL

disturbance, discharge of contaminants (to soil, land and air), water quality and use and development of the coastal marine area.

Of relevance to the Waikato Region, *Te Ture Whaimana o Te Awa o Waikato – the Vision and Strategy for the Waikato River* is part of the Waikato Regional Policy Statement. The Vision and Strategy contains 13 additional objectives that seek to restore and protect the health and wellbeing of the Waikato River and prevails over inconsistent provisions in the NZCPS and NPS's[15].

3.2.4 District Plans

District plans set out provisions relating to the use of land in relation to s9(3) of the RMA. Requiring authorities[16] have the ability to designate land, similar to a 'spot zoning', by serving a 'Notice of Requirement' to enable the development of public works (such as a wastewater treatment plant). In doing so the requiring authorities does not have to comply with district plan rules.

Once in place the requiring authority can do anything provided for within the designation's purpose by submitting an Outline Plan to the territorial authority which sets out the works intended to be carried out. The TA does not 'approve' an Outline Plan but can request changes.

Designations only apply to land within TAs jurisdiction i.e. cannot be applied to the coastal marine area. In addition, a designation does not exempt the requiring authority from obtaining any other resource consents that may be required under other sections of the RMA known as 'regional consents' (e.g. discharge of treated wastewater, construction of an ocean outfall).

3.2.5 Iwi management plans

Iwi management plans (IMP), are a plan prepared by Iwi or hapū group(s) to exercise their kaitiaki (stewardship) roles and responsibilities in relation to resource management[17]. They may include issues, objectives, policies and methods, and set out expectation for engagement and participation in the RMA process.

IMPs can be taken into account in several different situations, for example:

- To guide councils in giving effect to the purpose of the RMA (specifically ss6(e), 7(a) and 8);
- To inform council when preparing or changing policy (such as regional plans, regional policy statements and district plans);
- To guide council and/or applicants when processing or developing a resource consent application (including in respect to consultation and in identifying areas of interest or focus to the Iwi group).

As such in respect to the planning framework hierarchy in Figure 49, IMPs can 'feed into' and be considered at multiple levels of the hierarchy.

3.2.6 Other matters to consider

Section 104 of the RMA sets out the matters for a consent authority to consider in relation to an application for resource consent. This includes consideration of the actual or potential effects on the environment, relevant provisions of policy documents (mentioned above) and 'any other

[15] Refer to section 12 of the Waikato-Tainui Raupatu Claims (Waikato River) Settlement Act 2010
[16] The list of requiring authorities as at August 2017 is noted here https://www.mfe.govt.nz/rma/rma-processes-and-how-get-involved/applying-requiring-authority-status/list-of-requiring
[17] Whilst IMPs are not referred to specifically in the RMA, reference is made to "relevant planning document recognised by an Iwi authority" which are commonly referred to as IMPs.

matter' considered relevant (which may include non-statutory policy documents of relevance as an example).

3.2.7 Challenges facing Regulatory Authorities and Local Authority consent holders

A recent report has analysed the consent conditions applied to 38 wastewater treatment plants across New Zealand that range in scale, age and the environment into which they discharge. Key themes that have appeared from this review is inconsistency regarding monitoring parameters, reporting, the use of compliance limits and lack of Iwi/cultural considerations and monitoring.[18]

3.2.8 International examples

Wastewater discharge regulations for other countries are summarised within a Department of Internal Affairs Report[19] published in December 2019. Note that minimum discharge standards are a common feature of many overseas jurisdictions, including the European Union, Canada, USA, and Australian states.

In relation to Australia in particular, at a national level the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) is Australia's national environment law — the Act focuses on the protection of matters of national environmental significance (covering all 'actions' that may impact these matters), with the states and territories having responsibility for matters of state and local significance.

Apart from those matters specified in the EPBC Act, in general environmental management is undertaken on a state by state basis, with each state having its own environmental legislation/regulations and authorities.

In Victoria for example, the Environment Protection Act 1970 (EPA) requires discharges to the environment to be managed so that they do not adversely affect the receiving environment (for example, land, surface water or groundwater). This Act is administered by the state's environmental protection agency. Underpinning this are state environment protection policies (SEPPs), which are subordinate legislation made under the provisions of the EPA. This includes the SEPP (Water)[20] which sets out (amongst other matters):

- An application to discharge wastewater to surface waters can be made if the person makes all reasonable effectors to avoid, reuse and recycle the wastewater.
- An application to discharge wastewater to surface water must include all reasonably practicable measures to ensure the discharge does not exceed the environmental quality indicators and objectives of Schedule 3 (which sets out the water quality indicators based on the receiving environment). There are also a number of specific receiving environments with additional pollutant load targets (Schedule 4).
- Wastewater reuse and recycling must be managed in accordance with the Guidelines for Environmental Management – Use of Reclaimed Water.

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[18] *Wastewater Treatment Plant Consent Conditions (Draft Report),* prepared by GHD and Boffa Miskell for Ministry for the Environment, June 2020

[19] *Three Waters Review – Cost Estimates for Upgrading Wastewater Treatment Plants that Discharge to the Ocean*, prepared for Department of Internal Affairs, December 2019 found at https://www.dia.govt.nz/diawebsite.nsf/Files/Three-waters-documents/$file/Report-2-Cost-Estimates-for-Upgrading-WWTPs-that-Discharge-to-the-Ocean.pdf

[20] Refer to http://www.gazette.vic.gov.au/gazette/Gazettes2018/GG2018S499.pdf for the SEPP (Water)

- New discharges cannot be approved for specified water supply catchment areas or where the discharge may impact on the quality of water used for supply.

3.3 Key factors influencing environmental performance of WWTP and networks

3.3.1 Sensitivity of receiving environment

From the perspective of wastewater discharges, the environmental performance of WWTPs is largely driven by the particular consent conditions imposed on the discharge. A key factor in determining this is the relative sensitivity of the receiving environment. Treatment processes are then selected to provide the required treatment to meet the agreed conditions.

The relative proportions of discharges from WWTPs to each receiving environment is discussed in 5.3.

The effect (they can be adverse or beneficial or a combination) of the discharge (in solid, gas and liquid forms) on the receiving environment is measured by:

- The extent to which the cultural, social and recreational values of the receiving water (or land or air) are impacted by the discharge. For example, cultural impacts are often assessed through the preparation of a cultural impact assessment.
- The extent to which the biochemical properties of the receiving environment (often a waterway) are changed by the discharge. For example, an assessment of the eutrophic effects can be made through the measured difference in periphyton growth between upstream and downstream sites). Receiving water temperature, pH and dissolved oxygen are also used in assessing the levels of effects.
- The extent to which fauna in the receiving environment are affected by the discharge. This is often measured by Macroinvertebrate Community Indexing (MCI) and or typing and enumerating of the fish species. In the former, macro invertebrates are collected and enumerated over a period of time over reference and impacted reaches of the receiving water. In the later electric stun fishing is a common technique for identifying the numbers and species present. Both of these techniques consider both the sensitivity and the numbers of the species present (or not).
- The generation of offensive odours identified through public complaints or by regular, proactive odour scouting. The level of offensiveness is assessed by a person or persons with 'calibrated noses'. The concentrations of odorous compounds is determined in an olfactory laboratory.
- Atmospheric emissions (measured or assessed) of greenhouse gases from the conveyance, treatment and discharge activities themselves and from the treatment products in the environment following discharge.
- The depletion / destruction of soils by hydraulic or salt overloading.
- The extent to which the economic wellbeing of the locality, district or region is impacted by the discharge itself (e.g. restricts tourism activities) or by the cost of conveyance, treatment and discharge activities.
- The assessed public health risk for users of the receiving environment. Traditionally, this has been assessed using target discharge concentrations, dilution and comparison against measures such as the bathing water standards. Shellfish monitoring from viable beds has also been common. However, it is now recognised that, in enumerating bacterial and viral contamination of shellfish, it is extremely difficult to identify which organisms have human source origin and which are animal, bird fish etc. A probability

based method of quantitative microbial risk assessment (QMRA) is now very commonly employed in New Zealand to isolate the likely effects of the wastewater discharge activity from those of other activities in the same environment. QMRA combines modelling of field measurements with clinically derived dose response models know performance of treatment processes and statistical probability distributions.

Table 26 below shows a summary of the particular considerations that are applicable for the most common receiving environments in New Zealand and the key contaminants of concern for these environments.

Table 26: Receiving environments and their contaminants of concern

Receiving Environment	Dilution	Particular considerations	Key Contaminants of Concern
Ocean	Typically high, but dependent on length and location of outfall, currents, tidal flow and prevailing winds.	Length of outfall Depth of outfall Prevailing currents Wind and wave action Erosion potential Recreational use Food gathering Kai moana	TSS BOD FOG Pathogens Colour
Harbour	High-medium dependent on tide, wind and currents	Length of outfall Depth of outfall Prevailing currents Wind and wave action Potential for return of wastewater discharge on incoming tides Recreational use Food gathering Kai moana	TSS BOD FOG Pathogens Colour
Estuarine	Medium	Can return on incoming tide within tidal limits Recreational use Food gathering Kai moana	TSS BOD FOG Pathogens Colour
Freshwater	Medium-low dependent on size of receiving water and discharge and nature of discharge	Waterway flow characteristics Background water quality Aquatic ecology Freshwater flora and fauna	TSS BOD Nutrients Pathogens

Receiving Environment	Dilution	Particular considerations	Key Contaminants of Concern
		Recreational use Food gathering Mahinga kai	
Land	Localised (Typically nil)	Soil type, slope Climate Land area Land use Runoff during rain events Groundwater Proximity of neighbours Proximity of public spaces and waterways	BOD Nutrients Pathogens

For freshwater and estuarine receiving environments, the entire catchment upstream of the WWTP discharge contributes to the level of contaminants in the water body. As noted in the DIA report[21] "*In some circumstances, improvements to WWTP discharges may have negligible or little influence on improving the receiving environments to achieve a NPS Freshwater standard, and may be outweighed by other contributors in the catchment*." This is also true in relation to achieving the aspirational goals of particular regional policies. This is particularly the case in wet weather, where runoff from diffuse sources will contribute high contaminant loadings from catchments. However, this is not the case for smaller waterways where wastewater discharges may have a dominant effect over background sources.

Ocean and harbour discharges will have variable amounts of dilution, largely depending on the length, depth and discharge regime. Long outfalls in well mixed locations can achieve very good dilutions, however short and/or shallow outfalls in enclosed bays or harbours can lead to localised increased concentrations of contaminants.

Discharges to land have the advantage of further treatment of some of the contaminants by the microbes contained in the soil, or with some limited biofilm growth where more inert substances such as sand or gravel are used. While further biological action can also take place in water bodies, this tends to be very dispersed.

Discharge to land also has to consider the flow of groundwater from the location. This can at times end up in other catchments, spreading the contaminants far from the disposal site. Where run-off occurs due to ground saturation, undiluted contaminants can end up in water bodies in the area, and also be carried far from the disposal site.

New Zealand is relatively unique in the lack of drivers for reuse of treated wastewater, although there are many opportunities, particularly with large industrial water users and waste producers.

3.3.2 WWTP

Contaminant quantities from wastewater treatment processes are influenced right from the consultation process used during the consenting process, and throughout its life cycle by how

[21] Department of Internal Affairs Three Waters Review – Cost estimates for upgrading wastewater treatment plants to meet Objectives of the NPS Freshwater, September 2018

the WWTP is configured, operated and maintained, and is controlled against the discharge consents imposed.

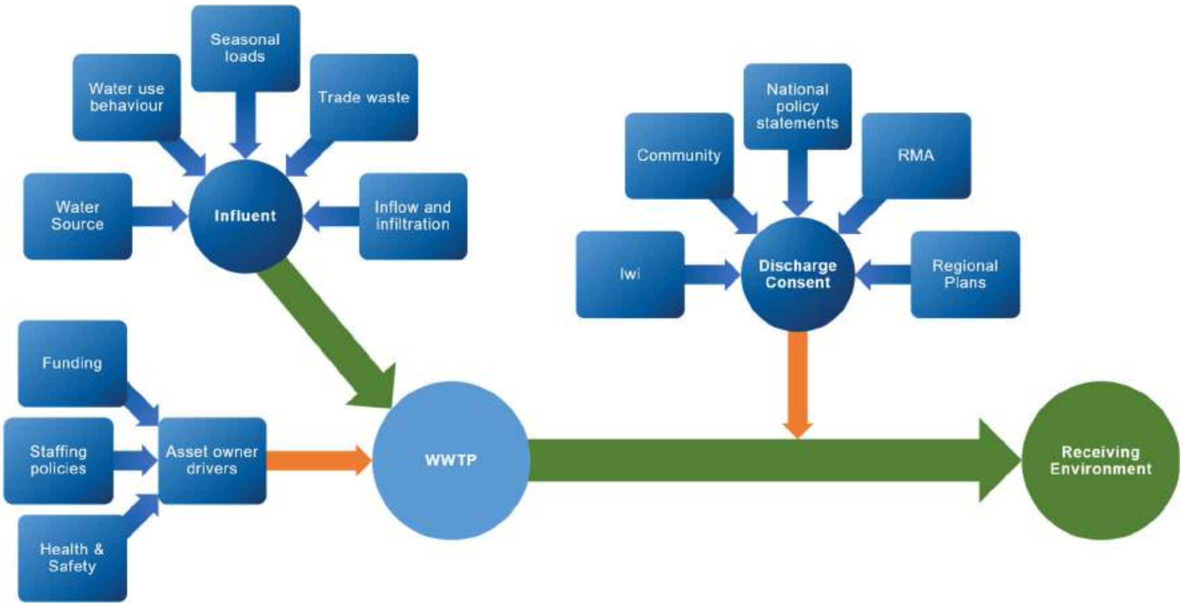


Figure 50: Summary of key influencing factors for WWTP environmental performance

Table 27 summarises the factors affecting contaminants quantities from wastewater treatment.

Table 27: Factors influencing contaminant quantities emitted from WWTPs

Topic	Comment	Driver or reason
Consenting or appeal process	While western science can provide technical investigations to support the assessment of environmental effects off discharges, tangata whenua and the community may have other values that must be taken account of and which may influence quality requirements and or discharge location	Public perception Opinion and knowledge of community members Cultural assessment
Engagement	Particular stakeholder groups will have interest in specific contaminants (quantities and/or concentrations) Stated positions (if validated), can become embedded in consent conditions.	Known impact on their area of interest
Treatment processes	Selection and design of the appropriate processes to remove key contaminants appropriate to the receiving environment	Discharge consent conditions

Topic	Comment	Driver or reason
Process capacity	Funding source availability to keep in line with growth pressure	Housing requirements and rate of development Inadequate infrastructure to support them
Trade-off between gas, liquid and solid phases	The more highly treated a wastewater becomes, the more atmospheric emissions will result from it (e.g. carbon emissions associated with energy use, nitrous oxide production)	Discharge consent focusses on liquid phase only
Incoming wastewater characteristics	Individual “fingerprints”/cocktails of incoming wastewater from the community and industry Each WWTP has to be designed individually to treat its own unique incoming wastewater	Lack of education Cost of water Control of trade waste
More incoming wastewater due to growth	More connections Stronger wastewater in greenfield areas due to water efficient appliances and more water-tight networks with new connections	Asset management Legislation Consumer demand
User behaviours	What is put down the wastewater network Water use	Cost “Too hard” to dispose of correctly Water metering/cost of water
Cultural considerations (see Chapter 5)	Desire to remove treated wastewater discharges out of water bodies	Mauri of water Water sources and waste should be kept separate Collection of un-contaminated food for consumption, particularly for visitors
Operation/management of plants	Control and optimisation Proactive maintenance	Cost Asset management Discharge consent requirements
Inflow and Infiltration (I&I) in network	Degree of I&I impacts on residence time and ability to treat contaminants	Cost Asset management Control of network connections

Topic	Comment	Driver or reason
Biosolids	Disposal routes limited by public perception, contaminants such as heavy metals Can be a resource for nutrient recycling Can be used to generate energy	Consumers (biosolids not going on food crops) Public perception (not in my backyard) Landfill levies Lack of outlets

3.3.3 Waste stabilisation ponds legacy

Waste stabilisation ponds are coming under increased pressure due to tightening consent limits, and growth in their catchments. As time goes on, increasing numbers of them are requiring significant modifications, add-ons or full replacement in order to meet tighter consent limits as the discharge consents come up for renewal. Chapter 1 has included a few examples of upgrading ponds to achieve higher effluent quality through in-pond upgrades or tertiary filtration.

Very often, the ponds take up most of the treatment plant site, making upgrades challenging due of the lack of land available on the rest of the site.

Low-technology solutions such as land-based treatment can be suitable for oxidation pond discharges, provided application rates are managed to prevent nutrient and sediment run-off. Discussion of land-based treatment is covered in Chapter 5.

3.3.4 Networks

Contaminants can escape from the sewer network either due to overflows, or concentrations both inside and outside the system can be affected by infiltration/exfiltration processes.

Infiltration is where water from the environment can enter into the pipes and manholes, usually because the groundwater is higher than the asset, or by water percolating from the top surface. Joints and connections are particularly vulnerable to infiltration, because of the age, type of joint, and methodology used during installation. This results in higher flows (usually during the wetter winter months), which in turn increases the flow into the wastewater system.

Exfiltration happens when groundwater levels drop, and wastewater leaks out of the joints and connections into the surrounding ground, thus contaminating the ground around the system.

Overflows can happen because the pipes or pump stations are not able to pass forward flows arriving at them. This can be due to capacity constraints (more flow than the pipes and pumps can take), partial blockages or full blockages in pipes and pumps, and issues such as mechanical issues, power outages, or control issues at the pump stations.

Factors affecting the quantity of contaminants coming from the sewer network into the surrounding environment are summarised in Table 28 below.

Table 28: Factors affecting the discharge of contaminants from wastewater networks

Topic	Comment	Driver
Type of network	Combined or separate Pumped or gravity Pressure or vacuum sewers	Topography Historical practices

Topic	Comment	Driver
Condition	Joints have lost grouting Pipes brittle Poor installation Illegal stormwater connections Low gully traps and manholes	Cost to replace
Overflows	System capacity exceeded Blockages	Growth Lack of funding to replace assets in poor condition Lack of education on what not to flush Poor trade effluent discharge behaviours
Management of network connections	Quantity and quality of connections	Cost Allow for development
Management of growth	Planning for infrastructure not ahead of growth	Development planning Cost

3.3.5 Climate change

Climate change is already starting to impact on the environmental performance of networks and WWTPs, mostly due to weather extremes with being very dry or very wet. Climate change is discussed further in Chapter 6.

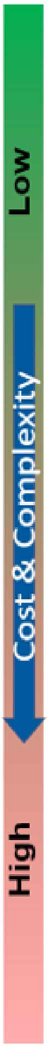
3.4 Key drivers of different wastewater treatment processes and their relative effectiveness

The cost to treat wastewater is driven by the degree of treatment required by the conditions in the discharge consent. As the treatment increases in complexity, and the consent parameter limits get more stringent, the cost to treat increases.

The discharge consent limits are influenced in a number of ways:

- The scientifically assessed effects or likely effects on the receiving environment
- Community – drive to reduce pollution into the environment, want to be more “green”.
- Cultural – keep waste out of water sources, food collection from water bodies. Preserve or restore the mana and mauri of the water.
- Environmental legislative requirements – RMA, NPS

Table 29: Drivers for evolution of wastewater treatment in New Zealand



Treatment type	Era	Reason for use	Cost
Oxidation ponds	60s-80s	Simple to operate Free disinfection - sunlight	Cheap to operate
Wetlands	80s-90s	Natural system Cultural considerations	Cheap to install High maintenance requirements
Biological processes	1990s-2020s	Tighter discharge consents Smaller footprint	High structure cost but 100 year life Aeration costs Higher operator costs High biosolids disposal costs
Physical processes	2000s-2020s	Footprint restrictions Growth – easy add-on	High structure cost but 100 year life Cost to treat sludge
Chemical processes	2010s	Phosphorus consents Use of carbon for more complex biological treatment driven by tighter consent limits	Disposal of metal-rich biosolids
Advanced activated sludge processes	2000s	Tighter total nitrogen standards Phosphorus removal Footprint restrictions	High structure cost but 100 year life Aeration costs
Membranes	2010s	Footprint pressure Public health Very low nitrogen limits	Membranes Chemicals
Biosolids	2010s	Energy production Solids reduction	Structure Control systems

3.5 Case studies

3.5.1 Case study – Te Kauwhata and Meremere WWTPs

Example where effluent discharge requirements are heavily influenced by the community and cultural factors

The town of Te Kauwhata is located in the lower catchment of the Waikato River. The wastewater scheme collects and treats wastewater from Te Kauwhata, the Springhill Correction Facility and Rangiriri. The original WWTP was upgraded in 2006 from basic oxidation ponds to an enhanced aerated pond system using the Aquamat technology (a submerged mat which provides surface area for the growth of microorganisms to treat the wastewater). Following this upgrade, the treated wastewater discharged from Te Kauwhata WWTP consistently met all resource consent conditions until 2015.

The WWTP discharges to Lake Waikare, which is a vital part of the flood control scheme for the Waikato River and is at the head of the Whangamarino wetland, a wetland of international importance. Lake Waikere is extensively used for recreational activities and is significantly important to Iwi, who have long-standing kaitiakitanga responsibilities for the mauri of the lake. The lake is very shallow and is hyper-eutrophic, in poor health, where vegetation and wildlife has been reduced over the last decades (since the lake level was lowered in the 1960s as part of the lower Waikato flood control defences) and is heavily impacted by farm runoff.

In 2008, Waikato District Council (WDC) applied for the renewal of the discharge consent from Te Kauwhata WWTP to Lake Waikare. The project found strong opposition from the community to use the lake as the long-term discharge option for treated wastewater. Studies undertaken by Environment Waikato at the time found that the main source for nutrients being discharged to the lake were the inflows from Matahuru and Te Onetea streams, and that the nutrient loads from the WWTP were relatively small.

A report by the Lake Waikere Steering Group (2007 cited in Mountfort & Bax, 2012) noted that removing the discharge from the WWTP would not result in significant improvements to the lake water quality. Nevertheless, the discharge consent application was rejected and the Te Kauwhata Consultation Group was formed to facilitate an agreement leading to a technically and culturally acceptable and affordable solution. A consent for discharging into the lake was finally issued in 2013 and will expire in 2028.

Further downstream on the Waikato River is the town of Meremere, which is 14.5 km north of Te Kauwhata. Meremere's wastewater is treated in an oxidation pond (surface aerator and baffle system), a planted rock filter and UV disinfected before discharging into the Waikato River. While only a tiny flow, the plant only discharges to the Waikato River at night. A key driver for this was public health concerns due to the regular use of the nearby Mercer reach of the river for training by rowing clubs.

The Meremere WWTP consents associated with the effluent discharge came into effect in 2003 and expired in August 2018. The lodging of a renewal of the existing consent in February 2018 for a five year period has allowed the continued operation of the WWTP pursuant to s124 of the RMA, while long term solutions are investigated.

Figure 51: Meremere WWTP wetland and oxidation pond

Over the last few years, both plants have experienced re-occurring non-compliances with the existing resource consent conditions. Te Kauwhata WWTP has exceeded the effluent TKN and

TN concentrations a few times since 2015, while Meremere WWTP has not met consented conditions for ammoniacal nitrogen, TKN and TSS for several years. As both WWTPs discharge to environments which have community and Iwi sensitivities, there is increased pressure to investigate further treatment and alternatives for the discharges.

The Vision and Strategy for the Waikato River (Te Ture Whaimana o te Awa o Waikato) is the overarching document with regard to the management of the Waikato River and its catchment, which has the purpose to restore and protect the health and wellbeing of the river for future generations. It was developed and published in 2008 under the guidance and direction of the Guardians Establishment Committee, following treaty settlements with Waikato Tainui and Maniapoto. This document sits above any Regional Policy Statement in the statutory hierarchy, and applications potentially affecting the river catchment will need to demonstrate ways in which it protects and restores the river in proportion to the activity to be undertaken, any historical adverse effect, and the state of degradation of the environment.

At this time, WDC in partnership with Watercare is progressing more advanced treatment options for Te Kauwhata and Meremere WWTPs. The Vision and Strategy for the Waikato River has been a key driver for planning future treatment upgrades, which has transpired to be more influential than the potential environmental effects of the discharges on the receiving environments. New or upgraded schemes will need to be consistent with the principles of protection and restoration of the Waikato River as set out in the Vision and Strategy for the Waikato River. For example, discharges from the upgraded Pukekohe WWTP (under construction) have been limited to a stringent level of 3 mg/L of total nitrogen and the Hamilton/Cambridge sub-regional facility is currently being conceptualised to a similar performance level.

3.5.2 Case study – Queenstown Lakes District Council

Example of centralised WW treatment with staged upgrades

Queenstown Lakes District Council (QLDC) provides a wastewater network for 24,550 connections (domestic and non-residential). Currently there are 65 pump stations across 11 catchments for 5 WWTPs, with 551 km of pipes in the reticulation. They operate in the challenging environment of a high visitor population, with approximately 34 visitors annually per 1 local resident. They also have been experiencing high growth rates of 3.5-4 per cent per annum, even though this was only projected at 2.5 per cent per annum.

Discussions on and implementation of consolidation of wastewater treatment across the district started many years ago and continues to progress with Project Pure (Wanaka) and Project Shotover (Queenstown) becoming the focal treatment plants. Given the growth rates in the district, including significant entirely new communities, it was becoming less cost effective to consent, develop, maintain and manage multiple small plants, each requiring consent renewals, upgrades and operational resources to keep up with growth. With the high visitor population numbers, some flexibility in the wastewater treatment is required, and the high growth rates accelerate the need for upgraded treatment processes. Communities such as Kingston and Cardrona are remote and as such will be serviced with new WWTPs in the future.

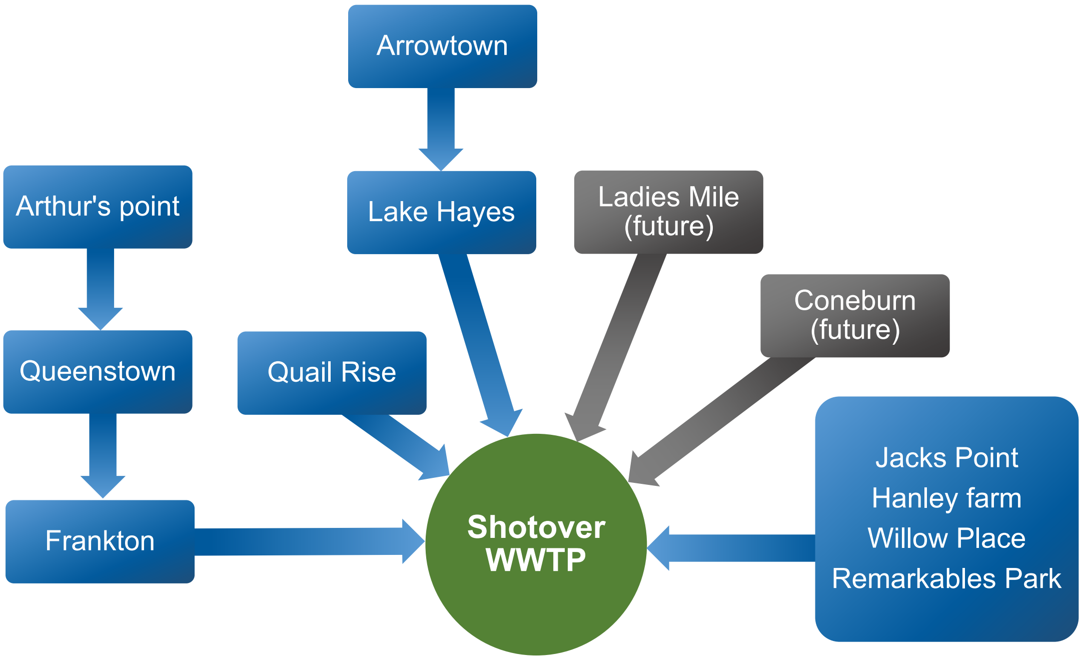


Figure 52: The Project Shotover wastewater network

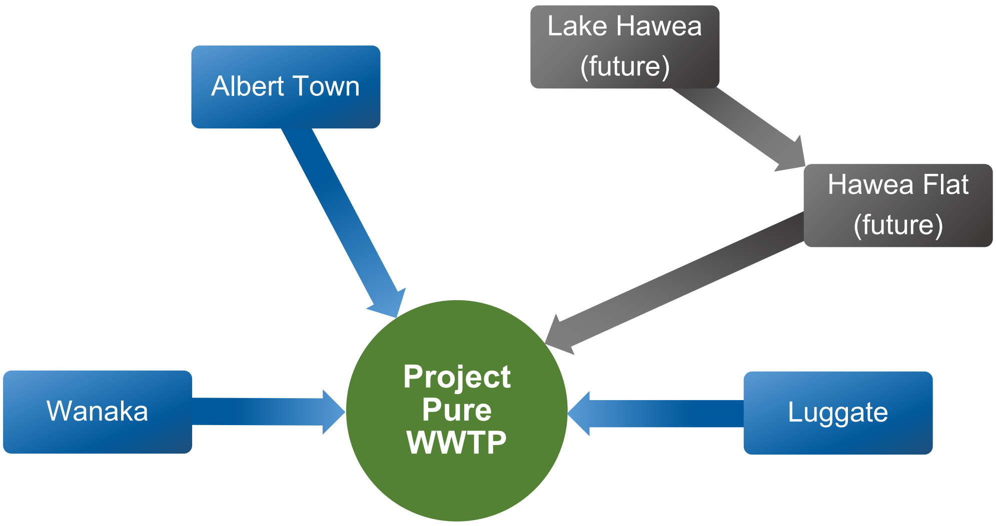


Figure 53: The Project Pure wastewater network

While the main disadvantage of having centralised treatment is the amount of pumping involved, there are a number of advantages in having one treatment plant for Queenstown and surrounds, and one treatment plant for Wanaka and surrounds:

- Economies of scale with one better plant
- One discharge location
- Less consents to review
- Master planning for one site
- One site to maintain

- Lower OPEX – fewer operators, fewer plant items to maintain and less general site maintenance

There is also the added benefit of the pipeline routes opening up areas for development, which previously had not been serviced by a wastewater system.

The pump stations are also being upgraded in order to cope with the growth in the district. This means better control systems, better visibility, and better diagnostics with the upgraded technology, in order to control the “daisy chain” of pump stations and to control flows arriving at the inlet works of the WWTPs.

There are benefits to the pristine discharge environments by having single, appropriate discharge locations and methods, rather than multiple sites being impacted by multiple discharge locations from multiple WWTPs. It also means assessments of the impacts are confined to fewer locations.

The centralisation of the WWTPs provides for the future development of opportunities around using the treated water and biosolids produced as resources, rather than being considered as waste streams. With ultimate users such as golf courses close by, and opportunities leaning towards a materials recycling facility/ecopark in close proximity to the Shotover WWTP, the scale of the operations mean these are more likely to become viable options. Energy recovery also becomes an option with the volumes involved, and opportunities beyond producing power from digestors present themselves with potential coupling of processes, for example waste heat being used on a neighbouring site to heat processes and buildings.

3.6 Discussion

The evolution of wastewater treatment in New Zealand was originally driven by public health risk on a localised basis. Septic tanks in backyards (and communal ones on river banks) were no longer a healthy or sustainable way of dealing with domestic wastewater, and sewerage systems were constructed to take the wastewater to a more centralised location. The treatment provided was driven by the need for a public health solution, at the minimum cost to provide ‘reasonable’ environmental performance. Ocean discharges only had gross solids removal, while more inland treatment plants were provided with the likes of oxidation ponds for simple, cost-effective treatment.

The evolution of wastewater treatment in New Zealand has been driven by the evolution of environmental and public health legislation (Table 29) and by the evolution in public expectations. This has been given effect through specific legislation such as the RMA, and regional regulation coming out of that, and through the consenting process, which is also influenced by inputs from the community and Iwi (Figure 50). These have collectively driven improvements in the environmental performance of WWTPs since about 1990 and will continue to do so into the future.

While there are still issues with environmental impact from wastewater escaping from sewerage systems, continual improvements through renewals, upgrades, improved materials, and improvements in technology (for example monitoring and control systems) will continue to reduce the discharges to the environment. Educational programmes such as ‘DrainWise’ in Gisborne, and ‘Save our Pipes from Wipes’ implemented across the country will also contribute towards lessening issues.

A key barrier to improvement in environmental performance in both the networks and the WWTPs is cost. Upgrades normally require significant capital investment ($millions to $tens of millions and more), and ongoing operational costs, which can be unaffordable for the community. The operational costs, and servicing of loans for the capital costs can be charged through targeted or district-wide rates, but there can be the issue of one community subsidising another within the councils' area. The ratepayer base may not be sizeable enough to fund upgrades through rates. Other sources of funding may need to be sought, but are limited to central government funding for this type of investment.

Ironically, the point source discharge often represents a tiny portion of the nutrient (for example) inputs to a waterway but upgrades are often forced, through the process of consent renewals, which cost a lot of money but which will make no measurable difference to or improvement in the receiving water quality. For examples:

- At 2019, point source discharges make up approximately 3 per cent[22] of nutrient loading to the lower Waikato River but there is of the order of NZ$1Bn identified for upgrades to the WWTPs generating those point source discharges.
- A small pond based WWTP (c400PE) in the Tararua District discharges to a local river. The discharge has no measurable effect on the river system into which it discharges. However, because there are certain active regional policies related to 'requiring' improvements (regardless of actual effect) to discharge performance, upgrades will be enforced on that plant that will cost of the order of NZ$2M. In this case, the reduction in nitrogen discharge is less than 1 tonne TN per year at the cost of at least an additional 12 tonnes of CO2eq greenhouse gas emissions per year from the plant.

In time, as all inputs into waterways improve, point source discharges could have more measurable cumulative effects on water quality, but catchment-wide improvements are required in order to improve water quality, which is where freshwater plan changes provide a framework to focus on whole-catchment improvements.

There is also considerable variability of discharge consents across receiving environments and across the country. With discharge consent durations being up to 35 years, the continual renewal and/or replacement of discharge consents across the country over time means that a discharge at one point on a river can be relatively relaxed, while at another location on the same river, much more stringent due to a more recently-issued consent. Currently there is no mechanism to standardise conditions of discharge across the board. In the European Union for example, Directives have standardised the approach to some of the conditions of discharge based on the size of a WWTP, irrespective of the receiving environment. This has driven the minimum treatment performance required of WWTPs where the Directives apply. This reflects the fundamental difference between New Zealand's 'Effects' based legislation and the 'Prescriptive' approach used in many jurisdictions, including Australian and European states.

With the development of sustainability strategies across the country, there is an increasing focus on carbon emissions. These start to tie together the threads not normally considered in the network or at the WWTP of air emissions and biosolids and give them more visibility.

[22] 2019 WRC presentation to H2A Stakeholders workshop

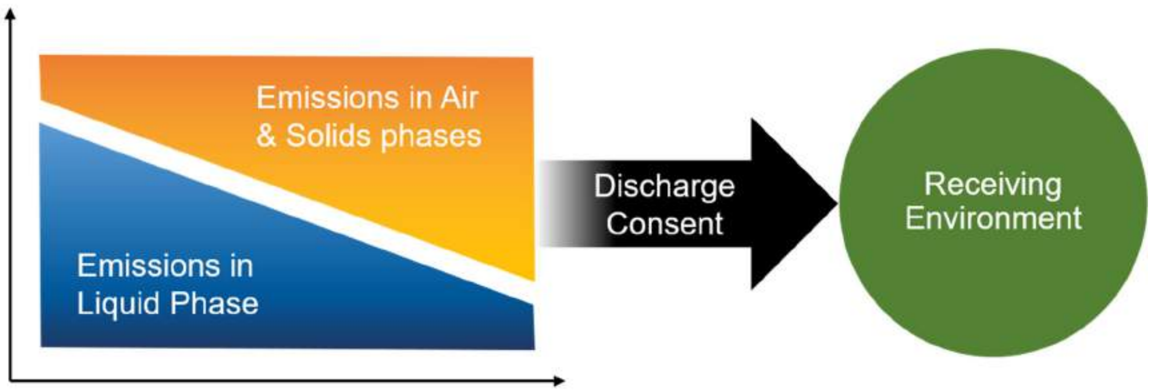


Figure 54: Relationship between emissions from the solid, liquid and air phases and treatment requirements in order to meet tightening liquid discharge consents

The discharge consent for the effluent drives the treatment required to produce the treated effluent, but by reducing discharge limits, the by-products of the improved effluent quality can be increased air emissions and more biosolids production. In some cases, air emissions are now being quantified particularly through carbon accounting, and with the volumes and nature of the biosolids being produced, biosolids are requiring more processing and treatment than ever before.

In summary, the environmental performance of treatment plants and networks is improving over time, but cost (more importantly affordability) will continue to be a barrier to any acceleration in improvements, even when legislation, the needs of the receiving environment, and Iwi and the community drive change.

CHAPTER 4
MĀORI VALUES

Photographer: Simon Devitt

4. Chapter 4: Māori Values

Chapter Purpose - A detailed description of the extent to which Iwi/Māori values and perspectives on wastewater management have been integrated into the design, management and monitoring of wastewater systems in New Zealand (e.g. through case study examples).

4.1 Acknowledgement

The text for this Chapter was provided by Antoine Coffin of Te Onewa Consultants and was peer reviewed by Te Pio Kawe (Boffa Miskell).

4.2 Tikanga Māori, Mātauranga Māori, Māori values and principles

The views and perspectives of Iwi (tribe) are most often seen through the lens of their ancestors, generations present and future, personal and shared experiences, observations, knowledge of traditions, events, resources and priorities of the time. They can be dynamic, changing and evolving but also static, fixed, and resolute.

The tikanga (right ways of doing things), matauranga (knowledge), uara (values) and matapono (principles) can vary from Iwi to Iwi. They inform, guide, and sometimes direct the views and perspectives of Iwi.

In relation to wastewater, whilst each Iwi and indeed each hapū will have their distinctive and specific experiences, there are some common, shared, and similar values and perspectives. At its most basic, human waste is considered harmful, tapu, and needs to be kept separate from where people cook, eat, harvest food, talk and sleep.

Wai (water) is a taonga and essential to life. In Māori traditions water was present at the beginning of origin stories. It has a mauri (life force) and can be a medium for both enhancing and removing tapu.

Papatūānuku (Mother Earth) is a primal parent, the foundation of all life. Papa is the cleanser and the place where all life returns.

Kai (food) sustains life. Harvesting wild foods and crops are an important tradition among Iwi. Specific species of flora and fauna are synonymous with Iwi identity, mana (prestige) and hospitality. The abundance and high quality of these species is of paramount importance to Iwi.

In 2010, Craig Pauling (Ngāi Tahu) and Ataria ((Rongomaiwahine, Ngāti Kahungunu, Ngāti Tūwharetoa) undertook a research study on traditional and contemporary Māori views and values, from a Ngāi Tahu perspective, on the management of human waste including the reuse of municipal biosolids. The report provides a relevant and succinct discussion focusing on the principal cultural values and issues relating to waste management and their applicability and importance to current and future waste management practice in New Zealand.

In summary the research found a diversity of Māori waste related terms, a universal Māori tradition of the dedicated community 'paepae-latrine', and a fastidious separation between waste disposal resources and places dedicated to living and food harvest/preparation/consumption.[23] There was also an implicit and critical separation between the human food chain and human waste streams.[24]

[23] Craig Pauling and James Atarea. Tiaki Para A Study of Ngāi Tahu Values and Issues Regarding Waste. Landcare Research, 2010. Pages 6-9

[24] Craig Pauling and James Atarea. Tiaki Para A Study of Ngāi Tahu Values and Issues Regarding Waste. Landcare Research, 2010. Page 10

At its core, the traditional Māori perspectives and values related to waste, in particular human waste was that it was harmful, tapu, and needed to be kept as far away as possible from where people cooked, ate, talked and slept.[25]

Our literature review and conversations with Iwi representatives has confirmed many of the findings of the contemporary views expressed by tangata whenua and individuals surveyed in the 2010 report. This includes:

- The important issues of environmental pollution/degradation, human health issues, impacts on abundance and access to mahinga kai, unacceptable treatment and disposal methods and impact on wāhi tapu.
- Of great concern is the presence of hazardous wastes, human waste, industrial, biological and farm wastes.
- Less concern is greywater, natural and garden wastes.
- There are mixed feelings about moving to a decentralised system where a centralised system exists.
- A general preference for centralised and individual local systems over decentralised municipal systems.
- Strong disapproval of discharge to water, freshwater, recreation areas, marine environment, and food crops.
- Higher approval for waste being used in generating electricity, applied to forestry, discharged to wetlands, and used on non-food crops.
- Residence time is a significant factor for approval of land discharges.
- Tangata Whenua would prefer not to use their lands for wastewater discharge.

There were a few subtle differences between our work and the research findings reported by *Pauling* and *Atarea*. Our findings have found that tangata whenua rate participation in wastewater management very highly, with aspirations to have both national and strategic discussions on the future of wastewater management. We have found that wetlands are preferred where they exhibit 'natural' qualities and other land alternatives are not possible. It has been difficult to ascertain much detail on 'natural' qualities, but it is understood to mean functional habitat, similar to wetlands in the natural environment and likely to include an element of scale and abundance. Tangata whenua have expectations that the treated wastewater will penetrate the ground in a meaningful way. Some Iwi has questioned whether rock beds and similar structures are sufficient to treat wastewater from a cultural perspective.

Recent controversial cases since 2010 include the Matata Treatment proposal, the Taipā Treatment plant, Gisborne Treatment Plant, Tauranga and the still in progress Te Awamutu network and Rotorua Treatment Plant. These projects have all involved Iwi and hapū either in their development and/or during the consenting processes. The Māori values expressed in these instances appear to be consistent with previous projects and literature reviewed by Pauling and Atarea.

In summary these Tikanga Māori, mātauranga Māori, Māori values and principles are:

- Separating wastewater treatment from places where people may live.[26]

[25] Sydney Moko Mead. Submission to Living Earth Joint Venture Company Limited and the Wellington City Council for a Biosolids Project, 1998. Page 4
[26] Matata Project

- A strong preference for discharge to land.[27]
- Higher quality of treatment of all contaminants.[28]
- Ceasing decentralised systems in the upper catchments and reticulating to a centralised system.[29]

For Ngāti Kahungunu ki Wairarapa the vision of having waterways free of point discharge, extends to having waterways free from non-point discharge. The total discharge of treated effluent is seen as a stepping-stone to the reuse of water on land for wider projects that include irrigation for cropping, nurturing livestock, promoting forest growth, watering public lands and countering the risks of drought.[30]

The Matata treatment proposal included the piping and discharge of treated wastewater via sub-surface irrigation system on Māori Land, leased by the Whakatane District Council. The lease and proposal were agreed to by the responsible trustees but strongly opposed by some of the landowners and Ngāti Rangitihi Trust who contended that the land was designated to be used for papakainga housing. The Matata project was declined by the Environment Court citing potential contamination of groundwater, odour issues, and lack of clarity of relationship between conditions and consents.

For many years Ngāi Tahu, along with several other Iwi, has consistently voiced a largely misunderstood and often lone concern for the way waste is managed in New Zealand (Waitangi Tribunal 1977, 1978, 1981, 1985, 1987; Kapea 1994; Puketapu 1997; Leith 2001; Te Taumutu Rūnanga 2003). Much of the concern has focused around the treatment and disposal of human effluent, especially where it is discharged to water, and of the need to protect significant cultural values such as mahinga kai and wāhi tapu. The importance of water and waterways to Māori underpins a broad support for alternative waste management strategies that involve land application.[31]

Despite these concerns being widely acknowledged and dealt with through a number of high profile legal disputes, Māori concerns have continued to grow. Many Māori believe that little is being done to understand Māori concerns and that there is a widespread lack of support for changing the current waste management paradigm in favour of more sustainable and alternative solutions that include some form of land treatment or that result in reduced use and degradation of water, and consequently valued mahinga kai resources.[32]

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[27] Taipa Project
[28] Te Awamutu, Gisborne, Rotorua, Tauranga
[29] Te Awamutu
[30] Rawiri Smith. A Māori Cultural Report for Martinborough Wastewater Treatment Plan Upgrade. Paragraphs 129-130
[31] Craig Pauling and James Atarea. Tiaki Para A Study of Ngāi Tahu Values and Issues Regarding Waste. Landcare Research, 2010. Page 1
[32] Ibid.

4.3 Core issues

During the course of the literature review and interviews with Iwi practitioners and representatives we sought to identify and understand emerging issues. What we most often experienced was a reiteration of the core issues confronting Iwi. These included:

- The use of water as a medium for transporting waste is offensive to Māori.
- Strong opposition to discharging treated wastewater to waterbodies (rivers, lakes, sea), mahinga kai and wāhi tapu.
- A preference for land-based discharge/treatment.
- No-one wants a WWTP next door.

Later in this Chapter emerging issues are listed.

4.4 Iwi perspectives

This section includes a summary of Iwi perspectives from the case studies. The main themes of the perspectives revolve around the discharge options, relationships and engagement with Councils, recognition of Māori knowledge and weight given to their views.

- Iwi have historically and continue to oppose the discharge of wastewater to water (lakes, rivers, sea).
- Iwi prefer discharge to land that involves meaningful penetration rather than cursory passing over rocks or shallow ponds.
- Iwi are most often describing effects of wastewater in 'mauri' terms.
- Those Iwi with professional staff and high-level relationships with Councils appear to be making significant gains in engagement, design, and land-based alternatives.
- Consent by consent consultation under the RMA is process driven, transactional, short-term, and adversarial.
- Many Iwi representatives are complimentary, and some have praised the council engagement processes and the exploration of alternative options, but this does not necessarily translate to a preferred or supported outcome.
- Iwi cite cost of alternatives, land availability and geo-technical reasons as barriers to land-based systems.
- Iwi perceive council staff as willing to engage.
- Iwi view decision-makers as ignorant or unaware of Māori cultural values, issues, and unsophisticated regarding measures to avoid, mitigate or remedy the effects.
- Low levels of matauranga Māori-engineering and design capability available nationally.

4.5 Statutory context and Waitangi Tribunal

The statutory interface between wastewater management and Iwi in New Zealand is often reflected in their participation in processes of the Local Government Act 2002 and the Resource Management Act 1991. Iwi find themselves most often engaged in resource consent processes which are adversarial, short-term focussed and technical.

The preparation and review of long-term plans and annual plans to propose and fund the development of, maintenance and upgrade of wastewater infrastructure is at the core of what territorial authorities do.[33] These plans represent the priority and financial commitment given to wastewater management.

Iwi can participate in the decision-making processes through making submissions to annual and long-term plans, attending hearings and advocating through formal representation and participatory structures. Councils have some broad statutory obligations to promote the social, economic, environmental, and cultural well-being of communities in the present and for the future[34], but also establish and maintain processes to provide opportunities for Māori to contribute to the decision-making processes of the local authority; and consider ways in which it may foster the development of Māori capacity to contribute to the decision-making processes of the local authority; and provide relevant information to Māori of achieving this.[35] Where land or a body of water is the subject of a significant decision, the local authority must take into account the relationship of Māori and their culture and traditions with their ancestral land, water, sites, waahi tapu, valued flora and fauna, and other taonga.[36]

Iwi would need to make concerted efforts over many cycles of long-term and annual plan reviews. This is unlikely on its own to be effective without high levels of awareness and understanding of Iwi values and perspectives and the political willingness of decision makers to consider alternative waste water treatment options.

4.5.1 Resource Management Act 1991

Part II of the RMA provides specific recognition of Māori values, principles and perspectives in these processes. In particular:

As a matter of national importance recognising and providing for the relationship of Māori and their culture and traditions with their ancestral lands, water, sites, waahi tapu, and other taonga,[37]

- Having particular regard to Kaitiakitanga,[38]
- Taking into account the principles of the Treaty of Waitangi.[39]

Iwi are more familiar with participating in the resource consent and designation processes of the RMA 1991. These processes give permission for wastewater management infrastructure to operate. Wastewater infrastructure projects and proposals for expansion, upgrading and operation are very likely to have involved early and ongoing consultation with Māori, and in increasing frequency Māori have direct involvement in the governance, management, operational and technical aspects of the proposals. The formal notification processes of the

[33] Reference LGA provisions for preparation of plans and engaging with Māori.
[34] LGA 2002, section 10(1)(b)
[35] LGA 2002, section 81(1)(a),(b)&(c) Contributions to decision-making process by Māori
[36] LGA 2002, section 77(1)(a)&(c) Requirements in relation to decisions
[37] RMA 1991, section 6(e)
[38] RMA 1991, section 7(a)
[39] RMA 1991, section 8

RMA facilitate submissions, hearings, and rights of appeal once a decision has been made. As this report will later explain, Māori involvement in wastewater proposals often continue during the operation of the infrastructure.

Iwi are less involved in the cascade of planning documents that set the policy framework for decisions on the beneficial and adverse effects of wastewater management.

4.5.2 National directions

The National Policy Statement on Urban Capacity directs local authorities to ensure that there is sufficient housing and business land capacity, and that this development capacity including wastewater network infrastructure in the short-term must be feasible, zoned and serviced. There are also some medium to long term requirements such as the infrastructure must be feasible, identified in relevant plans and strategies, and the development infrastructure required to service it must be identified in the relevant Infrastructure Strategy required under the Local Government Act 2002.[40]

The consideration of Māori views in the provisions of wastewater network infrastructure in this NPS is limited to situations where a local authority is carrying out a housing and business development capacity assessment. The input of 'Iwi' as well as many others is required to inform its production.[41]

Iwi outside large urban centres will have limited input or influence over long-term infrastructure decisions.

The NPS for Freshwater 2020 does not reference wastewater however has new requirements that will manage freshwater in a way that emphasises Māori values, participation in decision-making processes and incorporate Mātauranga Māori in monitoring.

The Te Mana o te Wai concept which must 'be given effect to', will raise the profile of wastewater issues through active involvement of tangata whenua in freshwater management (including decision-making processes). This will also raise tensions between current 'users' of freshwater and Iwi who are in the main advocating for restoration and protection of freshwater resources.

The inclusion of a new mahinga kai attribute also raises the awareness and advocacy for more intimate and meaningful conversations regarding the Māori preferences and views of wastewater management in New Zealand.

4.5.3 NZ Coastal Policy Statement

The New Zealand Coastal Policy Statement (NZCPS) has a broad and directive influence on many processes and tools under the RMA 1991. National directions, regional policy statements and plans, district plans, designations, and resource consent applications, must all give varying degrees of weight to the provisions of the NZCPS. The NZCPS references wastewater in the preamble, where wastewater discharges are stated as contributing to poor and declining coastal water quality in many areas.[42] Despite this one reference to wastewater, the broad and directive policies for tangata whenua are cast in a way that facilitates tangata whenua pursuing wastewater issues of concern to ensure those exercising powers under the RMA are:

- recognising the ongoing and enduring relationship of tangata whenua over their lands, rohe and resources;

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[40] National Policy Statement on Urban Capacity 2016, Policy PA1
[41] National Policy Statement on Urban Capacity 2016, policy PB5
[42] New Zealand Coastal Policy Statement 2010, Preamble, page 5

- promoting meaningful relationships and interactions between tangata whenua and persons exercising functions and powers under the Act;
- incorporating mātauranga Māori into sustainable management practices; and
- recognising and protecting characteristics of the coastal environment that are of special value to tangata whenua.[43]

4.5.4 Regional Policy Statements, Regional Plans and District Plans

Regional Policy Statements, regional plans and district plans prepared by local authorities all require consultation with tangata whenua through Iwi authorities when they are being prepared, reviewed, and changed. The issues, objectives, policies, and methods will have an influence on the decisions that affect wastewater management and the network infrastructure. This is particularly the case for the quantity and quality of treated wastewater discharged into the environment.

4.5.5 Consent processes

Designation and resource consent processes for wastewater network infrastructure under the RMA are where Māori are particularly involved and have experience in expressing their cultural preferences and raising issues of concern regarding wastewater design, management and monitoring. Consent applications are most often notified, submissions received and the consent authority (in considering the application and making a decision) must have regard to any actual and potential effect on the environment and any relevant provisions of the aforementioned planning documents as well as Iwi management plans.[44] Designations are provisions in a district plan that allow a local authority to undertake or propose to undertake a sewerage system or a network utility operation (such a treatment plant). These provisions are part of a large number of designations included in district plans for all manner of network utility operators, such as telecommunications, electricity, water supply, drainage, airports, roads and railways.[45] The district plan is reviewed every ten years allowing an opportunity to make submissions and new designations outside the 10 year reviews require a notified application and follow similar process to a district plan change. Similar to consents designations must have regard to the range of aforementioned policy documents, alternative sites, routes, or methods and other matters such as Iwi management plans.[46]

Because designations are reviewed periodically and the way they are described in district plans (contained in an appendix), designations are seldom subject to Iwi submissions and challenge unless a notified change to the designation has been sent to Iwi.

4.5.6 Treaty of Waitangi Act 1975

The Treaty of Waitangi Act 1975 established the Waitangi Tribunal, a body which enquires into and makes recommendations on any claim submitted[47] by a Māori person or group likely to be prejudicially affected by past and present legislation, regulations, policies or practise, and acts undertaken on behalf of the Crown.[48] There are a number of limitations to the scope and jurisdiction of claims and the commensurate recommendations of the Tribunal, however these are not essential to describe for the purposes of the report.

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[43] New Zealand Coastal Policy Statement 2010, Objective 3
[44] RMA 1991, section 104 (1)(a),(b),(c)
[45] RMA 1991, section 166 (a)-(i)
[46] RMA 1991, section 168A(3)(a),(b)&(d)
[47] TOWA 1975, section 5(1)(a)
[48] TOWA 1975, section 6(1)(a)-(d)

The Waitangi Tribunal has heard claims from Māori communities including Iwi and hapū regarding the potential and actual effects of wastewater discharges to waterbodies[49], prejudice in wastewater network site selection and the contamination of freshwater resources.[50]

The most recent Waitangi Tribunal consideration of wastewater has been the Wai 2358 case, National Freshwater and Geothermal Resources inquiry conducted in two stages. The most recent report released in 2019 reiterated findings of previous inquiries and confirmed the on-going concern of Māori with the contamination of waterways and the sea, their on-going degradation, the pollution of taonga and the risk to safe drinking water and food sources.

The Tribunal stated that ever since it issued the *Kaituna River* and *Motunui–Waitara* reports in the early 1980s, the Crown has been fully aware that the discharge of sewage effluent into water bodies is spiritually and culturally offensive to Māori, no matter how well the effluent is treated.[51]

Some of the pointed statements include:

- Tikanga Māori did not allow 'the discharge of waste of any kind to water'. The custom law team reported that '[b]odily waste, food scraps, fish scales and gut, or even pipi shells, were discharged only to land'.[52]
- The mauri of a water body can be diminished by the discharge of sewage into water, even if it is treated, and by the artificial fusing of separate water bodies.[53]
- Māori see the discharge of sewage into waterways as a 'deeply spiritual offence'.[54]
- When our waters and riverways are sick (mauri mate) then so are our people. When our waters and riverways are well (mauri ora) then so are our people.[55]

From the Crown's point of view, improved treatment systems, and more stringent management under the RMA, have resulted in less pollution from point source discharges. From the point of view of the claimants and interested parties in our inquiry, shown by the evidence about several rivers, point source discharges remain a cause of great cultural offence and a contributing cause of the nutrients and *E coli* in those rivers.[56]

The Waitangi Tribunal continues to be a forum where Iwi are able to air their grievances regarding wastewater and receive findings and recommendations that often support their views and perspectives in a Treaty of Waitangi context. This is a contrast to RMA processes where Iwi views and perspectives are one of many considerations.

[49] Wai 3 Rangataua Sewage Claim, Wai 4 The Kaituna River Claim, Wai 6 Motunui-Waitara Claim, Wai 8 The Manukau Claim, Wai 17 Mangonui Sewerage Claim.
[50] Wai 2358 National Freshwater and Geothermal Resources Claims.
[51] Wai 2358 National Freshwater and Geothermal Resources Claims. Paragraph 2.7.4.2, Page 135. 2019
[52] Wai 2358 National Freshwater and Geothermal Resources Claims. Paragraph 2.7.9, page 119
[53] Wai 2358 National Freshwater and Geothermal Resources Claims. Paragraph 2.7.9, page 119
[54] Wai 2358 National Freshwater and Geothermal Resources Claims. Paragraph 2.7.9, page 119
[55] Wai 2358 National Freshwater and Geothermal Resources Claims. Paragraph 2.7.9, page 119
[56] Wai 2358 National Freshwater and Geothermal Resources Claims. Paragraph 2.7.5, page 136

4.6 Emerging issues and opportunities

This section sets out emerging issues and opportunities identified by Iwi. Many of these issues and opportunities have been identified in cultural impact assessments, assessments of environmental effects and consultation with tangata whenua groups.

Table 30 Issues

Issue/Description	Description	Significance
Name	*What the issue/opportunity is*	*National-Regional-Local* *High-Med-Low* *Isolated/consistent* *Short-medium-long-term*
Climate Change	Risk of sea level rise which may inundate infrastructure causing failure – overflows. High intensity rainfall which may inundate infrastructure causing failure – overflows. Higher frequency of droughts – re-use of highly treated wastewater cannot be used in food production, costs of transport.	National Case by case Short - Long-term
Freshwater reform	The higher expectations of Māori for significant water quality improvements and changes in practise, higher policy settings and requirements of regional councils and water users take too long time and often do not deliver the expected outcomes.	National High Short-medium-long-term
Freshwater reform	Higher policy settings and requirements of regional councils and water users will require changes in practise and investment.	National High Short-medium-long-term
Fundamental value of water to NZers Expectations to live up to 100% pure brand	The fundamental value of water is not shared or at least not practised.	National High Short-med-long-term
Current Practise	Ongoing degradation of the waterways supported by resource management practise. E.g. (reasonable	National High Short-med-long-term

Issue/Description	Description	Significance
	mixing, receiving environment in a degraded state). Significant investment (money, time and science) in existing infrastructure a barrier to innovation and re-think of big picture wastewater approach.	
Competing Māori Values	Tension between values of finite land to generate income and wealth V use of land for discharging waste. Investment in high quality treatment V reducing quantities of wastewater requiring to be treated e.g. stormwater inundation, household, and commercial uses (flush and forget)	Med – long-term

Table 31 Opportunities

Issue/Description	Description	Significance
Size, nature and cost.	The apparent lack of micro-scale community projects that could be sustainable options for isolated, low population communities.	Med – long-term
Design	There is often design input in the landscaping, offset mitigation, and peripheral aspects of wastewater network infrastructure. There does not appear to be available Māori expertise in engineering and system design in wastewater projects.	National High Consistent Med-Long-term

4.7 Iwi engagement and participation

Our review of literature and interviews with Iwi and local authorities confirms that Iwi are commonly consulted as part of upgrades to WWTPs and large-scale network developments. Local authorities appear to be well aware that wastewater is an important issue for Iwi.

All of the case studies we have prepared include the preparation of cultural impact assessments and other documents that articulate cultural values of Iwi in response to wastewater management. It is not clear to us what the level of broad understanding is among Council decision-makers with regard to those values, the effects of wastewater discharges on those values and the measures that would avoid, mitigate or remedy those effects. The Council staff interviewed have all expressed a willingness and at the very least a good understanding of the key issues and tensions. We believe that there is a correlation between the quality of the engagement (willingness, time, resource, information, process, structure, skill) and the awareness and understanding on both sides.

Each local authority relies on the existing relationships it has with Iwi and in some cases have assistance from Iwi contractors to undertake or facilitate the engagement with Iwi members. We were not made aware of any cases where Iwi engagement did not occur.

Local authorities are using either existing relationships with Iwi to facilitate engagement regarding wastewater management and/or have dedicated structures established to facilitate input into decision-making processes. There are a broad range of approaches being used and from our assessments, there does not appear to be any one particular approach that is superior to others. In saying that, the consent by consent consultation under the RMA does appear to have some significant disadvantages from other engagement approaches due to being more process driven, transactional, short-term, and adversarial.

The range of structures (listed below) do identify one obvious area where Iwi are under-represented and would likely have significant latitude to advocate and promote cultural preferences to wastewater treatment. This is the dedicated committee(s) of Council that make the ultimate decisions on strategic direction, prioritising, and funding network infrastructure projects.

There does not appear to be a nationally consistent approach to engagement structures or processes other than those prescribed in the RMA and in some instances the LGA. The following table sets out the spectrum of engagement approaches used and the brief description of each.

Table 32 Engagement approaches

Type of Model/Structure	Description	Examples
Direct consultation	Consultation with affected tangata whenua groups on a project by project basis. This consultation could be as simple as following the notification process under the RMA. This engagement may be supported by a formal relationship document such as a MoU.	Te Awamutu
Community group	A diverse and representative forum for community,	Akaroa

Type of Model/Structure	Description	Examples
	stakeholders and tangata whenua to be informed and provide verbal input.	
Working group	A dedicated forum for identifying issues of concern, sharing views, receiving assessments, reports, and project staff interaction.	Gisborne Taipā
Project Steering Group	A formally established group of senior project staff, Councillors, tangata whenua representatives and in some instance's key stakeholders such as health professionals. Usually closely aligned to a council decision-making process.	Rotorua
Technical Advisory Group	This structure is normally an addition to one of the other structures providing technical assistance. Some of the TAGs have dedicated mātauranga Māori experts or Māori with infrastructure experience.	Rotorua Gisborne Akaroa
Committee of Council	A dedicated council committee that will make key decisions on strategic documents, proposals, funding, and timing. These most often do not have tangata whenua representation.	All
Advisory Group	A formal group of tangata whenua representatives and Councillors established as a condition of consent to monitor, review and make recommendations on specific aspects of the implementation of WWP consents.	Tauranga
Collaborative partnerships	Strategic partnerships that are collaborative	Horowhenua

Type of Model/Structure	Description	Examples
Co-Governance Groups	Dedicated and formal council and Iwi strategic partnerships where discussions are held on broad subjects of mutual interest.	Te Tatau o Te Arawa, Rotorua Te Hononga, Christchurch

Some examples of dedicated structures include:

- Tauranga City Council has a dedicated Tauranga Wastewater Committee with 4 tangata whenua representatives.
- Rotorua established a Project Steering Group with 13 Iwi and hapū representatives, a cultural assessment sub-committee, and a technical advisory group with a Māori engineer.
- Far North District Council have a forum established in a memorandum of understanding with Iwi, hapū and marae representation that discusses issues related to the Taipa WWTP.
- Gisborne District Council established the Wastewater Management Committee ("**WMC**") as a standing committee of Council. The WMC is mandated to comprise four tangata whenua representatives and four councillors, with other members able to be co-opted in an advisory or consultative capacity.
- Horowhenua District Council has established an Accord that includes a range of partners (including Iwi) collaborating on major projects including the commitment of moving to land-based treatment.

The comments from all those who have interviewed including Iwi and local authority staff is that engagement and participation could be improved. The key areas of improvement included:

- Availability of technical support to Iwi at the start of options consideration.
- Resourcing to participate fully in processes.
- Building capability.
- Consistency of membership.

4.8 Constraints on incorporating Māori values in design, management and monitoring

We asked Iwi members if they were involved in design of WWTPs and associated network infrastructure. All Iwi members had been involved in discussions regarding concepts, treatment options, discharge locations and methods of discharge, but few had direct design input. The outcomes of those discussions appear to have been significantly influenced by the existing legacy assets, the scope of the project, costs/budget for upgrades and community support.

There are a number of projects around Aotearoa that have involved design that responds to Māori values such as Rotorua WWTP land contact bed, Gisborne wetlands, Taipa, Whangarei, Cambridge and Tauranga wetlands, Hastings rock passage, and several gravel beds and rapid infiltration beds in Waikato and the top of the South Island.[57] These appear to be mostly related

[57] Jim Bradley. Maori Cultural Considerations in Developing and Operating Wastewater Systems – Case Study Experiences. Page 11.

to the discharge following treatment. It is likely that the discipline of *Māori wastewater water design* is in its infancy and may require some investment of multi-disciplinary teams to articulate frameworks, methodologies, and elements of design. We think it would be likely that such work would be readily picked up by Iwi and local authorities if it assists in responding to the outcomes sought by both parties. For example, for Māori the value of outcomes that are consistent with Māori values, tikanga and mātauranga Māori and for local authorities, being specific, achievable, sustainable, and cost effective.

We reviewed [12] recent sets of wastewater consent conditions to see if there were generic areas of incorporation such as participation or consultation, governance and management arrangements, technical support, design, or monitoring incorporating mātauranga Māori.

The results were mixed with few consistent and standard ways of addressing these matters.

- In all instances, the preparation of consent applications had involved consultation with tangata whenua. However, this was conducted at a range of levels; from the rudimentary notification (a letter or email), invitation to consult as part of the community, more specific and dedicated engagement such as through Iwi authorities, Iwi and hapū representatives and in some cases establishing a working group/advisory group.
- On-going participation of tangata whenua was only apparent in four instances through a formally established committee of Council or formal relationship specific to the project.
- Four of the twelve consents provided for specific tangata whenua input in design of such things as ocean outfalls, the performance of the treatment plant, infiltration, trench systems, and remediation. Three of these involved design inputs into alternative treatment options (including land-treatment).
- In five cases a role in monitoring was provided. Three involved input into the monitoring plan, three included specific input into species being monitored and site selection. One involved provision for tangata whenua in data collection and one could be undertaken if an enhancement fund application and successful approval were received.

It was not clear why so many of the consents did not provide for a tangata whenua role in monitoring, however it is assumed that some consents may involve input into the monitoring as part of the review of management plans, annual reporting of monitoring and the participation in formal engagement processes.

We did not observe any consents that had monitoring of effects on Māori cultural values. Again, this is difficult to reconcile as there are now a number of cultural frameworks that have been developed by practitioners such as Gail Tipa[58], Ian Ruru[59], Kepa Morgan[60] and others.

In regard to Mātauranga Māori, none of the consents mentioned this area of expertise specifically, however one consent did require the expertise of a person with kaupapa Māori expertise to assist with the periodic review of the consent by a panel of experts.

4.9 Case studies and experiences

4.9.1 Te Maunga WWTP - Tauranga City Council

Tauranga City Council operates two treatment plants, Chapel Street, Tauranga and Te Maunga. The Te Maunga WWTP consists of pre-treatment and secondary treatment comprising extended aeration, secondary clarification and sludge thickening and dewatering. The dewatered biosolids are transported to a consented landfill in the Waikato. The final effluent

[58] A Cultural Health Index for Streams and Waterways.
[59] A cultural framework for Wastewtaer Management in Turanganui-a-Kiwa.
[60] The Mauri model.

then gravitates to two flow balancing ponds from where it flows through a constructed wetland before being pumped through the UV plant and out to sea via an ocean outfall.

The consents for the treatment plant and coastal discharge were granted in 2005. They include a range of measures to address the concerns and participation of Tangata Whenua in the operation of the plant. These include the establishment and maintenance of a Wastewater Management Review Committee (WMRC) that includes two Ngā Potiki representatives and one Iwi representative each from Ngāti Ranginui and Ngāi Te Rangi. The WMRC receives operational reports, makes recommendations on policies in relation to wastewater management, treatment and disposal, makes decisions on an Environmental Mitigation and Enhancement Fund, recommendations of physical measures and initiatives to address or compensate for effects of the WWTP and network.

The other conditions of consent that responded specifically to Tangata Whenua concerns are:

- Decommissioning the Te Maunga Sludge Pond and future use of the pond.
- Conversion of the oxidation ponds to wetlands.
- $250,000 Environmental Mitigation and Enhancement Fund for avoiding, remedying and mitigating effects, environmental compensation, capacity building for Tangata Whenua, monitoring cultural effects, participation of Tangata Whenua in sampling, testing, and monitoring, water quality, ecological and shellfish research.
- Shellfish monitoring for heavy metals and E.coli.
- Comprehensive ecological survey around the outfall in 2014 and 2024.
- Repeal of the Mount Maunganui Borough Reclamation and Empowering Act that established the oxidation ponds.
- Prepare a Monitoring, Upgrade and Technology Review report every five years.

The land where the Te Maunga treatment plant is located occupies land within the ancestral rohe of Ngā Potiki a Tamapahore. Ngā Potiki have a marae and community facilities a short distance from the plant location. The treatment plant is located at the edge of Te Tahuna o Rangataua (Rangataua Harbour) and is about 1.6km from the ocean beach.

The authors of this Chapter interviewed Ngā Potiki members of the Wastewater Management Review Committee and Tauranga City Council wastewater management team.

Ngā Potiki hapū have historically opposed any discharge of wastewater to Rangataua harbour. As early as 1977 the Tauranga Executive of Māori Committees wrote to the Waitangi Tribunal, stating that they objected to the proposed sewage discharge, and requested the Tribunal to consider the matter. A formal claim was received on 13 June 1977. The claimants asserted that shellfish which they habitually collected in the area, titiko (mud snail) and kuharu (sunset shell), would be adversely affected by the proposed discharge. They also stated that Rangataua has traditionally been an important place for local Māori in historical and spiritual terms and that any discharge would be incompatible with this tradition.

In 2003-2004, TCC sought consents for the network and treatment plant. Ngā Potiki strongly opposed the discharge of wastewater to the ocean (Te Moananui o Toi Te Huatahi), the continuation of the WWTP at Te Maunga and recommended decommissioning the entire system.

The network and WWTP were granted consents in 2005, however the conditions of consent as stated above have been the main vehicle for Tangata Whenua engagement since that time.

Ngā Potiki members confirmed that the WMRC has been operating with meetings held each quarter to receive reports and make recommendations. The extent of their participation has been initially at meetings but has moved to include more workshops. These workshops have been more meaningful in having full and frank discussions, particularly with council staff and Councilor's. Formal meetings tended to focus more on procedure than substance and Tangata Whenua and engineers spoke past each other. The language used by the respective parties was different and no one could understand each other.

Tangata whenua have found the consenting process very dis-jointed and complicated. Council are very experienced in progressing consents one at a time. There does not appear to be a whole picture that can be engaged with, just the disparate parts. Tangata whenua feel driven into the RMA process but they would prefer more global conversations.

As mentioned above the Wastewater Management Review Committee is a committee of council. It is effectively an advisory committee rather than a co-management or co-governance arrangement. Tangata whenua aspire to having co-governance, co-management, and co-design, but those conversations do not last long.

Ngā Pōtiki consider themselves fortunate to have professional staff unlike other Tauranga Moana Iwi and hapū entities. This allows for Ngā Potiki to be represented consistently and have reports coming back to the organisation and community. Ngā Potiki think the positions such as the Wastewater Management Review Committee should have more status and be open to a wider talent pool. This would encourage expressions of interest and formal appointment processes that seek highly skilled and experienced candidates to be on the committee.

Tangata whenua representatives are not aware of any design elements that have been incorporated that respond to cultural values and principles. Ngā Potiki do not want the WWTP at Te Maunga and are opposed to an ocean discharge. They would prefer a land-based solution but feel that they are tied to the huge investment that has been made into the existing plant and its network. Ngā Potiki support re-use technologies and measures, but this is for kitchen and bathroom waste, not the toilet.

Figure 55 Te Maunga WWTP, settling ponds and wetland treatment on the shores of Te Tahuna o Rangataua, Tauranga.

4.9.2 Rotorua WWTP - Rotorua Lakes Council (RLC)

Rotorua has an existing centralised treatment plant located on Te Ngae Road adjacent the Puarenga Stream, Lake Rotorua and Puarenga Park. The WWTP services the residential suburbs and Central Business District of Rotorua.

The WWTP utilises a 5-stage Bardenpho process, the first full biological nitrogen and phosphorus process used for municipal wastewater in New Zealand. Depending on the weather, the sludge produced (biosolids) is composted on-site or sent to a worm farm in Kawerau. RLC is in the process of seeking consents to upgrade the existing plant to a full membrane bioreactor with several additional tertiary treatments including alum flocking, UV and possibly carbon beds. The treated wastewater is currently being discharged to land within the Whakarewarewa Forest via aerial sprayers. This arrangement was negotiated between the Crown and Council at a time when the forest was owned and operated by the Crown. Since then the forest is now owned by Central North island (CNI) Holdings (on behalf of Iwi) and the forests have cutting licenses with Timberlands.

Council and CNI have agreed that the discharge of treated wastewater would cease in 2019, recognising the effects that the water and nutrients were having on timber growth and operational requirements. Over many years of considering options, RLC has proposed a discharge of the treated wastewater to a land contact bed which ultimately discharges to Puarenga Bay, a portion of Lake Rotorua. This proposal is very controversial and is subject to a direct referral hearing of the Environment Court.

We spoke with the lead Council managers for the WWTP upgrade and discharge proposals as well as former members of the Cultural Assessment Sub-committee and Iwi members of the Project Steering Group.

The Rotorua upgrade project has involved initial consultation with Te Arawa institutions and leaders followed by the establishment of a Project Steering Group (PSG). One of the main purposes of the PSG was to recommend a preferred upgrade and discharge option to the RLC. Tangata whenua representatives recall the Council managers welcome being very warm and encouraging. The full PSG had some 19 members, 13 of which were tangata whenua representatives. The other members were councillors, CNI Forests and an independent chair and facilitator. The PSG met monthly and more often where important milestones or reports need to be considered. Tangata whenua representatives were appointed by their respective communities. The tangata whenua representatives spent time working out how they would conduct themselves. This included such things as treating each other with respect, always considered cultural customs, the history of the gifted land and wastewater management in the city, the impacts on tangata whenua, and upheld the mana of their ancestors.

A Cultural Impact Assessment (CAS) sub-committee was formed, made up of tangata whenua representatives and practitioners. A Te Arawa representative chaired the CAS and was supported by an Iwi consultant. This group held regular workshops to consider the effects of the various options, discuss alternatives, and measures to avoid, remedy or mitigate effects. The meetings and workshops were often held shortly before the PSG meetings so members would be prepared for PSG meetings. The CAS established some operational expectations for the upgrades. These included:

- Certainty of the technology to meet performance standards.
- Reliability of the technology to perform at optimal levels in a range of conditions.
- Avoidance of failure as a result of flow spikes, accidents, storm events and human error that would lead to untreated wastewater being released into the environment.
- Upgrading and improvements are possible over the duration of the consent.

- Effectiveness of the technology and processes to remove and minimise contaminants in the wastewater and meet tangata whenua expectations.
- There is capacity for storage (related to avoidance of failure and meeting optimum operational performance).

A large number of upgrade options were considered including some experimental and new technologies. There had been early interest and favourable results from a small onsite distilling plant, but up scaling was a challenging proposition. There was strong interest in reverse osmosis technology, so much so, that an engineer went to Singapore and other places to see the plants in operation. These processes proved to be very expensive to run, subject to maintenance issues and produced a by-product (a salty brine) that would require safe disposal at a special facility.

A technical advisory group (TAG) was formed to consider and discuss the technical aspects of options including commissioning of a range of reports. The TAG provided the PSG valuable reviews of the various options.

A broad range of options were identified and investigated. There were as many as 25-30 options and mixtures of options. A suitable and feasible option for the upgrade of the plant was agreed (by consensus) of the CAS and PSG members. This involved a transformation of the plant to a membrane bio-reactor plant with add-ons including UV, alum dosing and carbon beds. The final discharge option using a land contact bed and discharge to Puarenga Bay (Lake Rotorua) had majority support but some very strong objections. In light of those objections, further work was conducted on incorporating key Mātauranga Māori values and principles into the land contact bed concept. This facilitated the establishment of a Mātauranga Māori Expert Group that held wānanga to develop the concept further. That final concept was included in the applications for consent.

Applications for consent have been progressed and a direct referral of the project to the environment Court is pending. The discharge component of the project is the most contentious matter before the Court. At the centre of the concern, is the discharge of treated wastewater to Lake Rotorua, a tribal icon and taonga. Tangata whenua would prefer a discharge to land and there is unlikely to be a consensus on the proposals.

The proposals are still subject to a hearing and ultimately a decision. The oversight of operational and monitoring requirements is not yet set in stone, but the proposals suggest that tangata whenua would be involved in regular monitoring of the plant's performance and the effects of the discharge on water quality.

Tangata whenua are confident the process of participation and involvement in finding a solution was robust, but the issues of discharging waste were always controversial and will continue to be so. They were confident in their deliberations because of the expertise available, the encouragement of council staff and importance given to this issue. They were very complimentary of the staff at RLC and the consultants who assisted the process.

There is a high-level governance structure in place between Te Arawa and RLC called Te Tatau o Te Arawa. Some of those members have attended or been part of conversations regarding the wastewater treatment plan upgrade and discharge proposals. The Tatau has more capacity now with a secondment, a part-time manager, and a contractor.

Council note that there are diverse Te Arawa perspectives that can inform future engagement. It is hoped that a lack of consensus on a discharge option does not have a cooling effect of involving Iwi representatives in project steering groups. There have been lots of learnings, particularly with regard to:

- Improving the mauri of the water.

- Keeping water in catchments (takiwā).
- Keeping the 'paru' out of water bodies.
- The diverse perspectives.
- Engagement takes a lot more time than you think (7 years).
- Papatūānuku is a cleanser.
- Using water as a medium for transporting waste is offensive, but everyone is flushing toilets.
- The politics of wastewater are underestimated, and it takes a lot of time and energy to change direction.
- Letting tangata whenua representatives come to the right decision.

Of particular note in the proposals is the land contact bed. The concept involves the re-use of a storage pond and transformation of the site into a basin filled with kōhatu (stones) and elements that replicates the experiences of water in nature as it passes form the mountains to the lakes. The development of the concept drew on many mātauranga Māori experts from around Lake Rotorua. The object of the land contact is not to 'treat' the wastewater but rather to make the water 'mauri tau', neutral as it enters Lake Rotorua.

Figure 56 Concept plan showing water restoration land contact bed

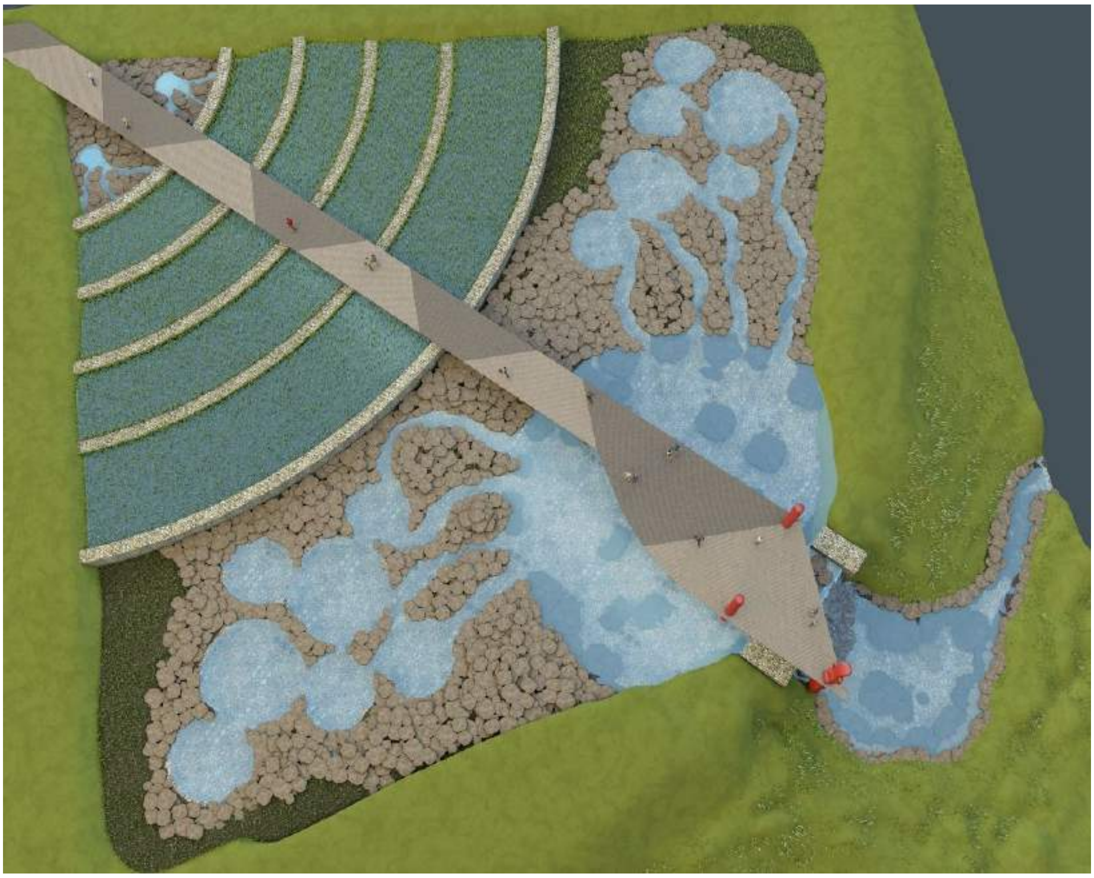


Figure 57 Concept plan showing water restoration land contact bed

Council staff also indicated that Rotorua does not have water shortages, it uses spring water in industrial processes and other uses which could re-use water, but the water is so available. They see this as a key challenge to the uptake of re-using high quality treated wastewater.

The council is positive about partnering with Te Arawa in the future, building capability and capacity both in-house and within Te Arawa in infrastructure management, operations, and technicians. They have also been philosophical in the sense that you may not be able to answer all the questions, get it all right and please everyone, first time. Co-design is yet to be explored and there is a wide scope for enhancing the concepts further.

4.9.3 Turanganui a Kiwa - Gisborne WWTP

The existing outfall was commissioned in 1964, and other than the installation of milli-screens in 1991 few other treatment steps occurred until the commissioning of the biological trickling filter. All domestic wastewater is processed through a new biological trickling filter system before being discharged through the existing 1.8km outfall to the sea. The trickling filter system enables fine wastewater solids to be transformed into plant-like matter in a process known as biotransformation.

Resource consent applications (approved in 1993 and 1999) for ongoing use of the outfall, were highly contested by groups and individuals within the community and included strong opposition from tangata whenua.

In 2002 the council launched its Wastewater Strategy. This Strategy outlined proposed upgrades to the existing system comprising primary sedimentation and the introduction of a high rate activated sludge plant (clarifiers) together with ultra-violet disinfection which were to be introduced by 2016.

In 2003, the Environment Court gave its decision (A162/2003) on appeals to the discharge consent and sent a strong signal to the council that it must address and resolve the violation of Māori taonga which was continuing with the wastewater outfall. Following that Environment Court decision, the discharge consent was limited in duration with an expiry date imposed of 31 December 2005.

The Wastewater Strategy and discharge application, which was then lodged in September 2005, included the addition of boulder beds, which are designed to provide a form of land-based treatment. The application was again met with strong opposition from submitters regarding the addition of the boulder beds as being a functionless and token gesture to alleviate cultural concerns.

The consents for Aerodrome Road were varied in 2009 to allow a change in location for the treatment plant from Aerodrome Road to the current site at Banks Street. The 2009 variations also provided for a single BTF to be constructed and timeframes were stipulated for the commissioning of the BTF by December 2010 and for wastewater disinfection by December 2014. Clause 4A of the decision also set the terms of reference for the establishment of a Wastewater Technical Advisory Group ("WTAG"). The purpose of the WTAG was to oversee the monitoring of the BTF plant and to provide advice and peer review for the Wastewater Alternative Use and Disposal ("AUD") Programme. The WTAG comprised membership of Tangata Whenua, the community, environmental groups, government bodies (Medical Officer of Health, Department of Conservation and Council staff.

The 2009 variations also required the establishment of the Wastewater Management Committee ("WMC") as a standing committee of Council. The WMC was mandated to comprise four Tangata Whenua representatives and four councillors, with other members able to be co-opted in an advisory or consultative capacity.

The authors talked to the team leader of Water and Coastal Resources, Iwi members of the Wastewater Management Committee and a hapū representative.

Iwi and hapū have historically and consistently opposed the discharge of treated wastewater to the rivers and the sea. The hapū representative recalls opposing the discharge of waste in the 1960s.

Of particular concern has been the human waste (from the toilet) and bodily fluids from the hospital and mortuary. The discharge of these wastes in any capacity is abhorrent to the Iwi and hapū. They have sought a segregation and alternative process of treatment or disposal for these wastes. This appears to have had some success with the hospital utilising a bespoke process.

The relationship between the various Iwi and the council have been borne out of a consent process rather than a more strategic and collaborative relationship. Once all Iwi have completed their Treaty settlements it is expected or more likely to occur. A key challenge for council has been having the time and resources to support a long engagement process.

Iwi and hapū representatives have been engaged and have participated in the various projects and upgrades of the wastewater network and WWTP. Iwi representatives have been encouraged most recently with the openness and willingness to listen and understand the concerns of tangata whenua. This has not translated into actions or outputs that would meet those concerns, but the relationship is much better than it was.

Council have acknowledged the current system impacts on fishing, harvesting kaimoana, waka ama and other activities and that a land-based would resolve these impacts. Iwi and hapū representatives have observed whānau travelling further afield, sometimes into the rohe of other Iwi to gather kaimoana because the kaimoana at Gisborne is affected by treated wastewater discharges. This situation is more acute for tangata whenua as the kaimoana in other rohe are not the same, for example pipi and tuangi at Gisborne are not plentiful elsewhere.

When asked if the Iwi representative would likely see a wastewater treatment system that would address their concerns, such as a wetland- he smiled and confirmed, 'not in my lifetime'.

Iwi are represented at the table, by being members of the WMC and the WTAG. There does appear to be a gap for hapū, who rely on the consultation processes of consents to have their say and express their concerns. The hapū representative interviewed said this was a significant challenge as significant choices had already been discounted or made before the consultation occurred and often the timeframes for consultation were too limited.

Council acknowledge there is a lot of technical information involved in considering wastewater and having the time and resources to review and understand this information is key being effective as a representative. A turnover of representatives and staff is also a key concern to maintaining continuity, trust, and knowledge.

Council have spent several years investigating a land-based system, in particular wetlands that included some trials. There was also some work on emerging contaminants. Finding a large enough area, conveyance to the land and avoiding a discharge to a waterbody were the three biggest challenges for a land-based solution. This option has not been dismissed but upgrades at the current plant are required such as UV.

Council see opportunities for re-use for high quality treated water being used on crops and forestry where there often droughts and shortages of water. For example, there are a number of catchments that are fully allocated. 'Food production' has restrictions on using treated wastewater but there may be other types of crops that may be applicable. There has been a cultural change within council to identify ways of passing a better environment to the next generation. This includes changing the terminology from wastewater to a resource that can be re-used. Council have seen large investments in water storage to address water shortages during summer season and fully allocated catchments.

Having the time, space, and willingness to discuss, understand and co-design a solution seemed to be at the front, middle and end of all the conversations.

It appeared that there is a recognition that the matters of importance to tangata whenua are identified and understood by council but there is still a way to go to have them recognised and incorporated into the wastewater treatment system.

Iwi and hapū representatives often cite the cost of alternatives, land availability and geotechnical considerations being the barriers to a land-based system that would address their concerns. Māori land trusts have been very generous in offering land for the land-based option. Some of these lands are quite far from the treatment plant, but there may be lands closer to the WWTP that would make the option more feasible.

It was unclear if Iwi and hapū representatives were participating in the monitoring of the wastewater treatment and discharge to sea. The WMC and WTAG appear to have access to monitoring information. As mentioned earlier Iwi members are part of the WMC and WTAG, whilst hapū members are not at present.

4.9.4 Akaroa WWTP, Banks Peninsula, Christchurch City Council

Akaroa wastewater treatment plant was constructed in the 1960s and is located at Takapūneke to the south of Akaroa township on Banks Peninsula. The plant has been upgraded in 1984, 1998 and in 2009. The treatment process of the current WWTP involves sedimentation in two Imhoff tanks, before biological treatment in a trickling filter and secondary sedimentation with UV disinfection. The treated wastewater is discharged to sea via a short marine outfall pipe.

The WWTP services about 650-800 permanent residents in Akaroa and large numbers of visitors (up to 4,000) during summer season. The WWTP and network does not service settlements 'over the hill' in Takamatua or the Ōnuku Marae community.

The current consent (CRC202179) is due to expire on 8 October 2020. Christchurch City Council (CCC) has been investigating, evaluating, and preparing proposals for new consents, having applied for a new consent in 2011. The land-based parts were consented but the discharge to the harbour was declined due to effects on Ngāi Tahu values and not adequately considering alternatives. Council intends to seek an extension to the current consents that discharge to the harbour and simultaneously seek consent to build a new wastewater scheme that will involve a discharge to land. It is understood that some $7M has been spent on exploring land-based alternatives. This has been both controversial and contentious within the local community. None of the land-based options are at Akaroa, which has provoked fears and concerns by residents in those vicinities. Current estimates suggest $45M for a harbour outfall and up to $82M for the most expensive land-based option. These costs would be unaffordable for a small community, but possible within a large city.

The current plant is located on a site at Takapūneke which is a place of particular significance to the Ōnuku Rūnanga. In 1830 a massacre of up to 200 of the pā inhabitants was carried out by Te Rauparaha. It is now widely acknowledged that construction of a WWTP at this site was an act of particular cultural insensitivity.

Ngāi Tahu has always been opposed to the discharge of wastewater to the harbour. As recent as 2015, Ngāi Tahu, Ōnuku Rūnanga, Wairewa Rūnanga and the Akaroa Taiāpure Management Committee have actively opposed the discharge of treated wastewater to the harbour and sought a land-based alternative.

The Mahaanui Iwi Management Plan sets out a clear preferred approach to wastewater discharge to land, locations of WWTPs, a holistic approach and consent terms of no more than 10 years and cultural health monitoring. It clearly articulates that "The discharge of wastewater into Akaroa harbour is cultural offensive and incompatible with the harbour as mahinga kai."

We talked to long serving senior staff members at CCC and members of the Iwi who have been involved in the project.

CCC have actively engaged with tangata whenua and have explored a large number of options. Each of these options considered cultural values and principles alongside other feasibility criteria. In 2006 a community working party was established, and Iwi were invited to be part of this group. Iwi preferred to have a separate and dedicated engagement process. This meant that the community working party members developed a high level of technical knowledge but were not exposed to Mātauranga Māori or Iwi perspectives. These parallel engagement processes have allowed groups to progress their thoughts and ideas quickly but facilitates entrenched views and increasing tensions when an idea is not supported by another group.

The Wairewa Rūnanga, Ōnuku Rūnanga and Te Rūnanga o Koukourārata were engaged in multiple hui. The long list of options was considered and over time unfavoured options dropped. In 2017 the Banks Peninsula Community Board established an Akaroa Treated Wastewater Reuse Working Party to look at alternatives. It had representatives of the receiving community, runaka representatives and elected members. It was a broad membership that held over 30 meetings. There were diverse views shared and sought to find a solution everyone could be happy with. This was not possible, mostly due to technical constraints on the land. These meetings could be 'gritty' and hostile at times. The use of particular language has been an important consideration to address public perceptions of wastewater. The use of terms such as 'restoration of the water' has a very different perception to 'discharge of the water'.

There does not appear to have been a formal technical advisory group but each of the parties (Ngāi Tahu, community and council) had access to their own experts. These experts would caucus from time to time. Representatives from Ōnuku would also come up with quite detailed options.

Rūnanga representatives were also busy keeping their respective runaka informed. This has been a positive and constructive working relationship that has had wider relationship benefits. It has been a trust building exercise that takes time. The staff preference is for a land-based option and this is supported by Ōnuku Rūnanga.

The project has not been subject to a MoU or formal terms of reference, however, there is a joint governance 'Te Hononga' between CCC and Papatipu rūnanga which includes the seven chairs of the local runaka and CCC councillors. This high-level governance arrangement has allowed the views of Ngāi Tahu to be heard and understood. Some of these councillors have attended the various hui and added value by cementing the governance to governance relationships, over and above the staff relationships.

The preferred option involves some 40ha of land with planted trees. The treated waste would irrigate this area. The resident time for the treated wastewater is some 8 days. This was deemed acceptable to Ngāi Tahu members who preferred more than 2 days and up to 40 days. The retention time was an indicator of meaningful penetration into Papatūānuku. There would also be a wetland to provide for infrequent overflows during storm events or peaks wet season.

Finding available land, the land being viable, feasibility of conveyance, and gaining community support are seen by council as the key challenges to land-based treatment.

The golf course has come on board and are looking at irrigation; that is reuse of treated wastewater. This has been achievable in part because the golf course land is owned by council.

There have been some members of the working party who want to explore potable reuse of the treated wastewater using methods such as reverse osmosis. But there is a 30% by-product that needs to be dealt with. It is not known what level of acceptability or trust for such a proposal is amongst the wider community. This type of option is certainly not acceptable to Ngāi Tahu and extends to discharges to groundwater (RIBs).

There is also work continuing at Lyttleton to cease all harbour discharges.

Council is required to put up the technically feasible options, otherwise there could be a challenge to not considering all the technically options. This creates a tension with the preferred option that is supported by Ngāi Tahu. The RMA process is very challenging to go through and present projections are that an approved option could take 8 years to implement.

Council would also consider using reuse of grey water but there is little scope to do this in the regulatory framework and strong community perceptions about waste.

4.9.5 Glentunnel

The Glentunnel Holiday Park is located in the Selwyn District, 55 km west of Christchurch. The campground is a popular destination during the summer season (December to February).

The holiday park has operated a treatment system that consists of a collector tank and a discharge to ground via a mounded sawdust bed located some 50 m from Waikirikiri (Selwyn River). It is understood that the system was not performing well during peak demand periods, causing odour and would not meet the Regional Land and Water Plan requirements.

The sawdust treatment bed has been used since the 1990s and had to be maintained by the Holiday Park staff. This system had a very specific and time-consuming maintenance program that must be adhered to, or failure of the system may result. The current cost of sawdust has increased significantly since the system was installed and disposal of sawdust with human waste residue is also a costly problem. After passing through the sawdust, the effluent then drains into soak pits and is discharged into the receiving groundwater adjacent to the treatment area.

Grey water and black water had recently been separated. The greywater and blackwater systems have their own pump chambers which pump the effluent to the disposal area, a sawdust treatment bed. The effluent then drains vertically through approximately 0.5 m of unsaturated sawdust and then through another 0.5 m of saturated sawdust.

Opus was contracted by Selwyn District Council to consider a broad range of options (but not a discharge to the river) that could be considered together with the strengths and weaknesses of each option. Selwyn District Council then engaged EcoEng (an engineering consultancy) to look at detailed options including septic tanks, sand pits and drip irrigation. They identified the key site constraints:

- Proximity of culturally and ecologically sensitive surface waters
- High water table on the lower terrace
- Proximity of a spring
- Protection of cultural values.

They also identified the key attributes of the site:

- Free draining soils
- Large area of land available
- Desire for irrigation of the golf course fairways.

Of the five options considered, one of which was preferred and supported by Te Rūnanga o Taumutu. This option included a secondary treatment, combined black and grey water, and pumped to drip irrigation fields on a nearby golf course. The option mitigated public and private health risks, effects on cultural values and local ecosystems. There would be no discharge to surface waters, less than minor risk of nutrient and pathogen contamination of groundwater, no risk of odour, and an acceptable setback from Waikirikiri (Selwyn River).

The project also identified future capacity issues for the local community facilities including the Rugby Club, cricket club and golf course that are currently using septic tanks. The project recommended the connection of these streams into one system in the future. This has allowed Council to share costs across a number of facilities.

We talked to the Selwyn District Council senior project manager, representatives of the marae and staff of Te Rūnanga o Taumutu.

Much of the district has old, isolated, and local wastewater systems. Reticulation and upgrading of wastewater are in its beginning stages.

Conversations started with the Te Rūnanga o Taumutu. Mahaanui Kurataiao prepared an assessment of the proposals and made a series of recommendations. They considered the various Iwi management plans, Iwi strategies and conducted site visits, initial consultation with the parties and workshops. They had experience in undertaking subdivisions and development. They used the Ngāi Tahu subdivision development guidelines – waste treatment and disposal. Their input was detailed and comprehensive. Te Rūnanga o Taumutu considered the report and its recommendations, supporting option 5.

There was considerable interest in water quality and making sure the wastewater did not enter the nearby spring and the Waikirikiri (Selwyn River).

Te Rūnanga o Taumutu supported the project to upgrade the Glentunnel campground and the connection with other community facilities.

Te Rūnanga o Taumutu has professional staff who are responsible for considering resource consents in their takiwa. They are focussing more on strategic relationships with other environmental agencies, councils, and research institutions to work on environmental restoration projects.

A lot of effort has been spent on clarifying the roles and inter-relationships of the various organisations who are responsible for the well-being of the Iwi and whānau.

One of the uncles led much of the work on Glentunnel. His dedication over 20 years has allowed for collaborative outcomes that the Rūnanga can support. Mahaanui Kura Taiao conduct the technical work, Te Rūnanga o Taumutu were involved in the engagement and consideration of options. There was also a Māori expert on the planning committee. The success of the project requires all the behind the scenes work and keeping a professional approach.

Te Rūnanga o Taumutu acknowledge high levels of awareness within Council on environmental matters, but there is work to do on other issues and at the different levels of governnace, management and operations. Whilst Te Rūnanga o Taumutu has high levels of capacity and capability in environmental matters, this is not the only area of work or priority for the Rūnanga.

The Rūnanga believes there is significant scope for working with Council on a broad range of matters over and above environmental matters, but it needs a mutual understanding, commitment and shared resources.

Tangata whenua representatives also mentioned a recent wastewater system that has been established at their marae in December 2019. They had looked at a lot of designs but the system they purchased was imported by Belgium and includes three treatment tanks, an ecotrench and then a discharge to a planted area (using evapo-transpiration). Taumutu wanted to lead by example, to walk the talk. They found the project very technical and quite challenging but are very proud of the result. One of the only downsides the marae has found is the increased cost of electricity from the pump.

4.10 Influencers and enablers

The interviews with council staff and Iwi members most often identified the project manager, the leadership of council, and champions within formal committees for facilitating, leading and providing the confidence to engage and have challenging and sometimes uncomfortable conversations.

The key elements that appear to have facilitated engagement with tangata whenua are:

- Active Iwi and hapū representatives.
- Consistency and a low turnover of local authority and tangata whenua representatives.
- Existing relationships between local authorities and tangata whenua.
- Dedicated expertise for engagement in-house, contracted or provided by Iwi.
- Formal relationships and/or formal structures to facilitate engagement and participation.
- Resourcing of informal and formal structures.

4.11 Capability and capacity of Tangata Whenua

Most of the tangata whenua representatives interviewed have day jobs, that is, they are not dedicated staff of the Iwi who have responsibilities for participating in wastewater management and infrastructure proposals. We are aware that some Iwi around New Zealand do have dedicated resource management staff, however these are predominantly within post settlement governance environments and large city jurisdictions.

We were made aware of several Māori experienced experts who work in the areas of wastewater management. Some are working nationally, and others are only focussed on local projects

Whilst councils interviewed were supportive and willing to train and employ Māori staff in the area of wastewater management, there did not appear to be any formal pathways and obvious programmes to achieve this.

Some of the suggestions provided by councils interviewed including internships, cadetships, formal training, experience in laboratories, monitoring and joining the forums that support the development of wastewater management projects.

Our literature review, interviews and working knowledge has not identified encumbrances for resourcing tangata whenua participation in the engagement structures, preparing cultural impact assessments, providing technical expertise and support.

4.12 Keys to successful engagement

The keys to successful engagement are the willingness of Iwi and councils to engage in mutually beneficial discussions, allow significant amounts of time to share their perspectives and the financial and technical resources to explore and understand the various options.

It appears that having high level formal engagement structures is beneficial to resolving tensions and raising awareness of Māori values and perspectives, as well as having Iwi representatives on decision-making committees.

Ultimately, good engagement does not necessarily mean agreement. The resolution of the core issues of concern for Iwi identified earlier in this Chapter will be at the forefront of any engagement process. We have been privy to a number of engagement processes that were praised by Iwi, but they did not support the final options selected.

CHAPTER 5
LAND BASED TREATMENT

5. Chapter 5: Land-based Discharges

Chapter Purpose: An assessment of the ability to transition towards 100% land-based wastewater discharges in New Zealand including a review of any practical, technical, and financial implications and considerations

5.1 Introduction to land-based wastewater discharges

Land-based discharges refer to the application of pre-treated wastewater to the land. This is achieved by using different engineering methods to control the discharge rates and application type. In New Zealand, land-based systems are mostly used for further treatment and/or disposal of secondary treated wastewater. In this report, land-based discharges refer to the application of municipal wastewater to land, and do not include individual on-site discharge systems to land.

Traditionally, the most widely used form of disposal of treated wastewater in New Zealand has been the discharge to waterways. Changes in legislation and an increased community interest in wastewater management have put growing pressure into looking for alternative ways of disposal. The RMA 1991 introduced requirements to consider alternative discharge methods as part of obtaining new resource consents for the discharge of treated wastewater to the environment. This, together with more inclusive engagement with tangata whenua and community groups has resulted in land application being considered as a treatment and disposal option for new and existing wastewater systems.

One of the main factors that have influenced the adoption of land-based discharge schemes in a number of communities is the desire from tangata whenua for treated wastewater to pass through land before it reaches a water body (refer to Chapter 4 for details). This has resulted in a number of wastewater schemes incorporating land-based discharges as the final disposal method or the inclusion of a land passage stage prior to final discharge to a waterway. However, the nature of that land contact and what is acceptable to tangata whenua in that regard varies widely across the country.

Environmental benefits can also be achieved by using a land-based discharge scheme. If application rates are managed appropriately, the soil-plant system is usually able to assimilate some of the contaminants present in treated wastewater. In this way adverse effects on surface waterways can be avoided and/or minimised. For example, volcanic soils in the North Island are generally capable of absorbing large amounts of phosphorus. The land application of wastewater can also be beneficial to land production as it provides nutrients and irrigation to soils.

Throughout New Zealand, different land-based disposal systems have been used depending on the particular conditions of the site and the nature of the discharges. In general, systems can be grouped into the following categories based on the application to land type:

- Slow rate
- Rapid infiltration
- Overland flow
- Land passage
- Deep bore injection
- Mixed systems

A description of each application type and some examples of where it has been used in New Zealand is shown below.

Slow Rate: These systems consist of the application of treated wastewater to a vegetated land surface, where soil and plants provide supplementary wastewater treatment by utilising essential nutrients for plant growth. Wastewater is generally applied at a low rate over land areas which may be covered by pasture or trees. Water is typically designed to be removed from the site by evapotranspiration and percolation, while surface runoff should be avoided. Plant selection is a critical factor for the success of the discharge scheme. Systems can operate as a soil-moisture deficit irrigation system (where irrigation is managed to minimise losses to groundwater) or a non-deficit irrigation system (where some losses to groundwater may occur). Treated wastewater can be applied to land by spray irrigation, however other methods such as border dyke or subsurface irrigation by driplines can be used depending on site conditions. Slow rate land-based treatment tends to be more expensive than other land-based solutions due to the high land requirements and the cost of reticulation and application systems. However, in some cases part of the cost can be offset by the commercial use of end products. Examples of slow rate application in New Zealand are the Taupō, Whangamata, Masterton, Leeston and Rolleston wastewater discharge schemes.

Figure 58: Slow rate irrigation at Carterton District Council

Source: https://cdc.govt.nz/services/wastewater/, June 2020

Rapid Infiltration: Is the controlled application of wastewater to earthen basins on high-permeability soils, where wastewater percolates and flows through the soil matrix to a water body or gets recovered by subsurface pumping/collection systems. Rapid infiltration systems may include vegetation cover, but its role in treatment is minimal as the contact time between plants and wastewater is usually not enough for a significant nutrient uptake. In general, the cost is lower than slow rate infiltration, as they require less land, however they require soils with higher permeability. The hydrogeological characteristics of the site are critical to achieve good results. Rapid infiltration systems need to be carefully designed where the quality of the nearby water bodies (rivers, lakes, aquifers) is critical. The solids content of the discharged effluent needs to be managed appropriately and, where the discharge is exposed to sunlight, the surface layers of the media frequently need to be scarified and or sacrificed to remove accumulated algal growth. Examples of rapid infiltration discharges in New Zealand are the infiltration beds in Motueka, rapid infiltration beds at Cambridge (photo below), Te Paerahi and infiltration trenches in Rotoiti-Rotomā.

Figure 59: Rapid infiltration bed at Cambridge WWTP

Overland Flow: Is the discharge of wastewater to gently sloped land at relatively high rates. Soils with low permeability are typically used, so little infiltration occurs. Wastewater flows downhill over the soil surface and it is collected at the bottom by collection ditches. Some additional treatment occurs at the soil and vegetation interaction with wastewater. The treated wastewater is usually disposed to nearby water bodies. Vegetation plays a major role in these systems. Perennial grasses are used to provide slope stability, control erosion and provide treatment. Suspended solids can be reduced by overland flow, but little nutrient removal is achieved. There is little experience in New Zealand in using overland flow discharges for wastewater treatment. Cases that have partially implemented it in the past are the Oamaru and Otaki wastewater discharge schemes (MWH, 2003).

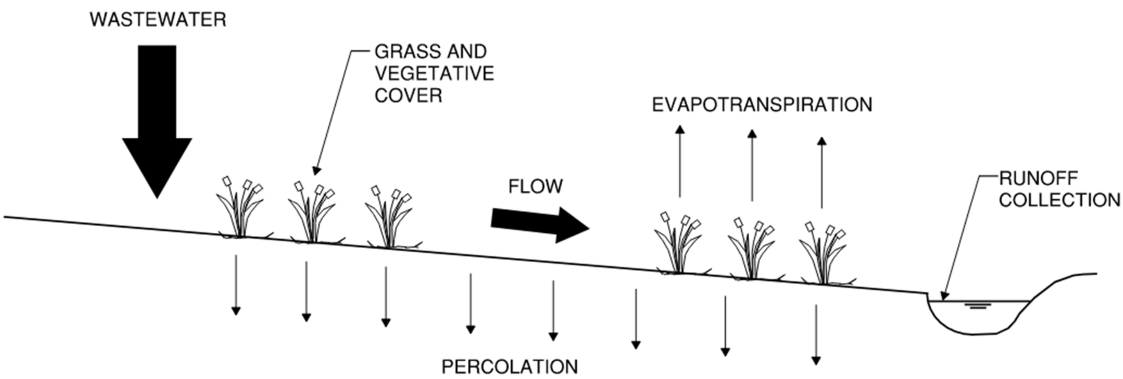


Figure 60: Overland flow

Land Passage: This technique is used mainly to incorporate Māori cultural considerations in respect of not discharging human waste directly to waterways. A general Māori cultural view is that the mauri (special nature / life force) of wastewater should be restored prior to the discharge to waterways, and the contact with Papatūānuku (mother earth) is one means of achieving this. Land passage systems are designed to allow for treated wastewater to flow through or over stone or rock beds before they enter a water body. Numerous land passage systems have been implemented throughout New Zealand, such as Morrinsville, Hastings, Napier, Te Awamutu and Te Puke wastewater schemes. These vary considerably in shape and form.

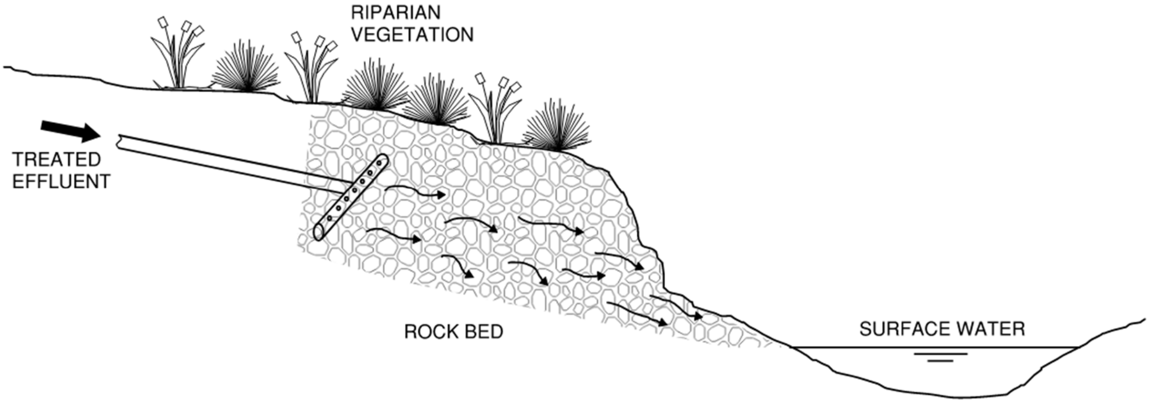


Figure 61: Land passage

Deep Bore Injection: Is a discharge system that consist of pumping treated wastewater into the subsurface using deep bores. The injection is done into porous geologic formations at a depth that minimises the risk of polluting groundwater sources for drinking water or surface water. There is little experience in New Zealand on this technique applied to municipal wastewater, but it has been used for stormwater and process wastewater from the oil and gas industry. Only the township of Russell has used bore injection for treated municipal wastewater discharge.

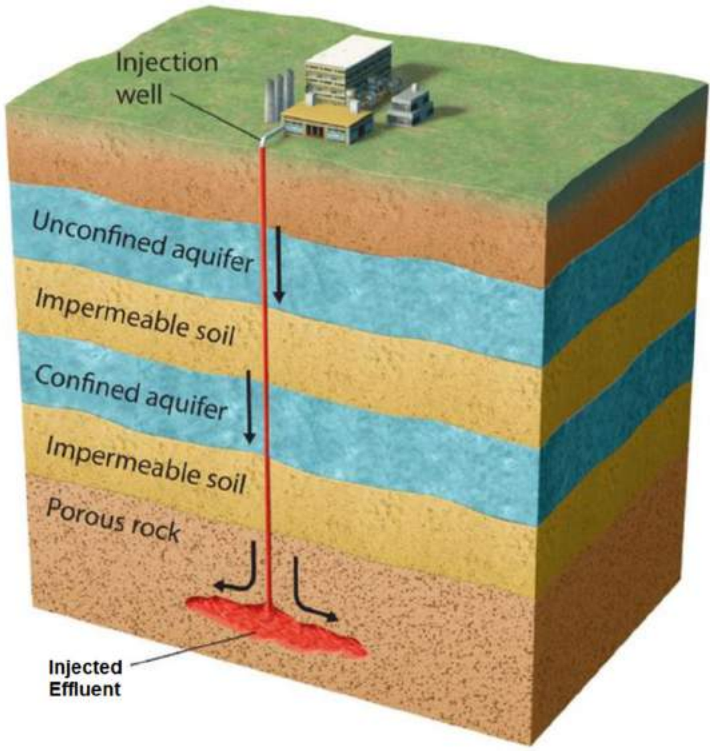


Figure 62: Deep bore injection

Source: Pearson Education Inc. ©, June 2020

Mixed Systems: Some councils have opted for a mixed system where land-based discharges are used for some parts of the year and the rest of the year discharges go to surface water, or where both discharge methods are used simultaneously. Blenheim and Ruakaka have adopted a mixed system for their discharges, which has the benefit of providing water for irrigation during the dry months when there is a need for it.

5.2 Factors influencing the ability to undertake land-based discharges

Implementing a land-based discharge scheme entails several challenges. Since the introduction of the RMA in 1991, the viability of land-based discharges has been extensively studied for many communities, large and small, throughout New Zealand. Some of the main factors that influence the successful adoption of land-based discharge schemes are shown in Figure 63 and described below.

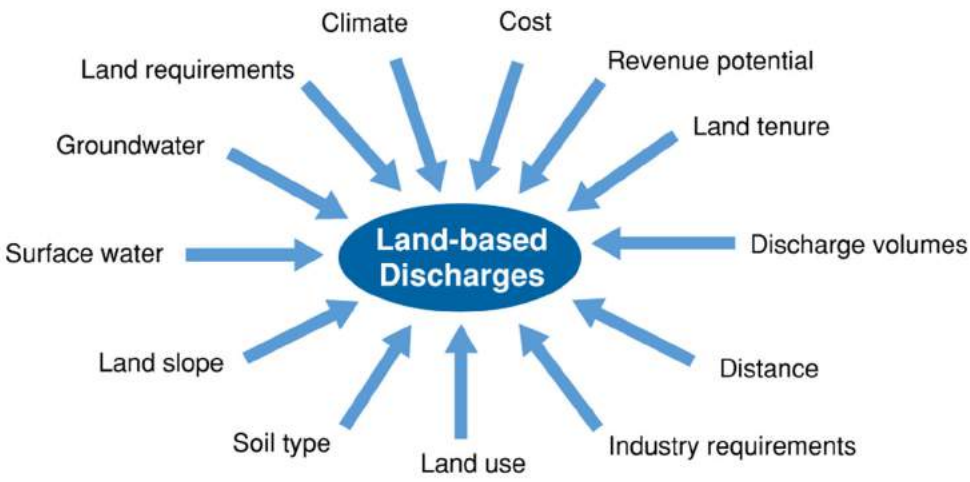


Figure 63: Factors influencing land-based discharges feasibility

Nature and volume of the discharge: Usually there is a lower or no requirement for irrigation during winter as the soil moisture is higher and plants are not actively growing. The greatest benefits from irrigation are achieved during the dry months when there is a higher water demand, however treated wastewater needs to be discharged during the whole year. In some situations, to achieve 100 per cent land application, storage of wastewater may be required so it can be applied to the land when it is actually needed. The storage required may be very large making this alternative less viable. For example, at the Mangawhai scheme, with an average daily flow of approximately 1ML, storage of 180ML is required.

Soil type: The soil permeability in the area where the discharge is to be applied is a fundamental factor for a successful system. The hydraulic capacity of the soil is a limiting factor for the volume of the discharge and hence determines the amount of land area required. Long residence times for wastewater in soil, leading to anaerobic conditions, need to be avoided. In low permeability soils runoff also is likely to occur if application continues after saturation is reached. Topsoil depth should be sufficient to allow plants roots development. The nature of the sub-soil minerals will also determine the amount of phosphorus that can be absorbed.

Land slope: The topography of the land to be used for wastewater discharge is an important consideration. Steep slopes may induce to higher soil erosion and runoff, and slope stability may become compromised under saturated conditions. Ideally irrigation would be carried out on slopes less than 15 degrees. 26 degrees is recognised as the maximum safe slope for regular irrigation to avoid surface run-off and the risk of serious erosion. Land slope will also dictate the plant species to be used, the harvesting frequency and treated wastewater distribution system type to be implemented.

Climate: The climatic conditions are important when determining the likely feasibility of land-based discharges in a particular area. Temperature has an effect on microbial activity in soil, which is reduced at lower temperatures. A soil can get saturated under high rainfall conditions, which will restrict the infiltration capacity and soil aeration. Land-based discharge systems should be designed to avoid freezing of the infrastructure, and also take into account the particular conditions of temperature, wind intensity and direction, evapotranspiration and rainfall of the site.

Groundwater: The distance between the soil surface where the wastewater is applied and groundwater levels is important to minimise the risk of contaminants reaching groundwater. A high water table also plays a role in plant growth by limiting root development. The distance to groundwater bores to be used as a water source or for other purposes becomes relevant when wastewater is being applied to land, and suitable mitigation measures need to be taken to minimise the risk of contamination of groundwater sources.

Surface water: Buffer zones are generally established for sites receiving wastewater application to help preventing surface runoff and nutrients migration to water either directly or via ephemeral water courses. Surface water can be affected by eutrophication if high levels of nutrients from wastewater reach them. In particular, phosphorus tends to accumulate in the topsoil and can get into waterways by soil erosion. Strong winds can also cause treated wastewater to reach surface water when sprinkler irrigation is used, so an adequate distance to waterways is required.

Land use: The distance from residential areas and public spaces (roads, footpaths, parks, cycle trails etc) to the site to be used for wastewater discharges should be enough to minimise the risk of contact between the community and the treated wastewater, and also to avoid nuisances such as odour and spray drift. In general, buffer zones are used to ensure an adequate distance is achieved, however the selection of a site may cause strong opposition from neighbouring residents who may be affected by odour and adverse amenity effects.

Distance to land treatment areas: The distance from the wastewater treatment plant to the discharge site is a key factor to consider in selecting a land disposal area due to the potentially high impact on capital and operational costs. Higher energy and pumping costs are associated with longer distances, and pipeline construction costs are increased. The elevation difference may become a factor that impacts ongoing energy costs.

Land requirements: Depending on the selected land-based discharge application type, the land requirements may be very extensive, especially for centralised systems or for those systems serving large cities. In New Zealand, successful schemes have generally been implemented in small and medium sized localities, however the land requirements for larger schemes make a 100 per cent land-based alternative less viable.

Revenue: When selecting the land application type, the economic benefits to be obtained from the crops also play a role. There is a potential profit to be obtained by using plants with a productive value. Yet, there is a risk of a negative market perception with respect to the use or acceptability of produce grown using treated wastewater.

Industry requirements: In many cases there is productive land that meets most of the requirements for a land-based discharge, however there is little interest from the industry to accept the treated wastewater, as they are seen as a high risk product with arguable value. For example, no discharges are applied to pasture used for dairy production, which is likely to be a result of a rule set by Fonterra that requests wastewater to be treated to California Health Law Title 22 standards before it can be used (Cass & Lowe, 2016).

Land tenure: In many occasions one of the main factors influencing the ability to undertake land-based discharges is that land is privately owned, and the investment needed to acquire land makes the option non-practical. For larger cities, significantly larger areas of land are required.

All the factors listed above need to be considered when assessing the viability of adopting a land-based discharge scheme. In New Zealand, several feasibility studies have been undertaken to review the land available for treated wastewater discharges and their suitability, with results that vary considerably between communities depending on the local conditions.

5.3 Overview of land-based schemes in New Zealand

This section provides an overview of the number of municipal WWTPs in New Zealand and the receiving environment for their discharges, with the purpose being to provide an indication of the extent of the adoption of land-based discharge schemes by region and by population size.

In 2018, a report prepared for the DIA required the collation and review of WWTP data across New Zealand (GHD and Boffa Miskell, 2018). Several data sources were consulted to develop a consolidated database, where 321 publicly owned operating WWTPs were identified.

The study classified each WWTP based on the dominant receiving environment as discharge to ocean, land or freshwater. In some cases, WWTPs discharge to more than one receiving environment, for example plants that have a mixed system for land-based and surface water discharge depending on the season. Where WWTPs discharge to multiple environments, the dominant discharge type was used in the study.

Discharges to land via rapid infiltration in close proximity to freshwater bodies or the ocean were not considered as land discharges for the purposes of the study. Land discharges included irrigation systems, engineered infiltration systems and engineered wetlands for the purpose of passive treatment and infiltration.

In 2019, the WWTP database was updated by an addendum to the previous report, where some of the discharge environments were amended following feedback received from councils (GHD and Boffa Miskell, 2019). Figure 64 shows the updated distribution of discharge types for WWTPs in New Zealand based on the updated report.

Figure 64: Discharge environment for municipal WWTPs in New Zealand

When considered by the number of WWTPs, the majority of them discharge to freshwater, followed by land-based discharges, which represent 33 per cent of the total number of WWTPs identified in the study. However, given that the largest WWTPs in New Zealand discharge to the marine environment (estuaries, harbours and ocean), the proportion of land discharges in terms of population is only 8 per cent of the total.

Figure 65 shows the distribution of WWTPs and their discharge environment when using the population size categories as described in the report prepared for DIA (GHD and Boffa Miskell, 2018).

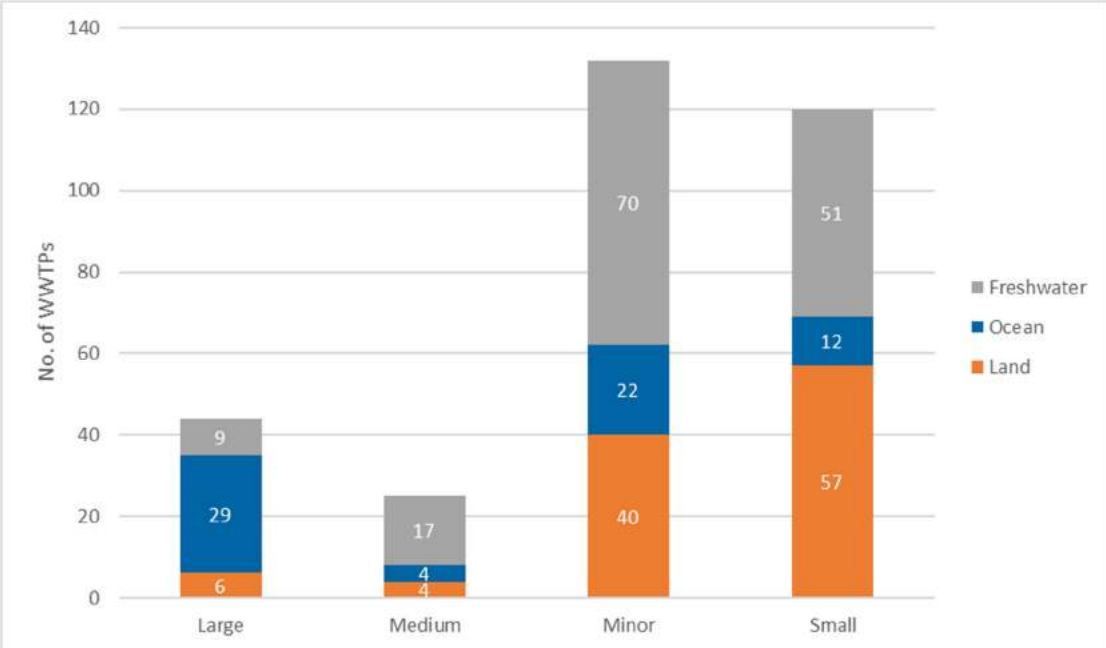


Figure 65: Discharge environment of WWTPs per population size

The figure above indicates that land-based discharges are frequently used for minor and small populations in New Zealand, however it has not been broadly adopted as a discharge option for medium and large schemes, where technical and cost related issues usually make this alternative less viable.

Figure 66 and Figure 67 below show the distribution of number of WWTPs grouped by discharge type, per region. It shows that Canterbury and Waikato regions have the highest number of WWTPs that use some form of land-based disposal. This may be explained by a high proportion of small communities in these regions that have their own treatment plants, which are located reasonably far enough from the coast to make discharges to ocean not viable. In Canterbury in particular, many communities are located inland where there is available land for soakage and rivers have low flow during the dry season to allow for treated wastewater discharges. In Waikato, wetlands are often used as part of the treatment processes, which explains the high number of plants that discharge to land, as the study considered wetlands to be land-based discharges. The Waikato Regional Plan also encourages land discharge as a preference over surface water discharge. On the other hand, the regions of Gisborne, West Coast, Marlborough and Nelson do not have WWTPs where land application is its main discharge type.

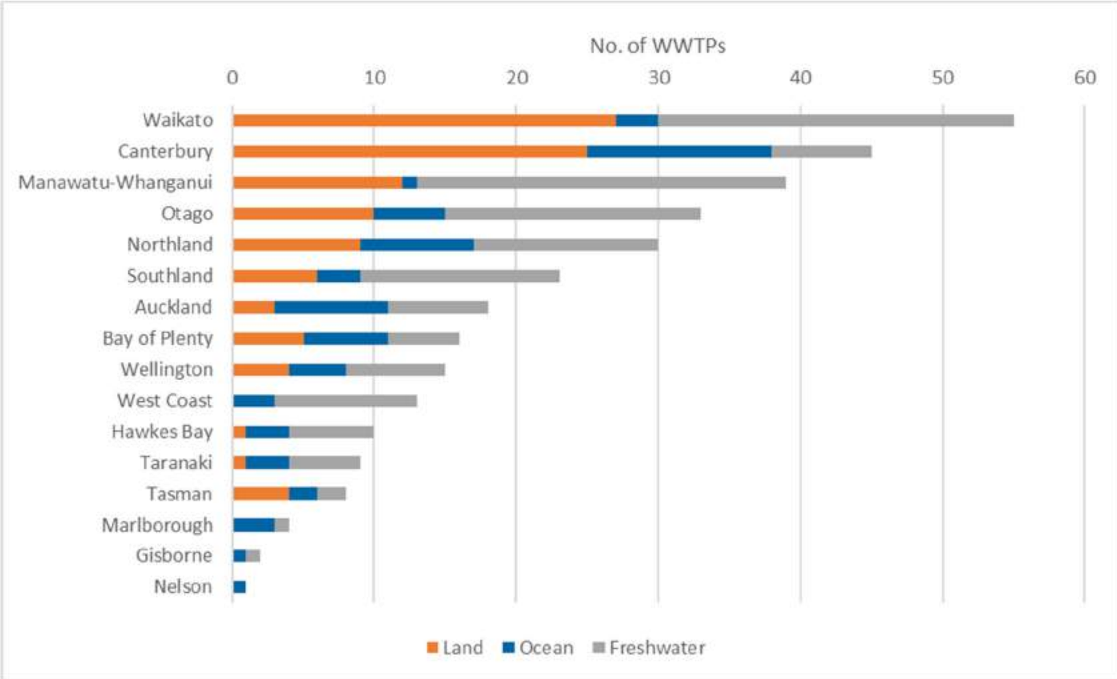


Figure 66: Number of WWTPs per region and their receiving environment

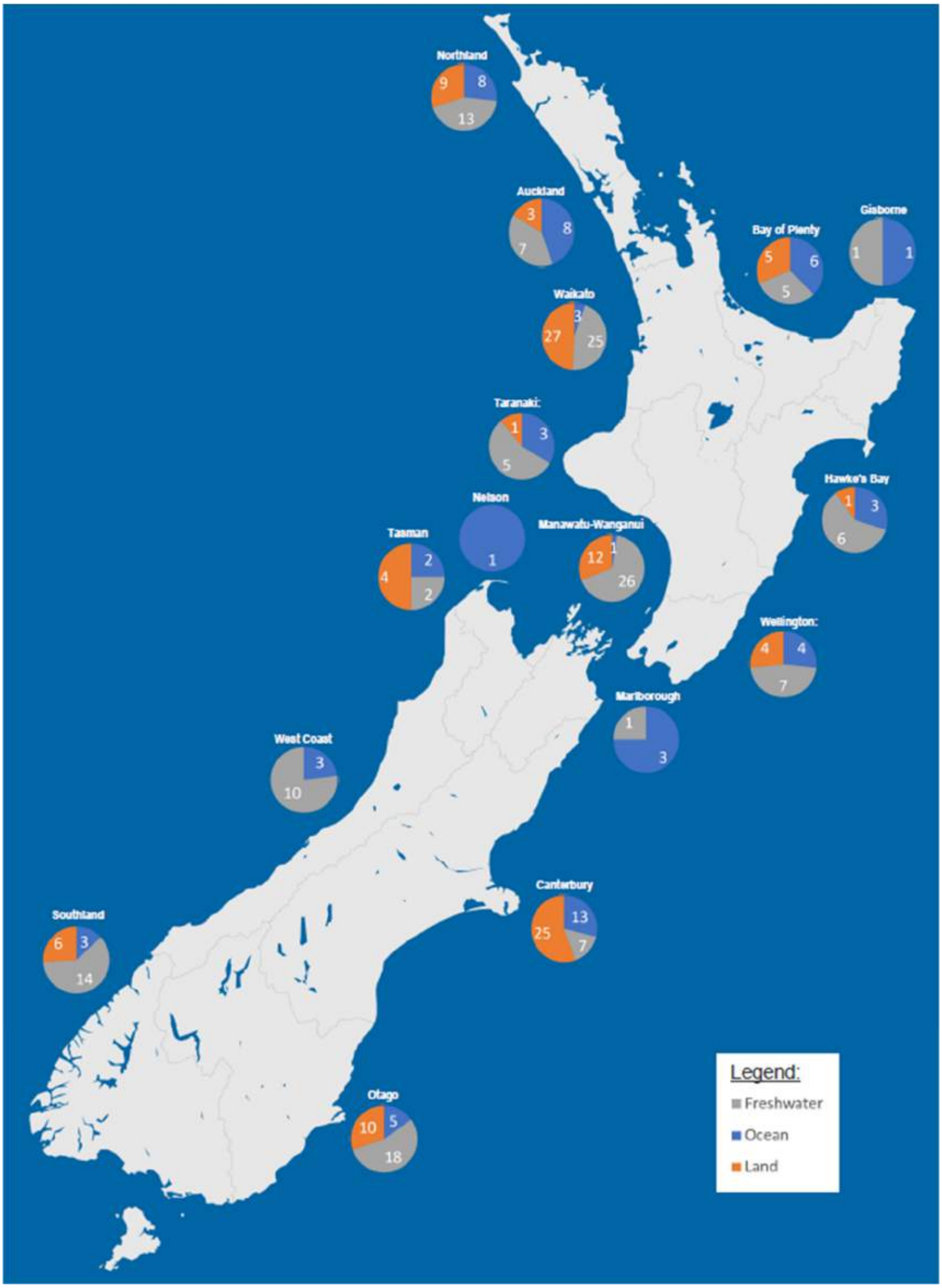


Figure 67: New Zealand WWTPs location and their receiving environment

In 2016, a study undertaken by Lowe Environmental Impact (Cass & Lowe, 2016) estimated the volumes of wastewater discharged to land by application type. Figure 68 shows that high rate applications make up 46 percent of the land-based discharges, followed by grazed applications (36 percent).

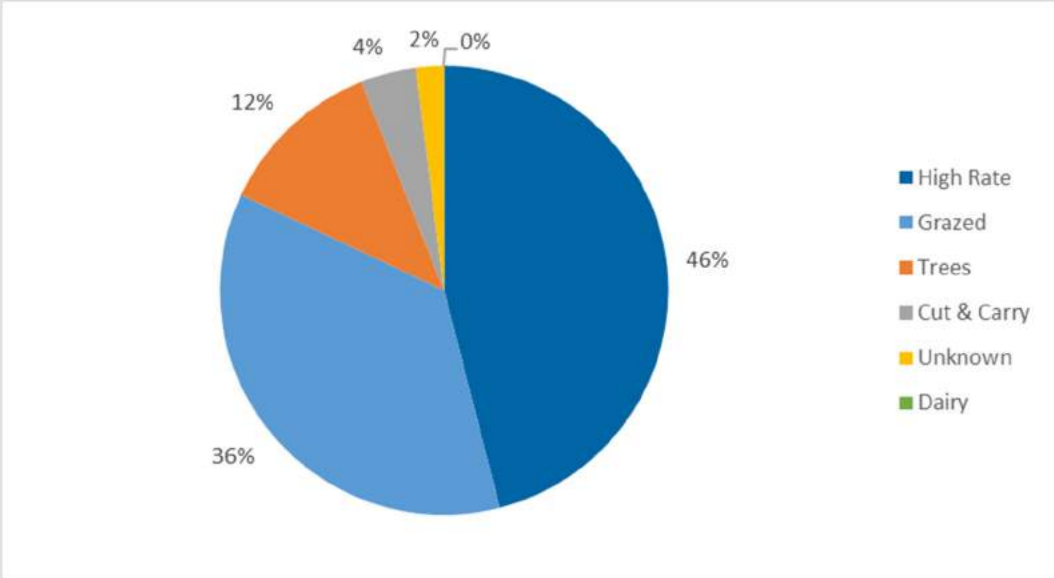


Figure 68: Land discharge methods in New Zealand

High rate discharges include different application types. Wetlands and soakage trenches are the majority of the high rate discharges. The unknown category included recreational uses such as irrigation of golf courses (e.g. Omaha WWTP). As stated in the previous section, the absence of pasture discharges for dairy production are likely to be due to Fonterra restrictions to irrigation with treated wastewater.

5.4 Case studies

Several communities across New Zealand have implemented land-based discharge processes with variable success. The following case studies provide some examples of the practical, technical and financial lessons learned in the implementation of these schemes and cover different population sizes and land-based discharge types. The population data used for the case studies was taken from the updated WWTP database (GHD and Boffa Miskell, 2019).

5.4.1 Case study – Taupō (pop. 24,000)

Example of a slow rate irrigation system (cut and carry) for a medium-sized scheme

The wastewater treatment and discharge scheme of Taupō is operated by Taupō District Council. The town is located on the border of Lake Taupō, which is characterised by high water quality and has a significant cultural, economic and environmental value. With the goal to limit the nutrients inputs into the upper Waikato River, a land-based discharge scheme was implemented in 1995 outside of the Lake Taupō catchment, to operate as a slow irrigation system using a cut and carry method. The system was seen as a big improvement on the environmental management of the discharges, which were moved away from the Waikato River. The initial site comprises 120 ha of land for irrigation by pop-up sprinklers.

A second stage of the system was commissioned in 2008 at a new site (120 ha) to cater for the future growth of the city and to assist the existing irrigation scheme. The irrigation method selected for the second site was centre pivot irrigators. Further expansion of the irrigation system of approximately 70 ha is now planned to allow for reduction in consented nutrient loading rates. With the full implementation of the new site, the system will have the potential to irrigate up to 15 MLD of wastewater. In practice, the annual average discharge is around 10 MLD, which is limited by the nutrient loads from the WWTP effluent.

Both sites have pumice soils that are very well drained, and the discharges are applied to relatively flat land. Perennial ryegrass was the crop selected to be used as a method for nutrient removal and to serve as an income source by cut and carry. Ryegrass is harvested between 4 and 6 times per year. The system operates year-round and there is no direct discharge to surface water.

Figure 69: Cut and carry irrigation at Taupō wastewater scheme

The consent conditions included a limit on the rate of nitrogen application and nitrogen leaching rate. A nitrogen budget was prepared based on treated wastewater volumes, bale numbers, nitrogen concentrations and other parameters to evaluate the application rates.

The site where pivot irrigation is used has shown much better performance than the pop-up sprinklers system in terms of nutrient uptake. In addition, several benefits were achieved by the use of centre-pivot irrigation compared to pop-up sprinklers, as many operational issues were associated with the latter. Mechanical failure of sprinklers and physical damage of them during the harvesting implied higher maintenance costs due to repairs.

Figure 70: Pop-out sprinklers and centre-pivot irrigation at Taupō wastewater scheme

Trials on the sites have shown that by increasing the harvesting frequency, the nitrogen removal could potentially be increased.

Biosolids are now also being processed at site by vermicomposting, which began in late 2016 with the first product produced in 2017.

The Taupō land-based discharge experience suggests that centre-pivot irrigation can be successfully used for cut and carry operations, however the particular site constraints need to be considered on a case by case basis for the selection of irrigation type. This type of system requires large area and relatively flat land. The land-based scheme achieved efficient nitrogen removal for a relatively low technology WWTP. Furthermore, the cut and carry has been effective in offsetting the costs by the additional revenue generated by the harvesting and minimising the need for additional fertilisers.

5.4.2 Case study - Blenheim wastewater scheme (pop. 30,000)

Example of a mixed system of discharge of treated wastewater to land and water

Marlborough District Council (MDC) owns and operates the Blenheim WWTP which treats municipal (residential/commercial), trade waste (mainly winery wastewater) and tankered wastes. Trade waste discharges in Blenheim contribute about 15 per cent of the overall flow into the WWTP.

The WWTP consists of two separate pond-based treatment systems. A fine screen followed by facultative and maturation ponds are used to treat the residential/commercial flows, while the industrial stream is treated using fine screening and facultative ponds with mechanical aeration. During the winemaking (vintage) season, the high organic load wastewater into the industrial ponds is redirected through twin Dissolved Air Flotation (DAF) units for solids separation and recycling to create an activated sludge process.

Treated wastewater from both treatment systems is then combined before discharging into a series of wetland cells which convey the wastewater approximately 1.6 km before discharging into a submerged outfall in the Wairau Estuary on the ebb tide. The wetland system provides some further “polishing” treatment of the combined flows and additional ecological habitat in planted areas.

Figure 71: View of wetlands and pond system on Blenheim WWTP

Source: Archer et al, n.d.

MDC was granted a 15-year consent in 2010 to discharge to both the estuary and to land when soil moisture and groundwater conditions allow. Approximately 160 ha of MDC-owned land around the WWTP is also available for wastewater irrigation, on a soil moisture deficit basis, from spring to autumn (typically November to April). There are three irrigation areas available (42, 32 and 86 ha) for irrigation.

The consent recognises the seasonal and climatic constraints of land application at the site and does not specify a percentage/or annual volume of the total flow that must be discharged to land. These volumes have varied significantly on an annual basis since the irrigation system was commissioned in 2014. However, in an average rainfall year, approximately 40 per cent of the treated wastewater flows can be applied to land.

Moveable k-line irrigators are used by MDC over the majority of the available land. These systems provide a relatively low cost, easy-to-operate means of irrigation over a relatively large area. However, in areas closer to boundaries with residences, buried driplines are utilised to ensure that there is no opportunity for spray drift to occur. The overall land application system is controlled using groundwater levels measurements and automated onsite weather stations (particularly wind speed and direction). Pasture harvesting (cut and carry) removes nutrients from the soils.

Figure 72: Irrigation of treated wastewater from Blenheim WWTP

The construction of the wetlands and irrigation system was overseen by local Iwi and provided additional useful information on the cultural and archaeological values of the area.

As part of the 2010 consents process, MDC also considered irrigating land areas outside the plant boundary. A number of nearby flatter and more hilly areas were investigated using non-deficit irrigation on a year-round basis. It was estimated that net areas of about 1,120 and 1,680 ha respectively, would be required to irrigate all of the anticipated future flows from the WWTP. As irrigation would be restricted to land with less than a 35-degree slope, the gross land areas required would likely be greater.

Year-round application to land was not favoured as a result of the investigation process, because of the very high capital and operating costs of the option. However, opportunities for additional land application will be re-assessed as part of the 2025 consent application in light of current district and national planning policies, stakeholder expectations and the likely future demand for additional water sources in this dry climate area.

5.4.3 Case study – Twizel (pop. 1100)

Example of a sustainable rapid infiltration treated wastewater discharge system for a small community

Mackenzie District Council (MDC) owns and operates the Twizel WWTP which treats wastewater from Twizel residential and commercial premises as well as tankered septic tank wastes. The WWTP is located on MDC land to the east of SH8 and Twizel Township.

Twizel is heavily reliant on tourism and there are no high water-use industrial connections.

The WWTP consists of a mechanical inlet screen followed by a series of three treatment ponds in series (which cope well with the seasonal population loadings).

Treated wastewater was originally discharged directly to the Twizel River but this practice was discontinued in the late 1980s in favour of discharge to an approximately 1750 m long trench. Further upgrade works were commissioned in December 2018, which consist of a series of infiltration basins at the southern end of the pond for disposal.

Figure 73: Twizel WWTP rapid infiltration basins

The rapid infiltration basins are located over permeable gravels, well separated from any water course. Groundwater lies at least 10 m below ground level and there are no downgradient potable water bores. The system consists of four 10 m wide x 100 m long basins which are automatically operated on an 8-day rotational basis (i.e. 2-day application and 6 days drying). Groundwater quality is monitored on an ongoing basis.

Keeping the basins from overtopping due to frozen ground impeding permeability in winter is a key issue. This risk is mitigated by keeping the internal sides and floor of the basins weed free and forming a ridge and furrow system in the basin floor.

The 35-year consent granted to MDC in 2018 had the full support of Iwi as well as other stakeholders as it provides a sustainable disposal system, with low visual impact in an environmentally sensitive landscape.

5.4.4 Case study - Akaroa (pop. 800)

Example of a small community where extensive feasibility studies were undertaken

Following engagement with Iwi (Ngāi Tahu) over cultural concerns relating to wastewater treatment and disposal practices at Akaroa, CCC established a wastewater working party in 2009 to identify alternative wastewater management options. The main concern was the discharge of treated wastewater to Akaroa Harbour and the impact of this discharge on customary food gathering as well as on the mauri (life force) of the harbour waters. There were also concerns about the occupation by the treatment plant of Takapūneke, a site of great historical and cultural significance (refer to Akaroa case study in Chapter 4 for more details on the cultural aspects of the wastewater scheme).

Early studies led to a CCC decision in 2011 to replace the treatment plant at Takapūneke with a new plant at a new site, to treat wastewater to the best quality and to discharge the treated wastewater to the middle of Akaroa Harbour via a new outfall pipe.

Consent applications were lodged for a new treatment plant and for disposal of highly treated wastewater to Akaroa Harbour in 2014. Consents for the new treatment plant and network upgrades were granted in July 2015. However, consents for the outfall pipe and harbour discharge were declined, on the grounds that a direct discharge to the harbour is offensive to Ngāi Tahu, and because land-based discharge alternatives had not been adequately investigated.

Through a collaborative process involving Ngāi Tahu, CCC, technical experts and another wastewater working party convened in 2017, a wide range of alternatives to the harbour outfall have been explored over a five year period, including irrigation to land, overland flow, wetland treatment, deep-bore injection, managed aquifer recharge and reuse of treated wastewater for non-potable purposes.

Ngāi Tahu strongly supported the option of irrigation to land, to either trees and/or pasture, as these options are consistent with their cultural values concerning water. The options of using wetlands or infiltration basins and a coastal infiltration gallery were not supported by the community or by Ngāi Tahu, so CCC decided not to further consider them until land-based alternatives had been investigated in more detail.

Akaroa is located within Banks Peninsula which is challenging in terms of potential for wastewater irrigation to land. This is due to steep topography with erodible loess soils and high risks of land instability caused by applying extra water. Flatter land near Akaroa that meets slope stability criteria represents less than 5 per cent of total land area and is tightly constrained due to existing developments, and the presence of sensitive natural features including watercourses and protected landscapes.

Figure 74: View of Akaroa harbour

Source: https://ccc.govt.nz/services/water-and-drainage/wastewater/wastewater-projects/akaroa-wastewater-scheme, September 2020

Existing development features including residential areas, lifestyle blocks and drinking-water catchments all diminish the available space with shallow sloping areas. Small rural communities also located within these zones may be exposed to potential effects from wastewater irrigation and are commonly opposed to such activities.

Extensive studies of potential irrigation sites were conducted including GIS modelling based on land slope and stability and other criteria such as buffer distances to streams and the coast. Geotechnical investigations and site-specific soil testing were also conducted at various sites following initial GIS screening.

Deep-bore injection and managed aquifer recharge were investigated as possible disposal methods, but the geology around Akaroa (solid volcanic basalt) was proven to be unsuitable for deep-bore injection. Investigations into managed aquifer recharge were discontinued when it was found there was a possibility that treated wastewater could enter the bores used to supply the town’s drinking water.

The alternatives of constructing an ocean outfall to the head of the harbour, tankering of wastewater to the Christchurch WWTP, or construction of an 80 km wastewater pipeline to Christchurch were all ruled out due to prohibitive costs, technical difficulty and environmental impacts.

At the conclusion of five years of investigations into a range of options and involving extensive input from Ngāi Tahu, the wastewater working party and the wider community, land irrigation has been found to be technically viable. At the time of writing, CCC is undertaking public consultation on four options:

- Inner Bays irrigation scheme, which involves irrigating new areas of planted native trees within the inner harbour area, with occasional peak rainfall events discharging to harbour via a subsurface wetland treatment process
- Goughs Bay irrigation scheme, which involves pumping the treated wastewater over the hill to one of the eastern bays, to irrigate a new area of planted native trees
- Pompeys Pillar irrigation scheme, which involves pumping the treated wastewater over the hill to one of the eastern bays, to irrigate a new area of planted native trees
- Discharge to mid-harbour via a new outfall.

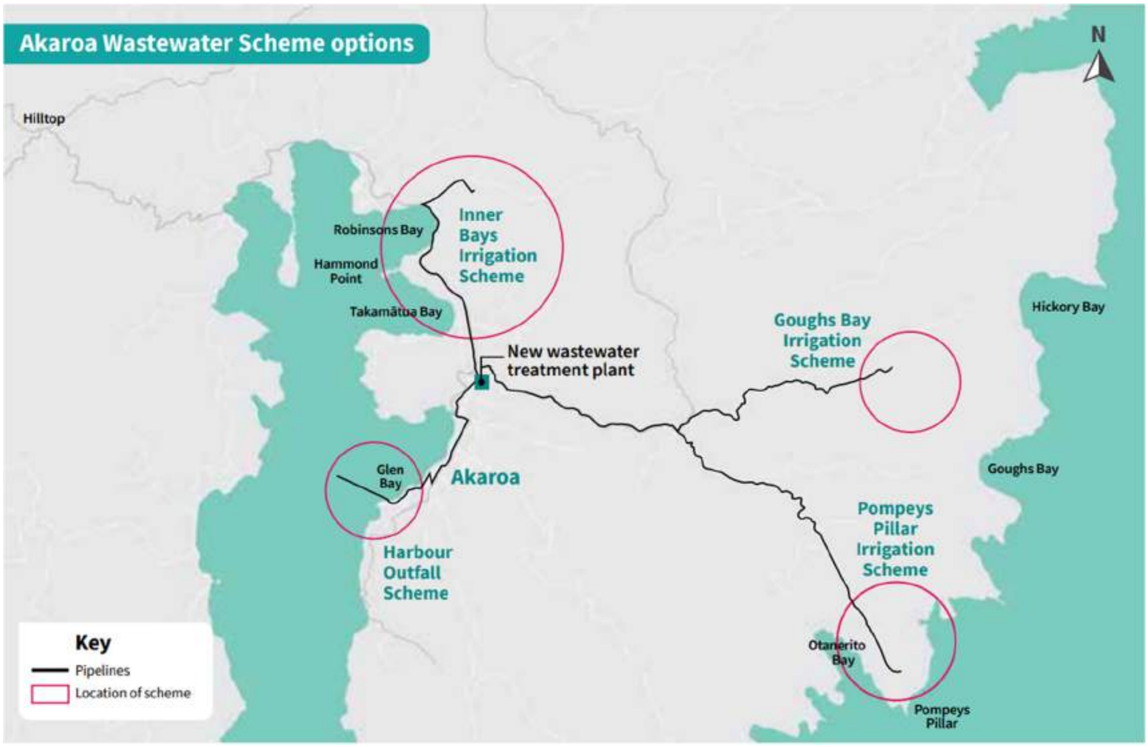


Figure 75: Akaroa wastewater scheme discharge options

Source: https://ccc.govt.nz/services/water-and-drainage/wastewater/wastewater-projects/akaroa-wastewater-scheme, September 2020

The final technically viable land irrigation schemes have all been met by significant opposition from the small rural communities that could be affected by them. The proposal to provide a very high standard of treatment and to plant and irrigate extensive areas of native trees as well as mitigate potential nuisance effects does not address all of the community's concerns which include social impacts and a sense that Akaroa's treated wastewater is being imposed upon them.

The likely costs of implementing any of the schemes are very high. The economic viability of the scheme is dependent on being located within a large metropolitan council district and through application of a unified rate to spread the cost across all Christchurch ratepayers that are connected to a wastewater network.

5.4.5 Case study – Rotorua (pop. 68,000) and Rotoiti-Rotomā (pop. 1400)

Example of a transition from irrigation to land-contact bed system and collaboration with the community

Rotorua Lakes Council (RLC) collects and treats wastewater from the Rotorua urban area and a number of lakeside and rural communities within the district. The Rotorua WWTP serves a population of about 60,000 people and treats around 20 MLD. In 1991, a land-based discharge system was implemented to irrigate the treated wastewater onto the nearby Whakarewarewa forest by spray irrigation. Prior to 1991, treated wastewater was discharged to Lake Rotorua.

RLC has an easement over 433 ha within the Whakarewarewa forest, which is one of New Zealand oldest exotic pine forests. The land treatment system covers approximately 350 ha, including 193 ha of irrigated area. Soils are sandy loams with volcanic origin and high permeability rates, where runoff is negligible.

Figure 76: Effluent ponds and irrigation system at Whakarewarewa forest

Source: http://www.baybuzz.co.nz/wp-content/uploads/2008/01/rotorua-wastewater-treatment.pdf; https://niwa.co.nz/publications/wa/vol16-no4-december-2008/natural-purification-of-groundwater, September 2020

The resource consent imposed conditions on the nutrient loads applied to the land and at the Waipa stream, a stream located downgradient of the land treatment system. During the early operational years, nutrient leaching was minimal as the soil retained most of the nitrogen and phosphorous. Nitrogen uptake from trees was not substantial, and after 10 years there were signs of the soil reaching its storage capacity. Nitrogen levels at the stream periodically breached the consent until 2012. Upgrades to the WWTP have reduced the load of nitrogen discharged to land over time and the plant has been fully compliant with total nitrogen conditions since November 2012.

The land treatment system has been highly effective at removing phosphorous from the treated wastewater. Application rates of phosphorus to land has been around 100 kg/ha/year, which has been stored in the soil and has not entered the lake directly, probably one of the most beneficial impacts of the system operation to preserve water quality of Lake Rotorua. Recent evidence shows that there are possible indications of increasing concentrations of dissolved phosphorous leaving the land treatment system, although the loads to the lake have remained below the consented limit since the system began in 1991.

- The existing resource consent for the land discharge system expires in 2021, but several reasons make the discharge into Whakarewarewa forest no longer viable as a sustainable option. Some of the reasons for moving away from the current scheme are:
- Since the implementation of the land application system, the land has been returned to private owners who did not show an interest on irrigation to continue.
- High operational costs (approx. NZ$1.2 million a year) mainly due to pumping. There is no revenue for RLC from the forest crop as the land and cutting tree rights are private.
- Negative impact on tree health from low soil aeration as ground gets saturated at the low lying areas.
- Insufficient additional area available to expand the system and reduce the irrigation rate.
- Public health risk associated with people accessing the irrigation area due to high E.coli levels in the discharge. The irrigation site has a recreational value that attracts people, which has increased over time.
- Cultural concerns on the system operation.

As part of more recent investigations RLC decided to explore a viable alternative location for the treated wastewater discharges. A committee consisting of key stakeholders, Council, experts and tangata whenua was formed to identify and select alternative options for treating and discharging Rotorua's wastewater. A comprehensive assessment of alternatives of wastewater treatment options, discharge methods, and discharge locations was undertaken. Refer to the Rotorua WWTP case study in Chapter 4 for more details on the community engagement and ongoing consultation process.

Not far from Rotorua, RLC is implementing a new land-based discharge system for the communities of East Rotoiti-Rotomā. Finding a preferred option has taken about ten years and has involved the community, investigation options and reaching a decision.

A community-led committee (Rotoiti Rotomā Sewerage Steering Committee) was established in 2014 after the Council's 2012 resource consent application for its chosen scheme, at the time, failed in the Environment Court. As a result, RLC made a fresh start, working closely with Iwi, community groups and the Steering Committee.

The committee required a preferred option to be selected on factors such as cultural preference, resilience in the event of earthquakes and technical requirements. The preferred scheme includes the construction of a Membrane Bioreactor (MBR) WWTP with nutrient removal, the installation of a reticulation network and a land discharge system by rapid infiltration trenches.

Figure 77: Construction of the Rotoiti-Rotomā WWTP and infiltration trenches

Source: https://letstalk.rotorualakescouncil.nz/rotoiti-rotoma-sewerage-scheme, September 2020

Working together with the community and local Iwi was the key for the success of the approval of the new scheme, which started operating in late 2019.

5.5 Discussion

The introduction of the RMA in 1991 and its requirements to consider alternative discharge methods for treated wastewater has set the framework for the increasing number of wastewater schemes that have adopted land-based discharges over the last decades. In addition, there is ongoing pressure from tangata whenua and the community in general to explore land-based disposal options to improve the quality of freshwater and marine environments. Local authorities now are often required to investigate the feasibility of land-based discharges in order to obtain new resource consents.

As discussed above, and demonstrated through the case studies provided, there are many successful examples of land-based wastewater discharges in New Zealand. However, their success is dependent on the particular conditions of the site and the characteristics of the wastewater scheme, which finally dictates the feasibility of the land-based discharges. Some common factors that makes a land-based scheme successful are identified below.

- The community/stakeholders desire of adopting land-based discharges plays a key role in driving investigations forward, as well as the cost and effort required for those studies. As shown on the Akaroa and Rotorua case studies, the feasibility study process can be quite extensive, and the involvement of the community throughout the process often dictates the success of the adopted scheme.
- The sensitivity of the receiving environment has also been an important factor for places like Taupō and Rotoiti-Rotomā, where maintaining a high water quality on the lakes is a priority for the community. The land-based disposal schemes provides extra measures to avoid contaminants entering the lakes.
- Successful schemes have been implemented in New Zealand where there is land available that meets the technical requirements for receiving the discharges. Many factors determine the technical feasibility of a site, for example flat and well-drained soils have allowed the Rolleston and Taupō schemes to operate in a successful cut and carry operation to date.

One of the main difficulties that local authorities have to face is finding available land for the discharges. The costs and the process for acquiring new land can be prohibitive in some cases, and leased land options may not be economically sustainable in the long term. Where there is not enough land available for irrigation, some councils have looked to the option of storing treated wastewater to achieve 100 per cent land-based discharges, however there are further (at time significant) costs involved with storage.

Over the years, the knowledge of land-based schemes that had been running for many years has increased. Different experiences across New Zealand are providing valuable information for the investigation and design of future systems. For example, the Rotorua irrigation scheme was successful in removing nutrients during the first ten years of operation, but once the soil became saturated with nutrients they started to move towards the lake. Nowadays, more advanced technologies and a better understanding of soil's capacity to receive nutrients are being used to optimise existing systems and reduce the potential impact of nutrients leaching. The development of tools for nutrients budgeting and modelling are being used to estimate the movement of nutrients throughout the systems, such as the case of Taupō.

Assessing the environmental effects for land-based discharges can be more challenging than for surface water discharges. Groundwater models are usually developed to determine the movement of groundwater and contaminants through the soil, but there are intrinsic uncertainties with modelling that makes it more difficult to predict where the contaminants will migrate to. As a result, generally more rigorous monitoring programmes are implemented for land-based discharges, which can include monitoring nearby groundwater bores and water bodies close to the land where the discharges are applied to, in addition to the monitoring of the treated wastewater. Higher costs for councils are usually involved with the implementation of land-based discharge monitoring programmes.

The use of treated wastewater for irrigation can provide positive effects to the land as nutrients and water are utilised for growing crops or forestry activities. However, in some cases the net benefit is marginal as the management techniques can be more costly. Cut and carry operations such as Rolleston and Taupō have been able to successfully generate revenue from the discharges, but in Rotorua the pine trees did not get significant benefits from the irrigation with treated wastewater.

Climate change is likely to become an important driver for the transition to more land-based discharge schemes in New Zealand. Water scarcity may change the view on treated wastewater as a resource rather than waste to be disposed of. International examples from dry areas such as Israel or Arizona show that treated wastewater has a high potential for reuse and reutilisation, for example for aquifer recharge, as a potable water source or for agricultural uses.

A few other considerations to be taken into account when assessing the long-term sustainability of land-based disposal schemes are listed as follows.

- By applying treated wastewater to land, it will become a HAIL (Hazardous Activities and Industries List) site due to potential land contamination associated with the discharges of treated municipal wastewater, which has implications for future uses of the site.
- There are current fears of emerging contaminants in wastewater and the potential effect on the food chain for food crops irrigated with treated effluent, which can have a far reaching impact on New Zealand's valuable export markets if food is found to be contaminated.
- When adopting a land-based discharge scheme, water originally taken for potable water is not being returned to its original source (ie taking raw water from a river is then discharged back to the river), which is particularly important for rivers and streams where a minimum environmental flow is to be preserved.

The review of the current situation of land-based disposal schemes in New Zealand indicates that the majority of WWTPs that discharge to land are for minor and small communities. Many of these small schemes operates in a sustainable and cost-effective way, as shown on the Twizel case study, where the volumes of the discharges and the land requirements make the operation viable and affordable. For larger cities, the situation may be different as the logistics of utilising a large volume of water on to land from an urban based plant such as Mangere may not be realistic (Cass & Lowe, 2016). The availability of land for discharges from large cities may involve extremely large amounts of storage at significant cost.

As most of New Zealand's urban centres are located not far from the coast, most large communities continue to discharge to the marine environment despite extensive options studies. Investigations have been undertaken for many large coastal communities and the two larger inland cities of Hamilton and Palmerston North, and almost without exception all reviews have included investigations into alternative options, including land-based discharges. In all but very few cases, the discharge to surface water has remained the preferred method (MWH, 2003).

The wide range of factors affecting the viability of land-based discharges makes the transition towards 100 per cent land-based wastewater discharges a case by case situation. A detailed study would be required for each site considering the particular characteristics of it. Currently, the feasibility studies generally occur as part of the re-consenting process. Cost implications, community and cultural concerns, climate change and technology are all factors and drivers that will determine the successful adoption of land-based schemes across New Zealand.

CHAPTER 6
CLIMATE CHANGE


Credit: NZ Herald

6. Chapter 6: Climate change considerations

Chapter Purpose - A review of the anticipated impacts of climate change on the wastewater sector in New Zealand, including the impacts of carbon reduction policies and the implications of anticipated changes in sea level rises and increased frequency of heavy rainfall and flooding events.

6.1 Chapter outline and context

This Chapter focuses on the potential impacts that climate change is likely to have on the New Zealand wastewater sector. The Chapter begins with a definition list of key words, then a discussion around international and domestic climate change policies, laws and their associated impacts on the New Zealand wastewater sector. Potential direct and indirect impacts of climate change as a result of forecasted alterations in precipitation, temperature etc. on the New Zealand wastewater sector are discussed. Examples of these potential direct and indirect impacts are drawn on at international and local scales. Examples of adaptive planning strategies currently being implemented within New Zealand by key stakeholders within the wastewater sector are discussed. An overview is provided of energy consumption and the greenhouse gas (GHG) emissions of WWTPs in the context of New Zealand's carbon reduction policies. Based on local and international case studies, the implications of these policies for the New Zealand wastewater sector will be considered. The likely results of imposing tighter GHG discharge standards and possible options to assist WWTPs in reducing and monitoring emissions is examined.

Table 33: Key definitions list

Key words	Definitions	Sources
Greenhouse gas	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. In addition to CO_2, CH_4, N_2O and, the UNFCCC and Kyoto Protocol also deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). Moreover, there are a number of other entirely synthetic greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol.	Intergovernmental Panel on Climate Change Working Group III
Climate change adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.	Intergovernmental Panel on Climate Change Working Group III

Key words	Definitions	Sources
Climate change mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). The Fifth Assessment Report (AR5) WGIII report also assesses human interventions to reduce the sources of other substances which may contribute directly or indirectly to limiting climate change. These include, for example, the reduction of particulate matter (PM) emissions that can directly alter the radiation balance (e.g., black carbon) or measures that control emissions of carbon monoxide, nitrogen oxides (NOx), Volatile Organic Compounds (VOCs) and other pollutants that can alter the concentration of tropospheric ozone (O_3) which has an indirect effect on the climate.	Intergovernmental Panel on Climate Change Working Group III
Climate change impacts	The effects of extreme weather and climate events derived from climate change on natural and human systems. Impacts generally refer to effects on lives, livelihoods, health, ecosystems, economies, societies, cultures, services, and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes.	Intergovernmental Panel on Climate Change Working Group II
Biogenic methane	Biogenic methane, as defined for New Zealand's domestic climate change targets, means all methane emissions released by the agriculture and waste sectors (as reported in the New Zealand Greenhouse Gas Inventory). Methane emissions from wastewater treatment processes are included.	Zero Carbon Amendment Act 2019
Gross emissions	Gross emissions means New Zealand's total emissions from the agriculture, energy, industrial processes and product use, waste and Tokelau sectors (as reported in the New Zealand Greenhouse Gas Inventory).	Zero Carbon Amendment Act 2019
Emissions budget	Emissions budget means the quantity of emissions that will be permitted in each emissions budget period as a net amount of carbon dioxide equivalent.	Zero Carbon Amendment Act 2019
Carbon dioxide equivalent - emission	The amount of carbon dioxide emission that would cause the same integrated radiative forcing, (the change in energy flux caused by a driver) over a given time horizon, as an emitted amount of greenhouse gas or a mixture of greenhouse gases.	Intergovernmental Panel on Climate Change Working Group III
Emissions budget period	Emissions budget period means a 5-year period for the years 2022 to 2050, (except that the period 2022 to 2025 inclusive is a 4-year period)	Zero Carbon Amendment Act 2019
New Zealand's Greenhouse Gas Inventory	New Zealand's Greenhouse Gas Inventory is the official annual report of all anthropogenic (human induced) emissions and removals of greenhouse gases in New Zealand. This includes the national estimate of emissions for wastewater treatment.	Ministry for the Environment

Key words	Definitions	Sources
	The latest inventory (for 1990–2018) was published April 2020, but this report also refers to the inventory published in 2019 (1990–2017).	
Measuring Emissions: A guide for organisations	Guidance to help New Zealand organisations measure and report their greenhouse gas emissions, based in part on NZ's greenhouse gas inventory published in April 2018	Ministry for the Environment

6.2 Laws and policy context

New Zealand has international and domestic greenhouse gas emission targets. New Zealand's Nationally Determined Contributions (NDC) are driven by the international targets and influenced by global pledges made under the Kyoto Protocol, Paris Agreement and UNFCCC. The domestic targets are set by the Zero Carbon Amendment Act (ZCAA). This section will discuss the influence of these international and domestic commitments on the New Zealand wastewater sector.

6.2.1 International context

1992 United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC was developed with the primary objective to stabilize greenhouse gas concentrations in the atmosphere at levels that would prevent dangerous anthropogenic interference with the climate system. UNFCCC commitments made by New Zealand include; to adopt national policies to reduce greenhouse gas emissions, to report on greenhouse gas inventories, national actions and projected greenhouse gas emissions and sinks (Ministry for the Environment, 2007).

The Kyoto Protocol and the Doha Amendment

The Kyoto Protocol is an international agreement which came into force in 2005 to reduce global greenhouse gas emissions which provides a framework for international emissions trading. The framework involves the use of a Kyoto unit (equivalent to one tonne of carbon dioxide) to aid in monitoring emissions globally. New Zealand has committed to using the Kyoto Protocol rules for emission accounting (Ministry for the Environment, 2019).

2006 IPCC Guidelines for National Greenhouse Gas Inventories (2006 IPCC Guidelines)

The 2006 IPCC Guidelines (Doorn et al., 2006) as adopted by the UNFCCC contain methods for estimating national anthropogenic sources and sinks of GHGs. These guidelines contain specific guidance on domestic and industrial wastewater; how to calculate, monitor, verify and report on emissions for methane (CH_4) and nitrous oxide (N_2O) emissions resulting from the wastewater treatment processes. Carbon dioxide (CO_2) emissions from the wastewater sector are not included in the IPCC Guidelines as they are of biogenic origin. These guidelines will be amended by the 2019 refinement to the 2006 IPCC Guidelines, although the 2019 version has not yet been adopted by the UNFCCC.

Official uses of the 2006 IPCC guidelines:

- The greenhouse gas inventory provides New Zealand's official estimate of emissions from wastewater treatment plants, which is based in part on 2006 IPCC guidelines.

The Ministry for the Environment also publishes a method for estimating CH_4 and N_2O emissions associated with domestic wastewater treatment (or handling) within the New Zealand in the Measuring Emissions: A guide for organisations (Ministry for the Environment 2019) and this is based on the estimate from the greenhouse gas inventory.

The Paris Agreement

The Paris Agreement is a global agreement on climate change, adopted under the UNFCCC in 2015. It commits all countries to take action on climate change, with the goal of keeping the increase of global average temperature to well below 2 °C, and to pursue efforts to limit the increase to 1.5 °C. Under this agreement, countries set their own nationally determined contributions (NDCs) to contribute towards the global targets (Ministry for the Environment, 2018).

New Zealand International Emissions Commitments

Under the Paris Agreement New Zealand has committed to a:

- 30 per cent reduction below 2005 (or 11 per cent below 1990) gross emissions for the period 2021-2030

Under the Kyoto Protocol New Zealand has committed to a:

- 5 per cent reduction below 1990 gross emissions for the period 2013-2020
- To reduce greenhouse gas emissions to between 10 per cent and 20 per cent below 1990 greenhouse gas emissions with the condition that there is a comprehensive global agreement.

(Ministry for the Environment, 2019).

6.2.2 Domestic laws and policies

Zero Carbon Amendment Act (ZCAA)

The sections of the ZCAA most relevant to the wastewater sector have been summarised below and their applicability outlined. The amended purpose of the ZCAA is to:

(aa) provide a framework by which New Zealand can develop and implement clear and stable climate change policies that –

(i) Contribute to the global effort under the Paris Agreement to limit the global average temperature increase to 1.5° Celsius above pre-industrial levels; and

(ii) Allow New Zealand to prepare for, and adapt to the effects of climate change.

Target for 2050

The ZCAA sets the following domestic emission targets for 2050:

1. *a) net accounting emissions of greenhouse gases in a calendar year, other than biogenic methane, are zero by the calendar year beginning on 1 January 2050 and for each subsequent calendar year; and*

   b) emissions of biogenic methane in a calendar year—

   (i) are 10% less than 2017 emissions by the calendar year beginning on 1 January 2030; and

   (ii) are 24% to 47% less than 2017 emissions by the calendar year beginning on 1 January 2050 and for each subsequent calendar year.

2. *The 2050 target will be met if emissions reductions meet or exceed those required by the target.*

3. *In this section, 2017 emissions means the emissions of biogenic methane for the calendar year beginning on 1 January 2017.*

Requirement for Emissions Reduction Plans

The ZCAA requires the creation of an Emission Reduction Plan. The plan must include:

- *Sector-specific policies to reduce emissions and increase removals; and*
- *A multi-sector strategy to meet emissions budgets and improve the ability of those sectors to adapt to the effects of climate change; and*
- *A strategy to mitigate the impacts that reducing emissions and increasing removals will have on employees and employers, regions, Iwi and Māori, and wider communities, including the funding for any mitigation action; and*

Monitoring

It is the role of the Climate Change Commission to monitor progress towards meeting emissions budgets. The Climate Change Commission will prepare annual reports, based on data from MfE that include:

- *Measured emissions; and*
- *Measured removals.*
- *The latest projections for current and future emissions and removals; and*
- *An assessment of the adequacy of the emissions reduction plan and progress in its implementation, including any new opportunities to reduce emissions*

ZCAA applicability to the wastewater sector

The wastewater sector will be influenced by international and domestic targets, including the three ZCAA targets.

- As WWTPs produce greenhouse gases (further discussed in section 6.4), target 1 (a) applies to CO_2 and N_2O emissions from the wastewater sector.
- As sludge, septic tanks and oxidation ponds within WWTP produce biogenic methane, targets 1 (b) and 3 apply to CH_4 emissions from the wastewater sector.
- Target 2 is also applicable to the wastewater sector emissions as it defines compliance with the targets.

The requirement to develop Emission Reduction Plan will very likely impact the wastewater sector through the development of sector-specific policies and multi-sector strategies. This plan will impact the wastewater sectors strategies in regards to reducing emissions, increasing removals and adapting to the effects of climate change.

The wastewater sector will be subject to monitoring their progress towards the emission goals through measuring emissions, removals and future projections for emissions and removals. This monitoring data is currently prepared by the Ministry for the Environment and will be included within the Climate Change Commissions annual progress reporting. Under the ZCAA the Climate Change Commission will be assessing the adequacy of measures to reduce emissions.

The wastewater sector will likely also be influenced by the future National Adaptation Plan which is estimated to be finalised within two years after the NCCRA is published.

National Climate Change Risk Assessment

MfE has produced the first National Climate Change Risk Assessment (NCCRA) in August 2020. The second NCCRA will be produced by the Climate Change Commission. This document focused on the risks to New Zealand from hazards caused, exacerbated or influenced by climate change. The potential for positive consequences (opportunities) were also considered. The purpose of the assessment was to build an understanding of the risks and opportunities from long-term trends in the climate to support the development of a National Adaptation Plan (NAP).

NCCRA applicability to the wastewater sector

The following risks have been identified within the NCCRA for the wastewater sector. These risks are projected to increase in frequency and severity as a result of climate change.

- Extreme weather events (including heavy rainfall), ongoing sea-level rise and drought
- Natural hazards such as inland flooding, coastal flooding, coastal erosion, and groundwater rise

Direct and indirect impacts resulting from these risks include:

- Increases in wastewater overflow events to waterways and harbours
- Risk to wastewater infrastructure located near the coast from coastal flooding. Additionally often discharge points of wastewater systems are at the lowest elevation of populated areas, making them particularly sensitive to coastal erosion and inundation.
- Drought can lead to a range of impacts on buried pipelines (subsidence and cracking)
- The infiltration of groundwater into storm and wastewater systems due to sea-level rise will lead to increased flow volumes and salinity. Saltwater can accelerate corrosion of pipe, pump and treatment systems, and potentially reduce treatment plant performance resulting in solids building up in pipes, and more concentrated wastewater flows.

The NCCRA highlights that the adaptive capacity of large WWTPs are low, whereas networks typically have a higher level of adaptive capacity. Adaptive capacity varies based on funding, age and the condition of infrastructure.

National Adaptation Plan

A National Adaptation Plan for New Zealand has yet to be completed. This plan will likely have implications on the wastewater sector. The NAP will be influenced by the risks outlined to the wastewater sector within the NCCRA. The ZCAA contains an outline of the plans required content:

- *The Government's objectives for adapting to the effects of climate change; and*
- *The Government's strategies, policies, and proposals for meeting those objectives; and*
- *The time frames for implementing the strategies, policies, and proposals; and*
- *How the matters in paragraphs (a) to (c) address the most significant risks identified in the most recent national climate change risk assessment; and*
- *The measures and indicators that will enable regular monitoring of and reporting on the implementation of the strategies, policies, and proposals.*

Resource Management Amendment Act 2020

The Resource Management Amendment Act 2020 (RMA 2020) will also focus on climate change and emissions management, which in turn will influence the wastewater sector. The RMA 2020 factsheet introduces the following changes relating to climate change, which will come into force at various times:

- *Councils must have regard to emissions reduction plans and national adaptation plans under the Climate Change response Act 2020 (as amended by the Climate Change*

Response (Zero Carbon) Amendment Act) when making and amending regional policy statements, regional plans and district plans

- *Councils may consider discharges to air of greenhouse gas emissions, as the sections prohibiting councils from considering discharges are repealed (that is, sections 70A, 70B, 104E and 104F)*
- *A Board of Inquiry or the Environment Court must take into account climate change when a matter is called in as a matter of national significance on the basis of its greenhouse gas emissions.*

6.2.3 Emission Trading Scheme (ETS)

The New Zealand ETS was introduced in 2008. Under the ETS, for each tonne of liable emissions applicable industries are be required to surrender a tradable emission unit to the government. Industries have the potential to acquire emission units via receiving them for free, buying them, and earning them via emission removal activities.

The scheme was originally designed to operate within a broader global cap set by the Kyoto Protocol. A review of the ETS by the New Zealand Government resulted in the Climate Change Response (Emissions Trading Reform) Amendment Bill.

ETS applicability to the wastewater sector

At this time the ETS is not enforced for the wastewater sector. Emissions from wastewater treatment are considered difficult to measure at an individual site and given there are hundreds of facilities across New Zealand the administration and compliance associated costs are considered likely to outweigh the benefits (Leining, Allan and Kerr 2017).

This is supported by the Governments current stance that ETS is unlikely to create sufficient financial incentive to reduce emissions from WWTPs. They reason that WWTPs currently emit relatively low emissions, have high capital costs and long life infrastructure (New Zealand Government, 2019).

Capacity issues for wastewater management teams within TAs may limit the ability of WWTPs to act on emissions reduction opportunities that exist. Concerns also exist regarding the indirect impact of the ETS on treatment standards. The ETS would result in additional costs to the wastewater sector for the treatment process. This may influence the capacity of councils to provide wastewater treatment to acceptable standards at an affordable price to consumers (New Zealand Productivity Commission, 2018).

6.2.4 Task Force on climate-related financial disclosures

The Task Force on Climate-related Financial Disclosures (TCFD) was established to *develop voluntary, consistent climate-related financial risk disclosures for use by companies in providing information to investors, lenders, insurers and other stakeholders.*

TCFD identified two main types of climate related risks, both of which are applicable to the wastewater sector; transition and physical risks.

Transitional risks include:

- *Policy risk, due to evolving policy actions by governments and regulators*
- *Litigation risk, due to an increase in climate-related litigation claims*
- *Technology risk, due to the significant impact of climate-related technological improvements or innovations*

- *Market risk, due to shifts in supply and demand in response to climate-related risks and opportunities*
- *Reputational risk, due to changing customer or community perceptions about whether an organization is contributing to or detracting from the transition to a lower-emissions economy*

Physical risks include:

- *Financial implications for entities as a consequence of direct damage to assets, and indirect impacts from supply chain disruption. These risks can be either event-driven (eg, the increased severity of extreme weather events) or driven by longer term shifts in climate patterns that may cause sea level rise or chronic heat waves.*
- *Entity performance may be affected by changes in water availability (sourcing and quality), changes in food security, and extreme temperature changes that impact on the entity's premises, operations, supply chain, transport needs and employee safety*

To aid in mitigating these risks TCFD recommends the following financial related disclosures, all of which are applicable to the wastewater sector:

- *Disclose the organizations governance around climate-related risks and opportunities.*
- *Disclose the actual and potential impacts of climate-related risks and opportunities on the organizations businesses, strategy, and financial planning*
- *Disclose how the organization identifies, assesses and manages climate related risks*
- *Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material*

(Ministry for the Environment & Ministry of Business, Innovation & Employment, 2019; Task Force on Climate-related Financial Disclosures, 2017).

6.3 Climate change impacts on the wastewater sector

The wastewater sector is vulnerable to the direct and indirect impacts of climate change. The wealth of knowledge surrounding the topic of climate change is extensive, therefore, the following sections of this report investigate a selection of the key direct and indirect impacts climate change is likely to have on the wastewater sector in New Zealand. Examples of case studies and adaptive approaches to these challenged have been drawn on at an international and local scale.

6.3.1 Potential direct implications

Direct implications of climate change are effects on the functionality and operation of the wastewater sector. Direct implications can include:

- Inundation and flooding because of rising sea level, storm surges and increased intensity of precipitation events
- Increased pressure and damage to infrastructure because of flooding, erosion, temperature rise and
- Pressures on the treatment process because of temperature increases, droughts and extreme weather patterns.

Direct implications can be caused by single or multiple climate change drivers, and each driver can have various impacts on the wastewater sector. A collection of the commonly discussed climate change drivers, and the potential direct implications, are explored in more detail below.

Sea level rise and storm surges

The Stocktake Report, from the Climate Change Adaptation Technical Working Group (2017), predict sea level rise to increase in New Zealand by 0.2 – 0.4 m by 2060, and 0.3 to 1.0 m by 2100. In addition to rising sea levels, sea level variability in terms of storm surges is likely to increase because of climate change (Hallegatte et al. 2011). Storm surges are the temporary rise of sea level in a coastal area because of low atmospheric pressure and sea-level gradients set up by strong winds. The influence of tidal activity during a storm surge will affect the intensity of the event (Bell et al. 2000).

New Zealand has over 15,000 km of coastline and approximately 75% of all residents live within 10 km of the coast (Hopkins et al. 2015). A considerable volume of infrastructure is therefore located in coastal areas. In 2012, the National Institute of Water and Atmosphere (NIWA) developed a coastal sensitivity index (CSI), to understand the sensitivity of the coastal margin of New Zealand to climate change. The CSI developed shows relative potential future sensitivity to two variables; coastal inundation and coastal change, referred to herein as coastal erosion. The CSI for both variables was developed using the same process, where each coastal segment (1811 in total) was assigned a score and weight in regards to the relative manner in which the geomorphic and oceanographic attributes are likely to be affected by climate change (Goodhue, et al 2012). The CSI for inundation and CSI for coastal erosion are shown in Figure 78 to Figure 81.

Analysis of the CSI for inundation identified 15 WWTP are located within 5 km of a highly sensitive segment of coastline to inundation, of which 13 are within 1 km, and 74 WWTP were within 5 km of a moderately sensitive segment of coastline (Figure 78 and Figure 79). This equates to 5% and 23% of New Zealand’s WWTP being located within 5 km of highly sensitive and moderately sensitive coastal inundation zones, respectively. These WWTP will be increasingly vulnerable to coastal inundation and storm surges as a result of climate change.

Analysis of the CSI for erosion identified 45 WWTP are located within 5 km of a highly sensitive segment of coastline to erosion, of which 23 are within 1 km, and 63 WWTP were within 5 km of a moderately sensitive segment of coastline, 14 % and 19% respectively (Figure 80 and Figure 81). These WWTP will be increasingly vulnerable to coastal erosion from sea level rise and storm surges as a result of climate change.

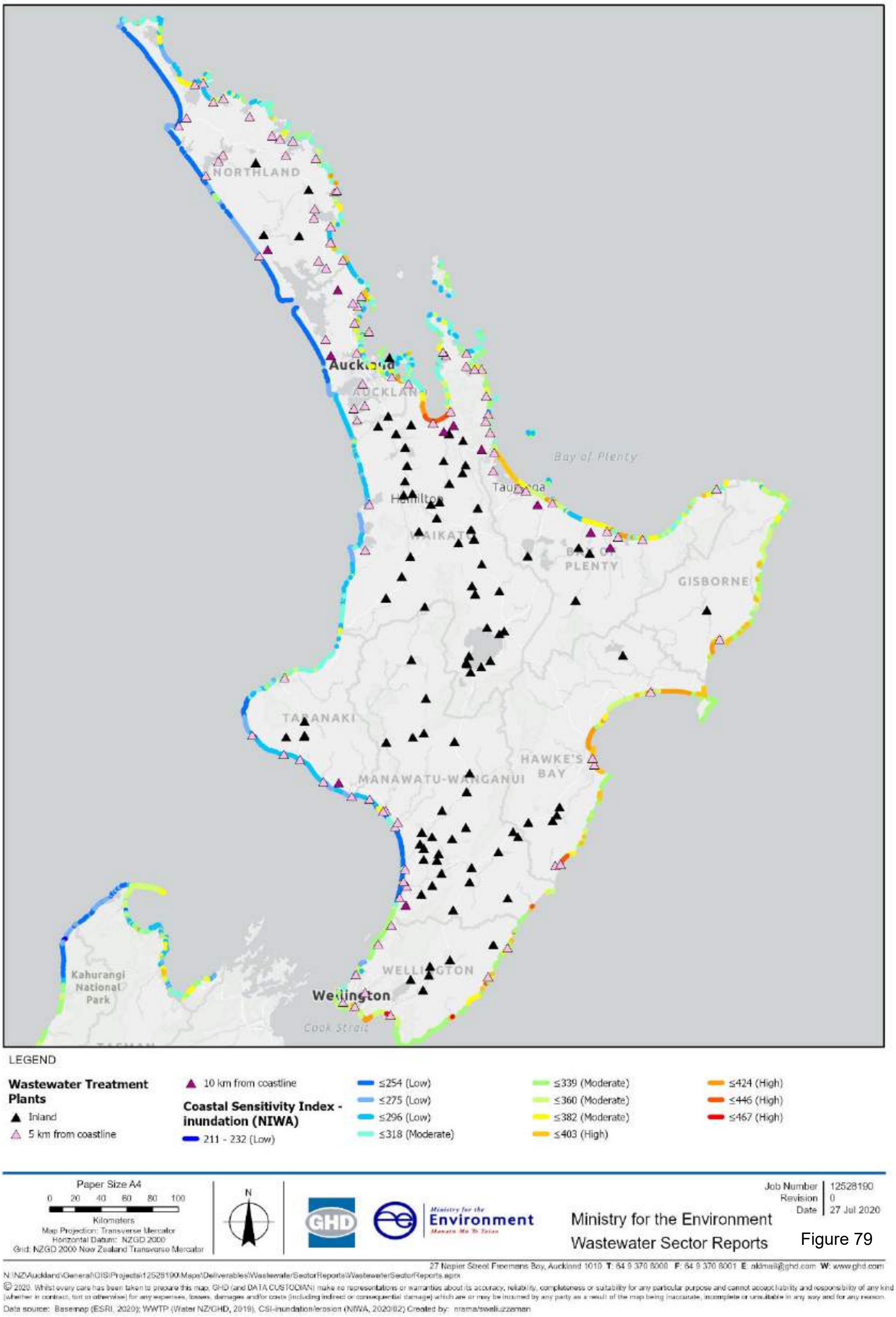


Figure 78: Wastewater treatment plant locations and the coastal sensitivity index (CSI) for inundation (produced by NIWA, Goodhue et al 2012) for the North Island

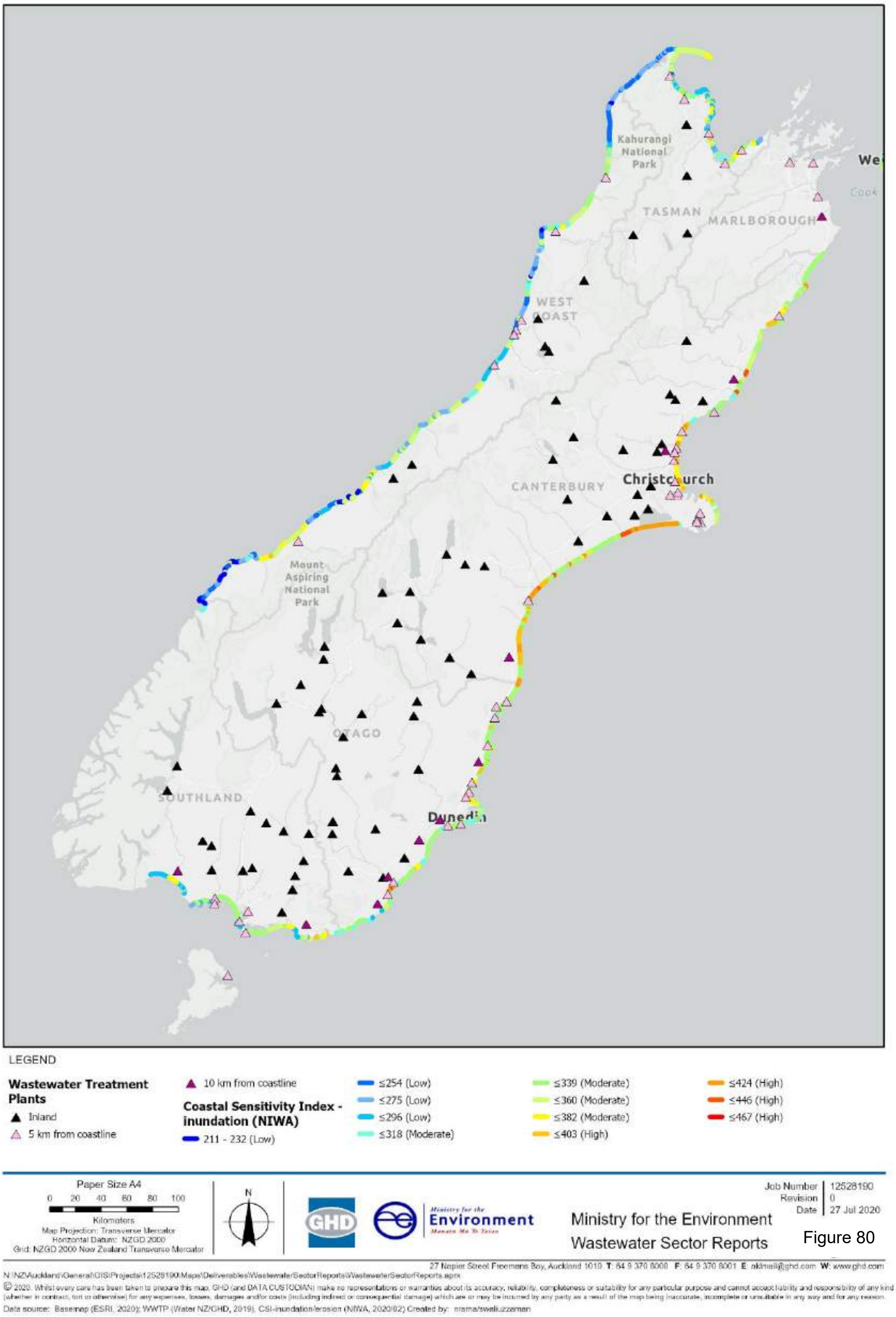


Figure 79: Wastewater treatment plant locations and the coastal sensitivity index (CSI) for inundation (produced by NIWA, Goodhue et al 2012) for the South Island

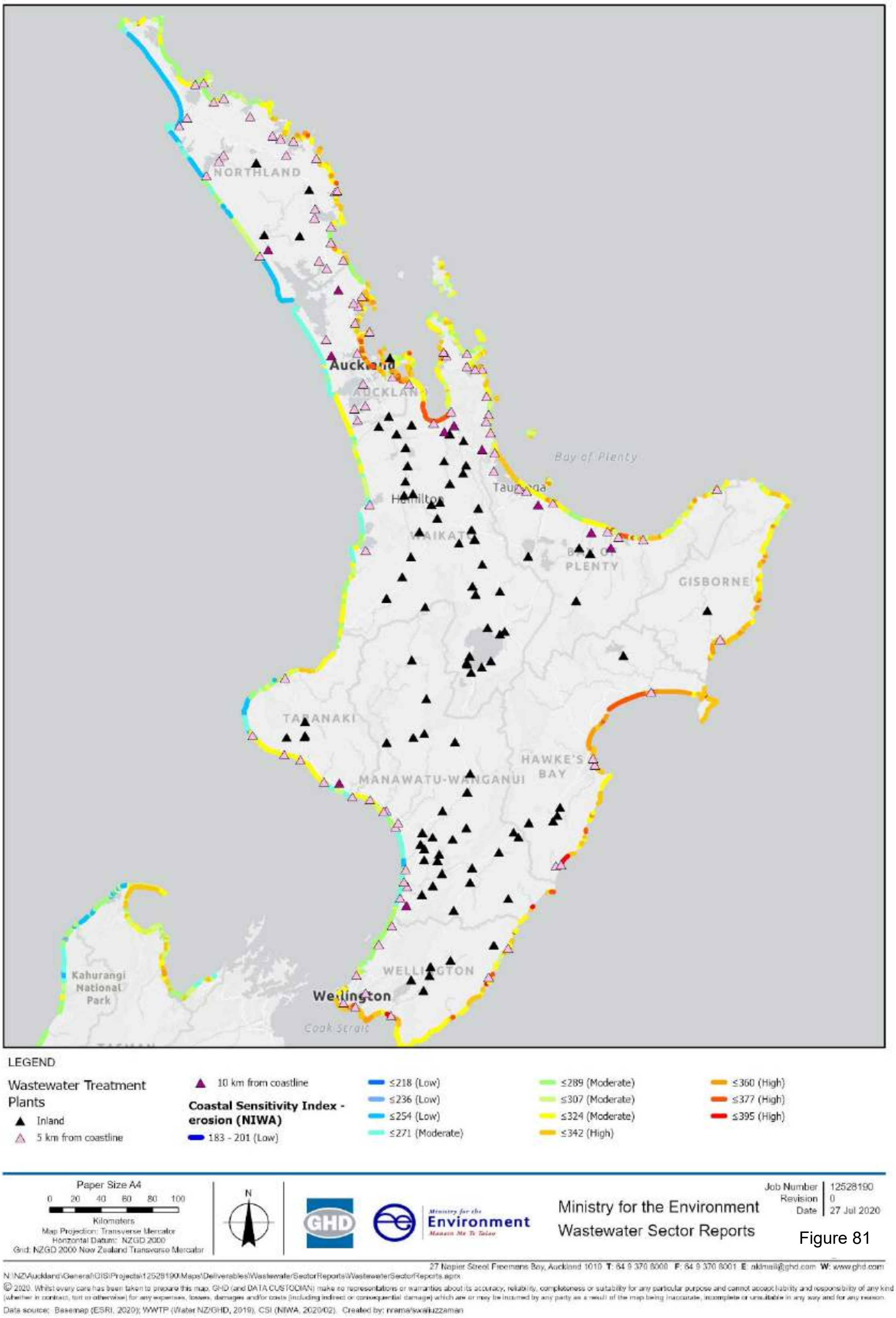


Figure 80: Wastewater treatment plant locations and the coastal sensitivity index (CSI) for erosion (produced by NIWA, Goodhue et al 2012) for the North Island

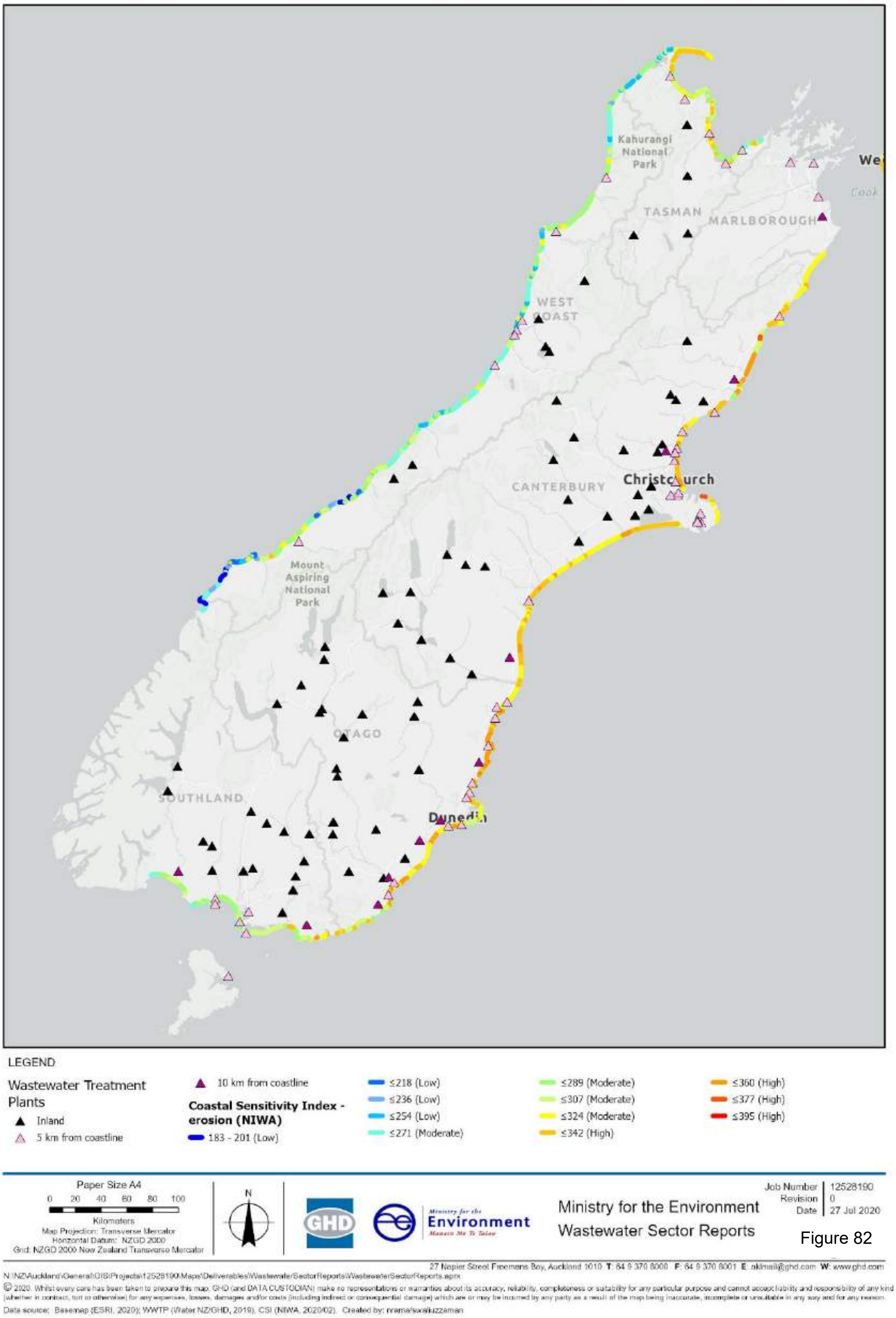


Figure 81 Wastewater treatment plant locations and the coastal sensitivity index (CSI) for erosion (produced by NIWA, Goodhue et al 2012) for the South Island

The primary risk of sea level rise and storm surges for wastewater sectors in New Zealand is damage to infrastructure through inundation, erosion, and corrosion from saline floodwater (Tolkou and Zouboulis 2015, Hummel et al. 2018). In conjunction to structural damage, there is a risk of damage to electrical systems. Damage to the electrical system could result in faults at key processing units within a plant, such as sludge and aeration pumping, or complete shutdown of processing at a facility (Blumenau et al. 2011). The degree of damage may initially be small or short lived, depending on the severity of the event. However, damage to infrastructure is costly, whether it is slow degradation or immediate damage. The cost can be associated with the direct and indirect damage. For example, the coastal flood in Thames in 1995, which coincided with the highest tide of the year (storm surge), caused $3-4M worth of damages (Bell et al. 2000). Whereas indirect damage costs can include environmental and wellbeing costs to the local receiving environment or community because of untreated discharge from failed infrastructure (Blumenau et al. 2011).

Precipitation patterns and flooding

In New Zealand, precipitation projections are highly variable with rainfall expected to increase in the west coast of both Islands over winter and spring and decrease in the east and north during winter and spring (MfE 2018). In the west coast of the South Island, annual mean precipitation is expected to increase by 5% in 2040 and 10% in 2090. In the eastern areas, including Northland and Auckland, projected precipitation could decrease by up to 5% by 2090 (Lundquist *et al.* 2011). The variability in seasonal and spatial rainfall predictions is highlighted in tables 10 -12 and figures 36 – 43 of the Climate Change Predictions for New Zealand report, prepared by MfE (2018).

Projections also indicate increases in rainfall intensity and frequency. The frequency of extreme precipitation events in New Zealand could nationally increase between 7-20% (Lundquist *et al.* 2011), with a potential 20% increase in very wet daily precipitation extremes in the South West of the South Island by 2090 (Climate Change Adaptation Technical Working Group 2017, MfE 2018). Projected decreases in the daily precipitation extreme (wet days) in parts of the north and east of the North Island are also expected (MfE 2018).

Increased frequency and intensity of precipitation events means more severe flooding is expected (Tolkou and Zouboulis 2015). Extreme precipitation and flooding poses a risk directly to infrastructure and the local environment. Flooding can overwhelm a wastewater facility by overloading pipe and pump capacity, and directly damaging infrastructure. For example, in 2010, the WWTP in the City of Norfolk, Nebraska, USA, was flooded and the weight of the water caused the 36-inch pipe, responsible for carrying wastewater into the facility, to collapse (Blumenau *et al.* 2011). New Zealand wastewater networks located in frequently flooded areas such as those located in Hauraki District or the Edgecumbe plant managed by Whakatane District Council will be vulnerable to similar risks. Increased inflow loads through direct inputs or inflow and infiltration have the potential to overload the collection systems, increase the risk of system overflows and decrease treatment efficiency (Flood and Cahoon 2011). Damage directly to the facility is not only costly to fix but can directly release untreated waste into the receiving environment, posing a risk for human and ecosystem health.

A portion of the wastewater facilities and infrastructure in New Zealand is located in flood zones or flood plains around New Zealand. Two case studies can be referred to, the Auckland Region, Figure 82, and the Waikato Region, Figure 83.Note the WWTP in both figures are numbered and the number refers to the WWTP identification system outlined in Appendix C. Figure 82 shows in the Auckland Region 7 of the 17 WWTP facilities, or 41% of the Regions WWTP, are located within a flood plain and all other WWTP in the Region are within 1 km of a flood plain. Resulting in almost half of the WWTP in immediate risk of increased flooding vulnerability under climate change predictions.

Figure 83 refers to flood vulnerability in the Waikato. It outlines the flood prone land which is protected by flood control schemes and the flood prone land unprotected, or partially protected by flood control schemes. Flood projection schemes, can include control structures, such as flood gates, stop-banks, dams and land drainage systems (Waikato Regional Council, 2020). Figure 83 shows in the Waikato Region 32% of the WWTP facilities are within a flood hazard zone, 41% are within 1 km, and 20% are within 5 km. The majority of the WWTP facilities are therefore vulnerable to flooding.

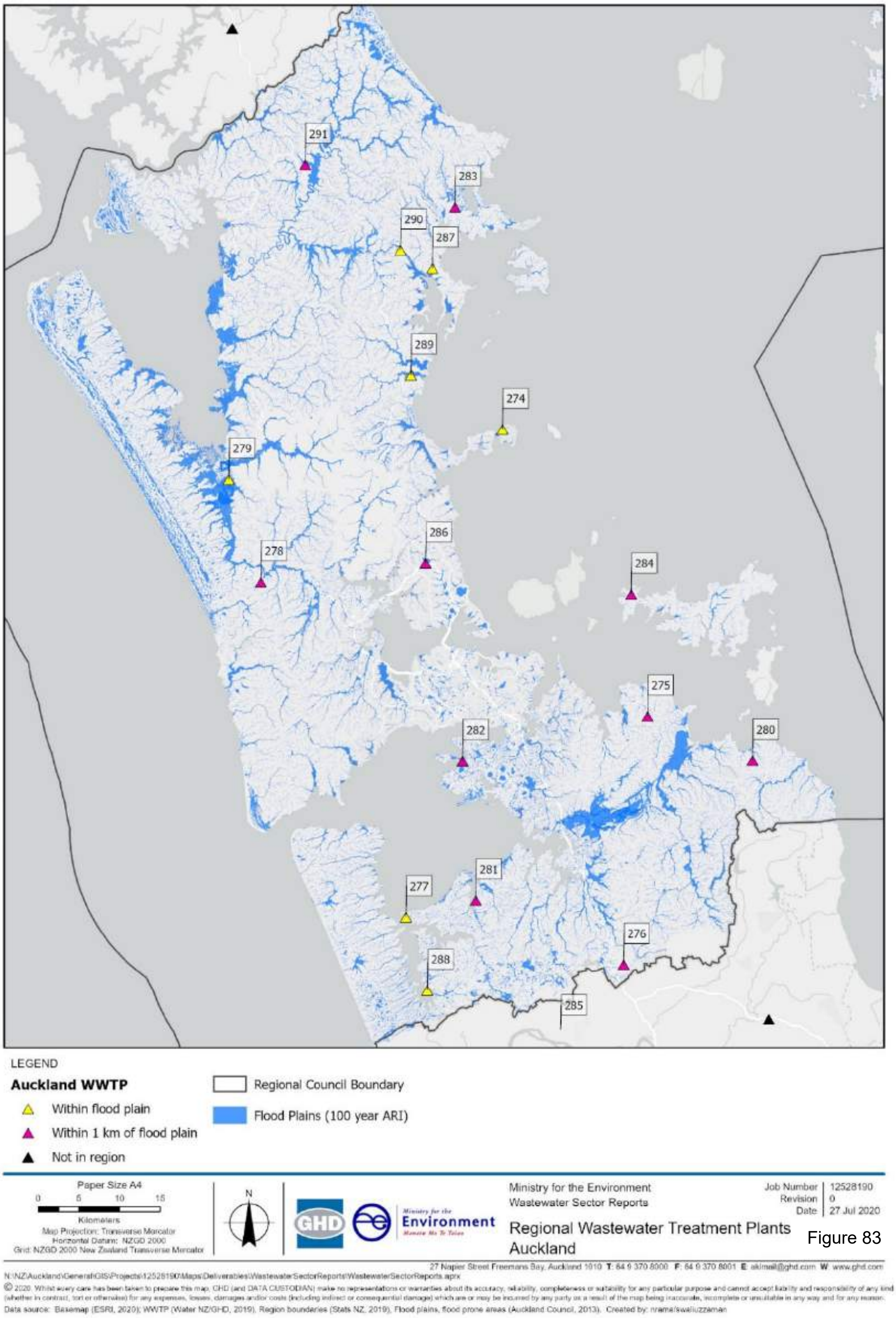


Figure 82: Auckland Region flood plains and WWTP proximity

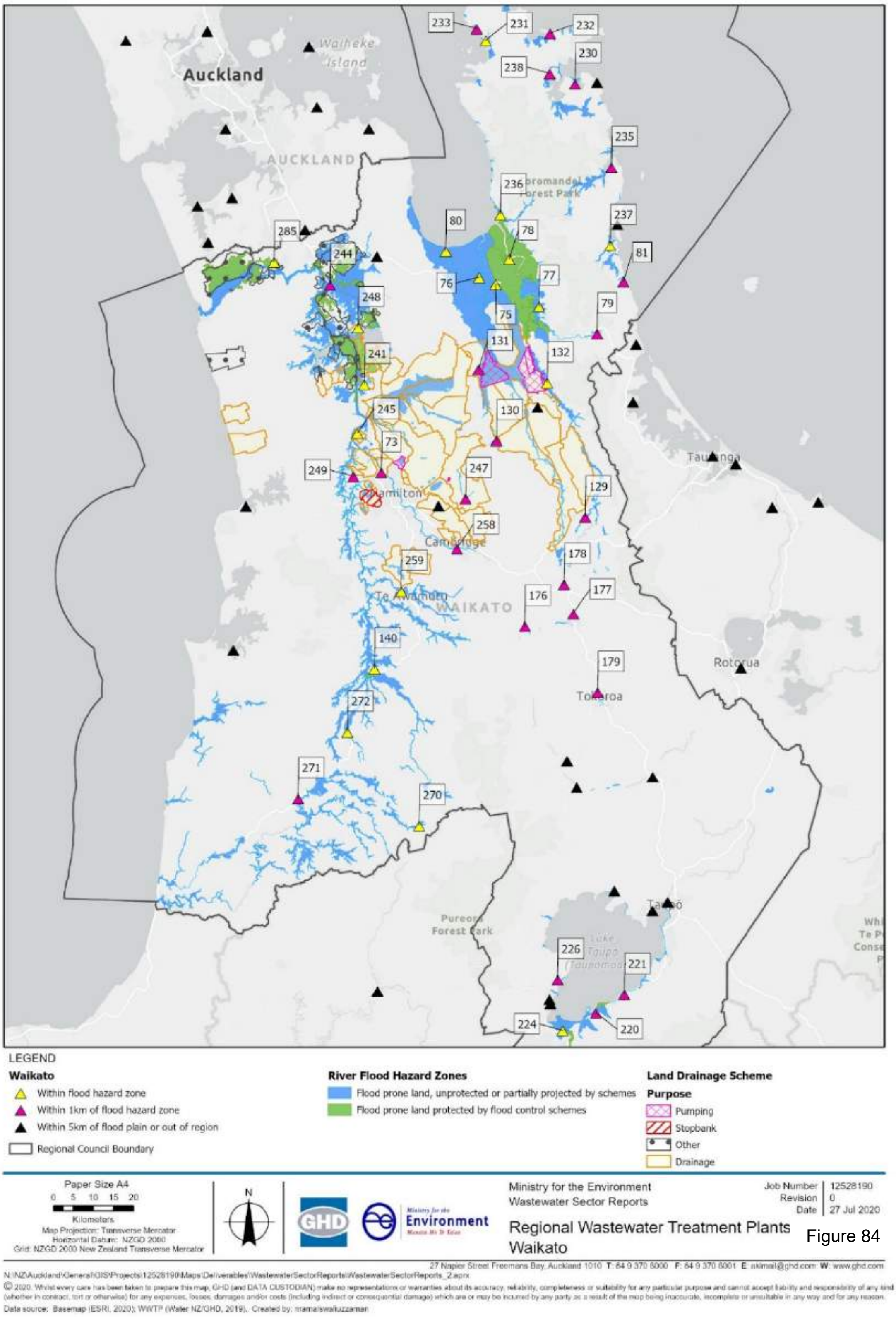


Figure 83: Waikato Region flood plains and WWTP proximity

Increase in temperature and drought frequency

General midrange estimates predict temperature changes to increase by 0.8 °C by 2040, and 1.4 °C by 2090, in New Zealand. With wide range predictions spanning from 0.2-1.7 °C by 2040, and 0.1-4.6 °C by 2090 (MfE 2018). The predicted changes in mean seasonal and annual temperature per region across New Zealand is further detailed in tables 5 - 7 and figures 8 -15 of the Climate Change Predictions for New Zealand report, prepared by MfE (2018).The Surface temperatures in New Zealand have increased by approximately 0.9 °C since the pre-industrial period and relative to the temperatures observed in 1980-1999, average surface temperatures could increase by 2.1 degrees by 2090 (Lundquist et al. 2011).

Temperature increases may affect drought intensity and frequency in New Zealand. The severity and frequency of droughts may increase, with a possible 50 mm+ increase per year of potential evapotranspiration deficit (in July – June) by 2090 (Climate Change Adaptation Technical Working Group 2017, MfE 2018). Drought potential could also increase in the western regions of New Zealand from 1-in-20 year return interval to a 5-to-10 year return frequency.

Drought conditions slow the overall flow of water in wastewater systems and can lead to build up of solids in the pipe network, causing blockages or breaches (White et al. 2017). Reduced quantities of water through the wastewater system can also result in reduced quality of the waste, i.e. an increase in contaminant concentrations (Tran et al. 2017). The increase in drought frequency in New Zealand is not an immediate challenge for the wastewater sector in regards to direct implications and could in fact be beneficial in terms of behavioural change and reduced per capita water consumption. However, adaptive planning measures will be required to manage the upkeep of infrastructure, especially concerning reduced flows, and the indirect implication reduced wastewater quality could have on the receiving environments and overall treatment process.

6.3.2 Potential indirect implications

Indirect implications of climate change on the wastewater sectors may include impacts on the quality of influent and effluent and the predicted reduction of water use for conservation purposes. The indirect implications of climate change on the wastewater sector can be more difficult to pre-empt and are extensive. Indirect implications can include:

- Treatment process efficiencies and energy usage
- Increased sensitivity of the receiving and surrounding environment and therefore tight controls on discharges and plant management
- Increased demand for storage capacity and reduced availability of land in vulnerable locations to accommodate increased buffer capacity
- Influent and effluent quality and bio-solids management

As described in the above section sea level rise, storm intensity, precipitation patterns and temperature increases are just some of the climate change factors which will have implications on the wastewater sector in New Zealand. The relationship between climate change pressures and the implications these have on the wastewater sector are not singular or linear, therefore, an example of an indirect implication caused by differing climate change impacts has been discussed below.

One of the key issues that face the New Zealand wastewater sector is the sensitivity of the receiving environments and maintaining efficient plant processes while reducing energy consumption and greenhouse gas emissions.

The quality of New Zealand freshwater and estuary environments has been a focal point of literature and legislation development over the last 10 years. Consents related to the discharge from wastewater plants in New Zealand are commonly bound by tight environmental controls and contaminant levels to maintain the ecosystem health of the receiving environment.

Increasing temperatures and rising sea levels are already posing a threat to many of the freshwater and estuary ecosystems in New Zealand (Jenkins et al. 2011). The indirect implication of this for the wastewater sector is the controlling limits on discharge quality and quantity are likely become more restrictive, catering to the increasing sensitivity of the receiving environments.

A direct implication of increasing drought severity is reduced base flows and increased contaminant loads (White et al. 2017). Under persistent dry climatic conditions, as wastewater facilities discharge permitted contaminant loads to receiving environments, the lack of base flow and precipitation can cause a higher concentrations of contaminant built up having an indirect impact on the receiving environment (Senhorst and Zwolsman 2005). Conversely dryer soil conditions in drought prone areas may reduce the extent of inflow and infiltration into the wastewater network.

Increased flooding, storm and inundation risks puts pressure on the infrastructure and overflow capacities of treatment plants, as discussed in Section 6.3.1. Uncontrolled release from a wastewater plant, or infrastructure (including pipe seepages) as a result of such events, may also have an adverse and indirect impact on the receiving environment, through addition of contaminants (Senhorst and Zwolsman 2005, Tolkou and Zouboulis, 2015).

Tighter restrictions on the discharge quality and quantity from wastewater facilities, subsequently puts indirect pressure on efficient plant processing and infrastructure maintenance. As a compounding factor the wastewater sector is then faced with the additional challenge of reducing greenhouse gas emissions and energy consumption. Greenhouse gas emissions and energy consumption in the wastewater sector is described in section 6.4 below in more detail. The expectation of higher levels of treatment *and* reduced emissions can often be at odds with each other.

The exact impacts of climate change, particularly indirect impacts, are difficult to quantify and predict. This challenge has led to the increasing global acceptance of adaptation planning for the wastewater sector and its resilience to climate change.

6.3.3 Adaptive pathways planning and the New Zealand context

The use of adaptive planning pathways is an emerging concept globally. Adaptive planning or planning with the use of adaptive pathways is the concept of planning for a range of future uncertainties and developing flexible long-term strategies that allow for adaptive responses to different plausible futures or outcomes. The adaptive planning concept is popular in the water sector and becoming a best-practice approach as the challenges of facing climate change, demand, and population growth increase.

The adaptive planning approached was pioneered in the UK, relating to the Thames Estuary 2100 Plan, and the Netherlands, relating to the Delta Program. It is also fastly growing traction in the United States of America and Australia. In America the adaptive planning approach in the wastewater sector has been described as having three categories: protection, accommodation or relocation. Where the protection approach consists of building infrastructure to prevent future damage to a facility. The accommodation approach is designed to be flexible and accommodate possible risks, such as elevating a plant to allow for temporary site flooding, and the relocation approach is designed to move a facility into a lower risk area (Hummel *et al.* 2018).

Across Australia the adaptive planning approach in the water sector has attempted to embrace future uncertainty by exploring the impact of multiple outcomes, with some organizations putting focus on the overall strategy and long term plan for adaptability, not individual assets or fixed outcomes. For example, Melbourne Water have created an Adaptive Pathways Planning Guideline in 2017-18 and specific plans such as the Western Treatment Plant Adaptation Plan 2018. The Western Treatment Plant Adaptation Plan is a multi-year work plan that enables Melbourne Water to complete a 100 year adaptation plan for the plant to understand the options available, interaction between actions and identify knowledge requirements to face change and future uncertainty in a coastal environment.

Majority of the wastewater facilities and associated assets in New Zealand are considered old and suffer from historical under investment therefore, some Regions require significant upgrades to the current facilities to assist with resilience to population growth and climate change pressures. It has been observed in New Zealand that wastewater facility upgrades are driven by the level of service required by the local area and the quality of the existing infrastructure. Followed by the secondary driver, implications from climate change pressures.

From interviews with a selection of Local Government authorities in New Zealand it has become clear there is a considerable journey ahead to prepare the wastewater sector to respond to the direct and indirect implications of climate change. A summary of the key finds is outlined below in Table 34**.**

From the interview process sea level rise, flooding and changes in precipitation intensity and frequency have been identified as the key immediate issues facing the participants interviewed. Most interviewees expressed they had treatment plants that were vulnerable or at risk of implications due to these climate change variables.

The interview process identified that the organizations are at differing stages with some well underway with climate change strategies and response, i.e. Watercare, and others who have not started to draft or consider plans, i.e. Westland and Tauranga City Council. A similar observation was made with regard to the management of greenhouse gases. Some organisations are monitoring and working towards reducing these, i.e. Whakatāne and Watercare, whereas Hauraki and Westland do not monitor greenhouse gas emissions at this time. In some cases smaller service providers have started their climate change response by first building understanding of their Green House Gas emissions whilst much less focus seems to be apparent on adaptation approaches such as retreat, treatment plant consolidation in less vulnerable locations, or infrastructure resilience.

The interview process also identified the following knowledge gaps and hurdles perceived by the participants:

- There is an overall budget and cost issue, where upgrades, resilience and adaptation is required but comes at a cost above and beyond what the organisation can afford or secure through funding. This is especially pertinent for those with small rating bases and dispersed communities.
- The rate of change is unknown with many of the climate change variables and more regional specific data and monitoring is required now to aid in the understanding and future planning.
- The risk, vulnerability and financial circumstances of service providers vary significantly and thus they are facing different challenges. Therefore, national level guidance and policy needs to be flexible enough to enable location specific responses to be developed whilst also providing a nationally consistent general approach in terms of outcomes sought, policy and objectives set and overarching rules, regulations and standards.

Table 34: Key findings from wastewater sector interviews

Questions	Tauranga City Council	Anonymous	Hauraki District Council	Thames-Coromandel District Council	Whakatane District Council	Watercare	Westland
What do you consider are the key risks, associated with climate change, that face your wastewater treatment facilities?	Changes in rainfall, sea level rise, flooding, rising groundwater tables and associated salinity	Possibly flooding, although more concerned about cumulative effects of climate change, growth and changes to disposal requirements.	Flooding and increased storm frequency and intensity	Sea level rise, storm events, and drought.	Sea level rise, coastal inundation, flooding, precipitation intensity and rising groundwater tables	Sea level rise, surface flooding, rising groundwater tables, increased intensity of rainfall and increased in hot and dry days	Flooding, river rise and increase in precipitation intensity and frequency
Which sites are your key concerns in relation to the implications of climate change? Why?	Both plants. The Chapel Street and Te Maunga Plants are low laying and coastal therefore at risk of coastal inundation. Just beginning to look at climate change and how to address these issues. Design of new infrastructure is beginning to be tailored to ensure resilience against climate change factors	Currently focussed on energy usages and GHG emissions. To help determine what the key risks and concerns are there is discussion about building a model to help inform the requirements in this space.	All 7 WWTP original consents have either expired or are up for renewal, climate change factors will be wrapped up into the long term design and management of these facilities.	The Thames WWTP because it is low lying and vulnerable to inundation. Compliance with strict consent conditions moving forward will be increasingly difficult. Long term the oxidation ponds at this plant are at risk of inundation.	Whakatāne, and Ōhope are coastal plants. Whakatāne and Edgecumbe are also located in the ancient floodplains of the Rangitāiki River. Therefore these plants are a key concern regarding increased flood risk and sea level rise / inundation. The Edgecumbe plant was also affected significantly by the 1987 seismic activity and is already experiencing issues with precipitation events	Many of the WWTP are in low laying coastal areas at risk of coastal inundation and rising groundwater tables with tidal influence, for example Mangere and Helensville.	Hokitika is the key plant of concern at the moment but not for climate change reasons. Increased flooding and river rise is a risk for the Franz Joseph Plant.

Questions	Tauranga City Council	Anonymous	Hauraki District Council	Thames-Coromandel District Council	Whakatane District Council	Watercare	Westland
Is there adaptive capacity at the current sites that enable them to be resilient in the face of climate change?	N/A	N/A	Yes for some, no for others. Land has been purchased and is currently leased around some of the WWTP to allow for better management and future growth.	There is additional land available to provide flexibility for changes to the plants. Most plants are considered secure and have potential for adaptive capabilities. This is more challenging for the low lying plants.	At the Whakatāne treatment plant, yes. But it is the only plant that is currently being investigated for adaptive capacity.	Yes, there are some planning adaptive capabilities through the use of a dynamic adaptive planning approach, and also through operational set up.	N/A
Do you have, or are you in the process of developing, a climate change policy or strategy	Not yet	Currently in the process of developing a Climate Change Action Plan	Yes the Planning division of the Council is working on this.	There are two pieces of work occurring at the moment that relate to climate change response; The Shoreline Management Plan, which considers sea level rise and maps vulnerability and risk, and the GHG Reduction Plan, which will set out targets for GHG emissions.	Yes, the Climate Change Strategy and Action Plan. The Action Plan is in a draft phase, aiming for completion in 2020. WDC also implemented the Climate Change Principles in 2019 which were developed to guide-decision making.	Yes. The Climate Change Strategy covers both mitigation and adaptation to climate change.	No
Do you monitor and report greenhouse gas emissions in relation to your WWTPs	Yes, monitoring has only recently begun	Yes	No, but it is acknowledged as a current knowledge gap.	No, but monitoring and assessment will be implanted in the future.	Yes, monitoring has been underway for 2 years	Yes and this feeds into the emissions reduction targets.	No

Questions	Tauranga City Council	Anonymous	Hauraki District Council	Thames-Coromandel District Council	Whakatane District Council	Watercare	Westland
Do you have key concerns or questions you would like raised?	Key concern is there needs to be good clear guidance on environmental preference at a National level ie clear objectives and outcomes sought and clear areas of focus. TCC support the current modelling but have concerns regarding the accuracy for use to build Government Policy	No comment from an informed perspective.	There is no industry standard for design (i.e. do you design and plan for a 1 in 10 year flood or 1 in 100 year flood?) Traditionally three waters are addressed individually but in the climate change space there is a lot of overlap and interaction therefore there should be a collective lens applied when addressing this issue.	There is a desire from the community to see smart and environmentally focused options but meeting these expectations is difficult due to funding. Rating base is small and communities are diffuse which makes it difficult to consolidate effort and fund infrastructure improvements.	From an asset management perspective WDC want the Central Government to consider specific communities not just a general approach. WDC also want guidance with flexibility. Locally applying the existing information is questionable. What does a climate change response look like for communities and how does it affect specific communities in each region.	An area of key concern is that the current method for monitoring emissions factors has some shortcomings and does not take into account treatment processes or there upgrade.	The Three Water Reforms indicate the industry will be pushed into tighter controls and moving away from things like oxidation ponds, especially in challenging in some geographical areas. Westland are concerned about the funding needed to carry out such upgrades in the future

Case study of Watercare

Example of a wastewater service provider faced with climate change implications and how they are preparing for these implications with an adaptive planning approach.

Watercare is owned by Auckland Council and is New Zealand's largest water and wastewater services provider. Watercare own and manage infrastructure assets worth $10.1 billion. Daily they collect, treat and dispose of approximately 460 million Litres of wastewater in Auckland.

Climate change will have significant impacts on the way wastewater is managed and hence the way in which Watercare will manage wastewater in Auckland. Watercare has created a Climate Change Strategy which, in the short term, will guide them till 2025 in incorporating climate change considerations into their monitoring, future projections, and asset management. The strategy sets out Watercare's objective of becoming a low carbon organisation that is resilient to climate impacts.

In the long term, Watercare is adopting an adaptive planning pathway, which is currently being implemented at a regional strategy level and also when planning specific upgrades to wastewater treatment plants and other assets with a long life span. As a part of their Climate Change Strategy Watercare has begun implementing adaptive planning pathways to aid them in taking a holistic approach that considers climate change as well as other pressures on their infrastructure.

This adaptive planning pathway involves:

- Using the following to inform decision making:
    - Climate change modelling
    - Demand management
    - Water source resilience
    - Environmental stewardship
    - Emergency preparedness
- Taking into account treatment and network resilience in regards to assets
- Taking into account development, land use and utility partnerships.

This information is then used to assess the appropriate long and short term options/portfolios in regards to infrastructure upgrades and management. The four main long term pathways which these portfolios will be used to inform are capital intervention, operational optimisation, policy/regulatory frameworks and whether to abandon assets.

Alongside this, Watercare is managing ongoing emissions mitigation in regards to planting and carbon removals, energy efficiency, energy neutrality, process efficiency and low carbon infrastructure. This strategy is depicted in the diagram below created by Watercare:

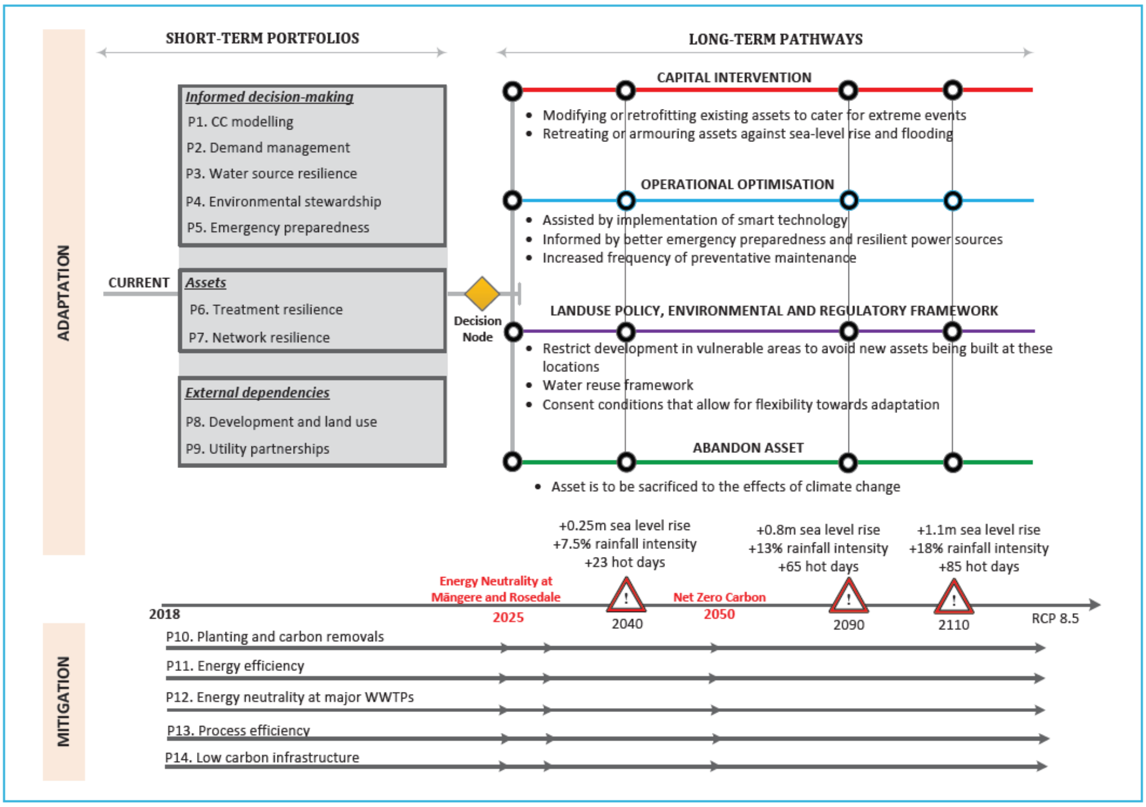


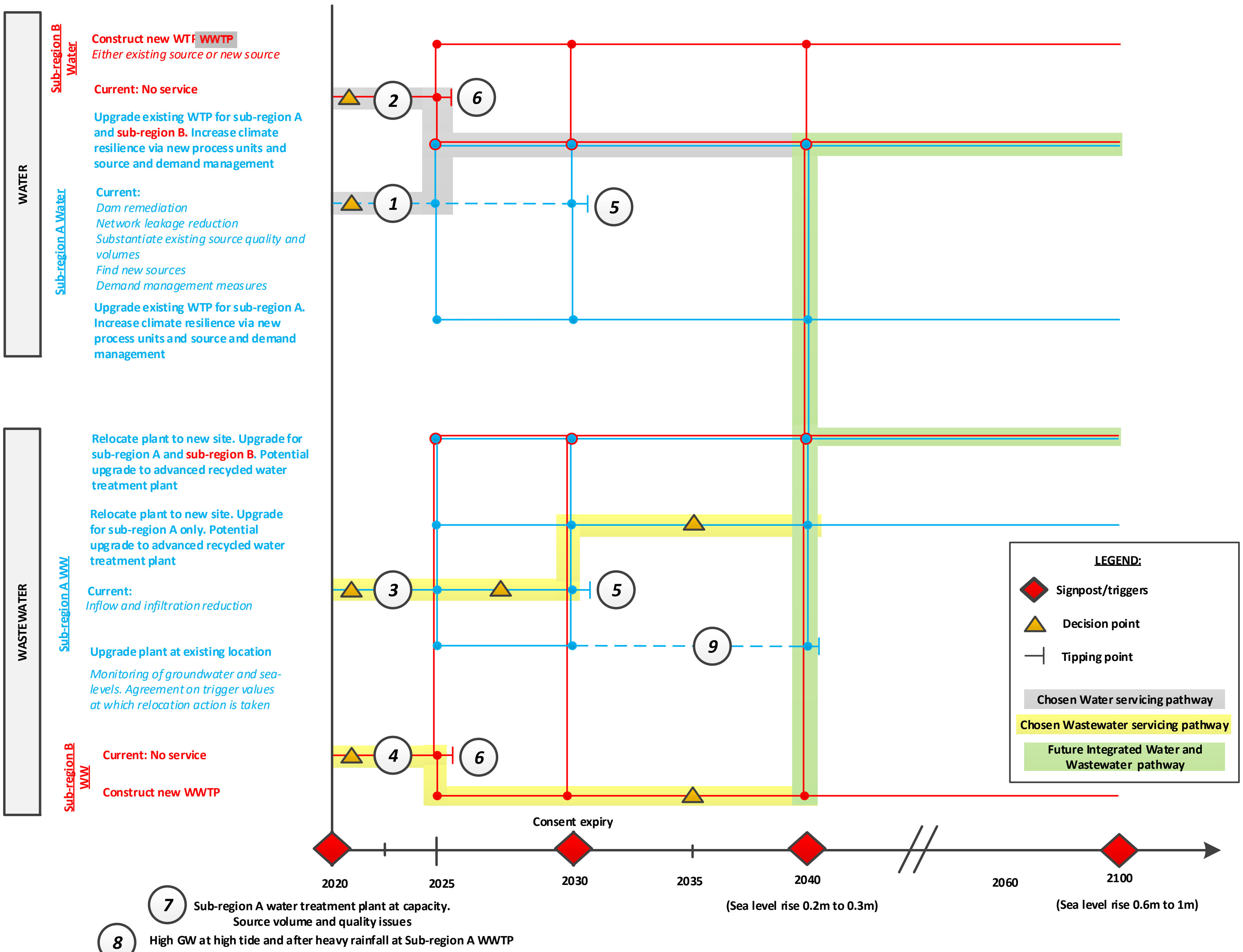
Figure 84 Watercare emissions mitigation strategy

Watercare has implemented the dynamic adaptive policy pathways approach in their long term infrastructure planning. Decision making in water and wastewater infrastructure planning today requires long term considerations of deep uncertainty due to climate change and population growth, as such infrastructure is typically long lived (~100-year design and service life).

Adaptive planning enables complex decision-making by generating multiple infrastructure options, rather than a single, static option. Therefore, short-term pathways can be selected that avoids locking in future solutions which may become unsuitable as environmental conditions, societal perspectives and preferences change. In this way, long-term plans are able to retain flexibility and adapt to a variable and deeply uncertain future to ensure water and wastewater services can continue for Aucklanders.

The figure below depicts an example of a typical adaptive plan used in Watercare's long-term servicing strategies. This would be applied to a particular region that required water and wastewater services over time.

A generic example of long-term water and wastewater infrastructure planning for two sub-regions facing population growth and climate triggers



Equivalent population								
TOTAL	4000EP	4500EP	5000EP	7500EP	10,000EP	12,000EP	15000EP	24,000EP
Sub-region A	2000EP	2400EP	2800EP	4000EP	5000EP	5000EP	5000EP	5000EP
Sub-region B	2000EP	2100EP	2200EP	3500EP	5000EP	7000EP	10,000EP	19,000EP

10

Current pathways 1 2 3 4

Sub-region A has existing water and wastewater services. Sub-region B has no existing water or wastewater service

Tipping point where current pathway is no longer feasible

5 *At Year 2030 for sub-region A water and wastewater treatment when the water take and treated effluent discharge consent expires*

6 *At Year 2025 for sub-region B water and wastewater servicing triggered by new development*

Growth, capacity and climate triggers

7 *Sub-region A water treatment plant (WTP) is at capacity. Raw water source to this WTP has declining volume and quality*

8 *Sub-region A wastewater treatment plant (WWTP) is low-lying and impacted by high groundwater levels at high tide and during wet weather events.*

9 *The groundwater table is expected to rise as sea level rises by approx. 0.3m in 2050 making upgrades at the existing location increasingly vulnerable to climate impacts*

10 *Population growth predictions for sub-region B forecast more than double the existing population in the next 20 years to 5000 people*

Chosen future pathways at current decision point:

Combined water servicing at both sub-regions by upgrading the existing WTP within the next 5 years. This will enable addressing existing source volume and quality issues. A single larger water treatment plant is more cost effective for the higher level of treatment required to address declining raw water quality. Larger flows also provide opportunities for in-line hydropower generation technologies. This pathway retains the ability for future integrated water and wastewater management.

Separate wastewater servicing for each sub-region with a future option to integrate both services into a single advanced recycled water treatment plant in 2040. This pathway retains flexibility in current servicing for both sub-regions while leaving the option open for a future recycled water source to add resilience to the region's overall water supplies.

Figure 85 Watercare infrastructure planning example

These sorts of adaptive plans are also being incorporated during the planning stage of individual assets. A planner is being asked to consider a deeply uncertain future and this technique provides a method of considering multiple pathways. The particular application has been beneficial in looking at upgrade pathways for specific wastewater treatment plants that have some of the following characteristics:

- Uncertain population projections in an area
- Existing assets that are already being impacted by high tides and storm surge
- Treatment plants with a network of pipes and conveyance that may be influenced by large storm events causing storm water infiltration or overflow contamination

The two images below, Figure 86 and Figure 87 supplied by Watercare, are examples of low-lying regional plants built near the coast at the lowest point of the catchment. These are oxidation ponds servicing a population of 4000- 6000 people. These have planned upgrades to meet growth and consenting requirements. Adaptive Planning Pathways are being considered from a planning and capital expenditure perspective and will be a tool for use in public consultation when that occurs.

Figure 86 Snells WWTP, a low lying WWTP in a coastal area.

Figure 87 Helensville WWTP, a low lying WWTP in a coastal area.

6.3.4 Conclusion of key points

- Sea level rise, flooding and increased storm intensity are the key climate change issues facing the New Zealand wastewater sector.
- Indirect issues include network inflow and infiltration, the tension between increased levels of treatment, energy usage and GHG emissions.
- Most service providers are at an early stage in understanding the relative risk of their infrastructure to climate change factors and therefore developing an adaptation response. However Watercare is well progressed and has adopted an adaptive strategy approach.
- Interestingly, prior to being interviewed most service providers had begun to consider and/or measure GHG emissions and energy efficiency measures.
- Almost all of the service providers noted that wastewater infrastructure is historically underfunded and that small communities are reliant of rates to finance infrastructure upgrades would find it difficult to fund their own research to build understanding and to respond to the climate change related priorities identified
- The sector would benefit from a more consistent guidance and assistance in terms of policy direction and objectives but noted that flexibility would be required to allow for varied vulnerabilities, levels of risk and ability to respond to them.

6.4 Greenhouse gas emissions

Emissions, as a result of anthropogenic activities, are increasing the concentration of atmospheric greenhouse gases (GHG) globally. WWTPs and the wastewater sector have been identified as contributing to the emissions of GHG in the atmosphere (Parravicini *et al.* 2016). Direct GHG emissions from wastewater contribute an estimated[61] 1.6% of total global emissions (IPCC, 2014). To this may be added the contribution from WWTPs to GHG emissions associated with electrical energy use. For example, in Australia, this contribution may be

[61] Emissions will vary by country and region according to the extent of wastewater collection, as well as the level and type of wastewater treatment.

estimated[62] at approximately 0.6% of the electricity sector emissions, or approximately 0.2% of the national GHG inventory. The emissions due to energy use associated with wastewater pumping is likely be of a similar order, depending on location, topography and nature of the sewer collection systems (Cook *et al*. 2012). Methane emissions from sewers are highly variable, and potentially a significant additional source of global GHG emissions, but typically have not been included in GHG reporting protocols (Liu *et al.* 2015).

This section of the report will provide an overview of the GHG emissions and consideration of the energy consumption of domestic WWTPs, with specific reference to the New Zealand context. For illustration, a comparison of GHG estimates is presented between the MfE approach (Ministry for the Environment, 2019a) and the Australian 'NGER' approach (Australian Government, 2017), using the WWTP database prepared by GHD for DIA in 2019. It is recognised that this inventory has been in development in recent years and might contain some inconsistencies or errors. However, since the same inventory was used for the two GHG estimation approaches compared, the data was considered sufficiently accurate for discussion purposes here.

6.4.1 Emissions guides and New Zealand's greenhouse gas inventory

In this section, two approaches were used to compare greenhouse gas emissions estimations from WWTPs:

- **MfE 2019 Measuring Emissions Guide (MEG)**: New Zealand's detailed guide to measuring emissions for organisations (Ministry for the Environment 2019a).
- **NGER 2017-18 Guidelines**: NGER technical guidelines in Australia (Australian Government 2017)[63]. The so-called 'Method 1' for domestic wastewater handling in the NGER technical guidelines in Australia was used here, being the nearest equivalent to the MfE 2019 MEG approach.

These two methods are similar but differ on points of detail. Both methods reference descriptions of emissions sources provided in the *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006)[64]. The MEG is aligned with *ISO 14064-1:2018* and *the GHG Protocol Corporate Accounting and Reporting Standard*. The estimation methods in the Australian Government's NGER guidelines are based on those used by the Australian Department on the Environment (at the time) in preparing the government's annual submission to the United Nations Framework Convention on Climate Change (UNFCCC) in the *National Inventory Report*. The NGER Guidelines also have provision for alternative methods (so-called 'Method 2' or 'Method 3' for domestic wastewater handling). These methods required more detailed data inventories from WWTPs, and the merits of these methods were briefly discussed.

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[62] Estimate for Australia based on weighted average of WWTP energy use from WSAA benchmarking study (de Haas et al. 2018) and quarterly update of Australia's national greenhouse gas inventory to March 2018 (Australian Government 2018)

[63] An update to the NGER Determination was published by the Australian Government was recently published (July 2020) but the amendments therein have not been included in this review.

[64] It is important to note that in 2019 the IPCC published 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, including Volume 5, Waste that covers wastewater (both domestic and industrial). These IPCC 2019 Refinement Guidelines include a number of revisions around approach and emission factors that are relevant to the discussion in this report. Reference is made to the IPCC 2019 Refinement Guidelines in Section 5.10 below. However, the IPCC 2019 Refinement Guidelines approach and emission factors were not used in the estimated methods compared for this report since they had not been incorporated in the New Zealand detailed guide to measuring emissions for organisations (Ministry for the Environment 2019a), nor the NGER 2017-18 Guidelines (Australian Government 2017).

In New Zealand, the MfE 2019 MEG forms part of greenhouse gas inventory reporting at national scale (Ministry for the Environment, 2019b, 2020). In this report, reference is made to the greenhouse gas inventory up to 2017[65] (Ministry for the Environment, 2019b).

Both the MfE 2019 MEG and NGER 2017-18 Guidelines include emission factors for grid electricity, which differ regionally according to the energy sources powering the grid. In the national greenhouse gas inventory report, emissions due to grid electricity use for wastewater treatment are included in the national total for energy, but not separately reported for wastewater treatment. The direct emissions for wastewater treatment and effluent discharge are reported in national inventory (Section 5D), with recognition of uncertainties in the activity data (i.e. WWTP inventory) and a number of emission factors.

6.4.2 Emissions scopes

Consistent with the IPCC guidelines (IPCC 207, 2019), the dominant greenhouse gas emissions (GHG) from WWTPs are methane (CH_4) and nitrous oxide (N_2O) with the latter being mostly associated with higher levels of treatment such as biological nutrient removal processes. For owners and operators of WWTPs (e.g. water utilities, local councils), these are classified as direct (i.e. Scope 1) emissions associated with wastewater handling and treatment. These are the emissions considered for discussion purposes in this section of the report.

When comparing the MfE 2019 MEG and NGER 2017-18 Guidelines, it should be noted that there are differences in points of detail between the approaches for estimating emissions due to wastewater handling (treatment and discharge). For example, the MfE 2019 MEG includes provisions for emissions from septic tanks whereas the NGER 2017-18 Guidelines do not. In New Zealand, it is estimated that septic tanks serve a significant portion of the population (approximately 10% of total). Another example in respect of N_2O emissions. The MfE 2019 MEG does not distinguish N_2O that is potentially produced in the treatment process itself, but rather allocates all the N_2O emissions to effluent discharged (i.e. using one emission factor, as a fraction of nitrogen discharged per capita via the wastewater to the WWTP). The NGER 2017-18 Guidelines aim to distinguish N_2O emissions associated with 'secondary treatment' in the WWTP from those associated with (treated) effluent discharge, using respectively different emission factors and taking into account the receiving water environment[66]. The sum of the N_2O emissions associated with secondary treatment and effluent discharge are reported as Scope 1 under the NGER Guidelines.

Other Scope 1 emissions that might be associated with WWTPs might include fossil fuel use (e.g. by vehicles directly used for plant operation and maintenance, for standby power generation, or heating) or refrigerant use (e.g. hydrofluorocarbons or sulfur hexafluoride) for refrigeration units, air conditioners and heat pumps. However, the emissions from fuel and/or refrigerant use directly related to WWTP operations are typically very small relative to those for CH_4 and N_2O. For this reason, fuel and refrigerant use have not been further considered in this section of the report.

Scope 2 emissions are indirect emissions associated with electricity purchased from a national grid. Since grid electrical energy consumption is significant for most WWTPs, Scope 2 emissions are usually included in GHG emissions inventories for a WWTP but are separately listed. For comparison against Scope 1 (CH_4 and N_2O), Scope 2 emissions have been considered in this section of the report. It is noted that for New Zealand however, a significant

[65] The greenhouse gas inventory up to 2018 (Ministry for the Environment, 2020) was not published at the time the calculations were undertaken that underpin this report.
[66] Enclosed waters (including rivers), estuarine waters and open coastal waters (ocean). Open coastal waters have zero N_2O emission factor under NGER Guidelines. The accounting issues around GHG emissions from the oceans and international waters is a matter to be resolved by the IPCC.

proportion of our electricity supply is derived from renewable sources so emission are typically significantly less than for similar Australian plants for example.

Scope 3 emissions are other indirect emissions that are expected to be reported elsewhere in the economy as direct emissions. Depending on the reporting and financial boundaries for a given organization (eg, a water utility operating one or more WWTPs), some emission sources may be either Scope 1 or Scope 3. Reporting of Scope 3 emissions is voluntary for most organisations. Examples of Scope 3 emission sources include:

- Transmission and distribution losses associated with grid electricity;
- Freight transport (including chemicals consumed at a WWTP or biosolids produced and removed from a WWTP);
- Materials production (including chemicals produced outside a WWTP boundary but consumed at the WWTP); and
- Waste (including transport and disposal of biosolids or other solid waste products from a WWTP, if a waste contractor is responsible).

Scope 3 emissions have not been included in this section of the report.

6.4.3 Total emissions

In New Zealand, as shown in Figure 88, it is estimated that direct Scope 1 emissions from domestic wastewater treatment in total contribute a small proportion (approximately 0.3% to 0.5%)[67] of the total gross GHG emissions in New Zealand. Similar proportions have been reported in other countries, for example Australia (Australian Government 2018). Based on the magnitude of emissions, other sectors might have a greater opportunity to contribute to GHG reduction at the national scale[68].

The Scope 2 emissions, associated with grid electricity use, for New Zealand WWTPs is estimated to be in the order of 21 kilotonnes/ annum CO_2-e (i.e. around one-tenth or less of the WWTP direct emissions)[69]. Scope 2 emissions are reported as direct CO_2 emissions by the electricity generators that burn fossil fuels, and as such will be included as part of the Energy sector in the national total gross emissions reported for New Zealand. However, it is useful to note that New Zealand's Scope 2 emission factor for grid electricity is relatively low (0.0977 kgCO_2-e/ kWh) because a large proportion of the nation's electricity comes from renewable energy sources (e.g. hydro). By comparison, a country with electricity generated predominantly from black thermal coal will have a Scope 2 emission factor around 1 kgCO_2-e/ kWh.

There is less scope in New Zealand, therefore, to significantly impact emissions through choosing a non-fossil fuel derived electricity source.

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[67] Uncertainties are associated with the underlying WWTP activity data and a number of emission factors for CH_4 and N_2O.

[68] By comparison, according to Ministry for the Environment (2019b), in 2017: the Waste sector contributed 5% (including domestic, 0.32% and industrial wastewater, 0.13%), and Industrial Processes and Product Use contributed 6%, whereas the Energy sector and Agriculture sector respectively contributed 41% and 48% of the national total gross greenhouse gas emissions. (Gross emissions do not include offsets due to Land Use, Land-use Change and Forestry).

[69] The estimate of 21 kt CO_2-e annum Scope 2 emissions was derived in this study by extrapolation of WSAA benchmarking energy data (de Haas et al. 2018) to New Zealand WWTPs, based on available inventory data, estimated equivalent population loading and type of treatment process. Previous estimates by MfE (Chris Bean, communication with GHD, 2020) suggested Scope 2 emissions for New Zealand WWTPs in the range 30 to 40 kt CO2-e/annum. These estimates are of the same order as those from this study. The differences are likely attributable to the limitations of the available inventory data, assumptions and/or extrapolations made (e.g. from WSAA study).

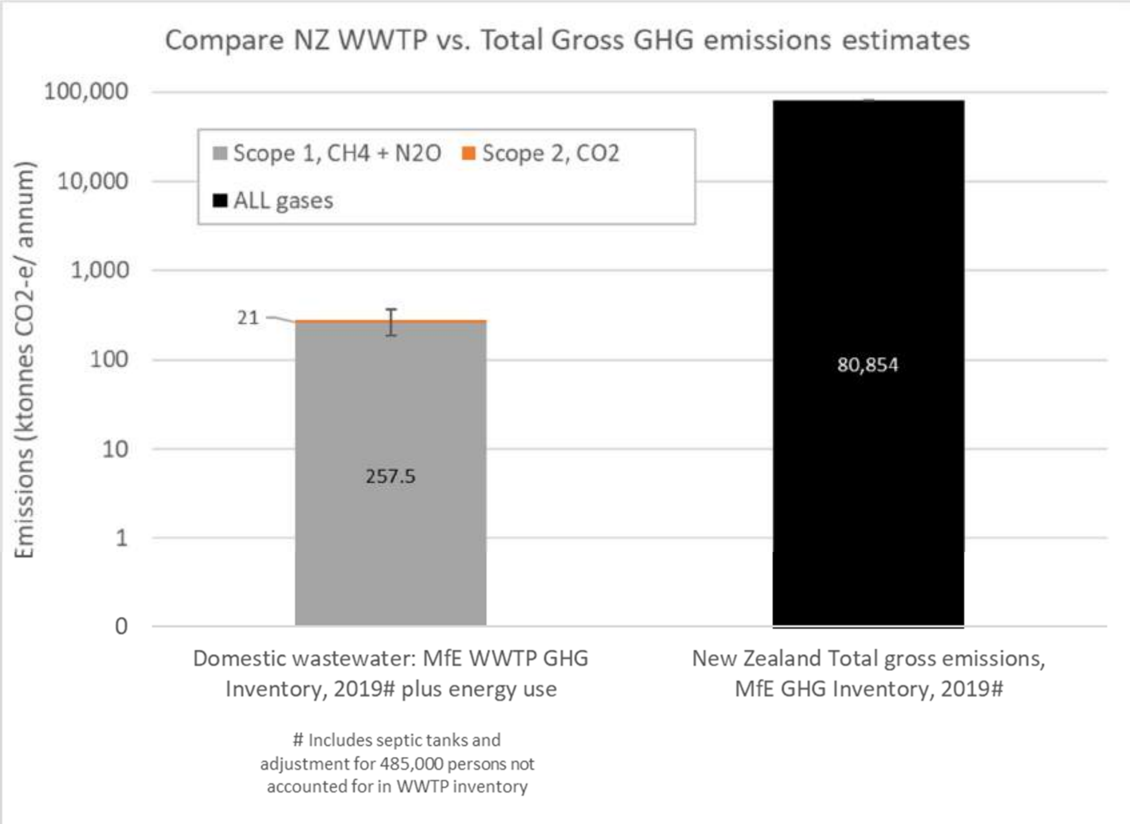

Figure 88: MfE Domestic wastewater estimates compared with total gross emissions for New Zealand (Ministry for the Environment, 2019b)

Note for Figure 88: Scope 1 Domestic wastewater includes both WWTPs and septic tanks, which account for between approximately 10% and 32% of Scope 1 emissions, depending on the emission factors adopted. The Scope 2 CO_2-e emissions result from estimated energy consumption at WWTPs, and is reported as part of the energy sector in the national GHG inventory

6.4.4 Comparing methods

Internationally there are multiple methods for how emissions are estimated. The method for estimating Scope 1 (CH_4 and N_2O) emissions associated with domestic wastewater treatment (or handling), as described in the New Zealand detailed guide to measuring emissions for organisations (Ministry for the Environment 2019a), was reviewed in detail for this study and compared to the equivalent method (for domestic wastewater handling) in the NGER technical guidelines in Australia (Australian Government 2017).

The differences between the New Zealand measuring emissions guide and Australian NGER guidelines are illustrated in the results from the comparison for this study, as summarised in Figure 89 and discussed in detail in Appendix A. The results highlight that the methods give similar CH_4 and N_2O emissions estimates, although the NGER 2017-18 Guidelines gave a higher proportion of CH4 and a lower proportion of N2O, relative to the MfE 2019 MEG. This is largely attributable to the differences in N_2O emission factors, including the distinction between ‘secondary treatment’ vs. ‘effluent discharge’ under the NGER Guidelines. For example, some of the largest WWTPs in New Zealand discharge to the ocean, which would be designated as ‘open coastal waters’ under the NGER Guidelines, with a zero N_2O emission factor. By comparison, under the MfE MEG (2019), all WWTPs are allocated N_2O emissions for effluent discharge at the emission factor (effectively 0.5% of influent total N load).

Appendix A gives additional detail on how the further breakdown of CH_4 and N_2O emissions estimates according to plant type can influence the emissions calculations, based on the method being used.

It is understood that there is a challenge in relation to reducing GHG emissions through reduced electrical energy use (associated with Scope 2 emissions) and the expectation of increased levels of treatment that potentially result in an increase in nitrous oxide emissions (Scope 1 emissions). This trade-off is currently not reflected in typical GHG reporting protocols.

Most reporting protocols (including IPCC Guidelines and the NGER 2017-18 Guidelines) rely on a single emission factor for nitrous oxide from all wastewater ('secondary') treatment processes, which is arguably a significant shortcoming (Yuan and de Haas, 2019). This issue hinges on the inherent variability of N_2O emissions from WWTPs, and a lack of international consensus or guidance on N_2O emissions factors for different processes. Effectively, under current reporting protocols, there is no driver to reduce N_2O emissions factors from wastewater treatment processes.

Similarly, the MfE 2019 MEG, allocates N_2O emissions for WWTPs only to the effluent discharge and, for this purpose, applies single emission factor relative to influent total N load. The NGER 2017-18 Guidelines applied a similar emission factor[70] for effluent discharge to 'enclosed waters' (e.g. creeks and rivers) as that for 'secondary treatment', a lower factor for estuarine receiving waters and zero for open coastal waters (oceans).

[70] The latest revision of NGER Determination (Australian Government, 2020) applies lower emission factors for enclosed water and estuarine waters than previous NGER Guidelines.

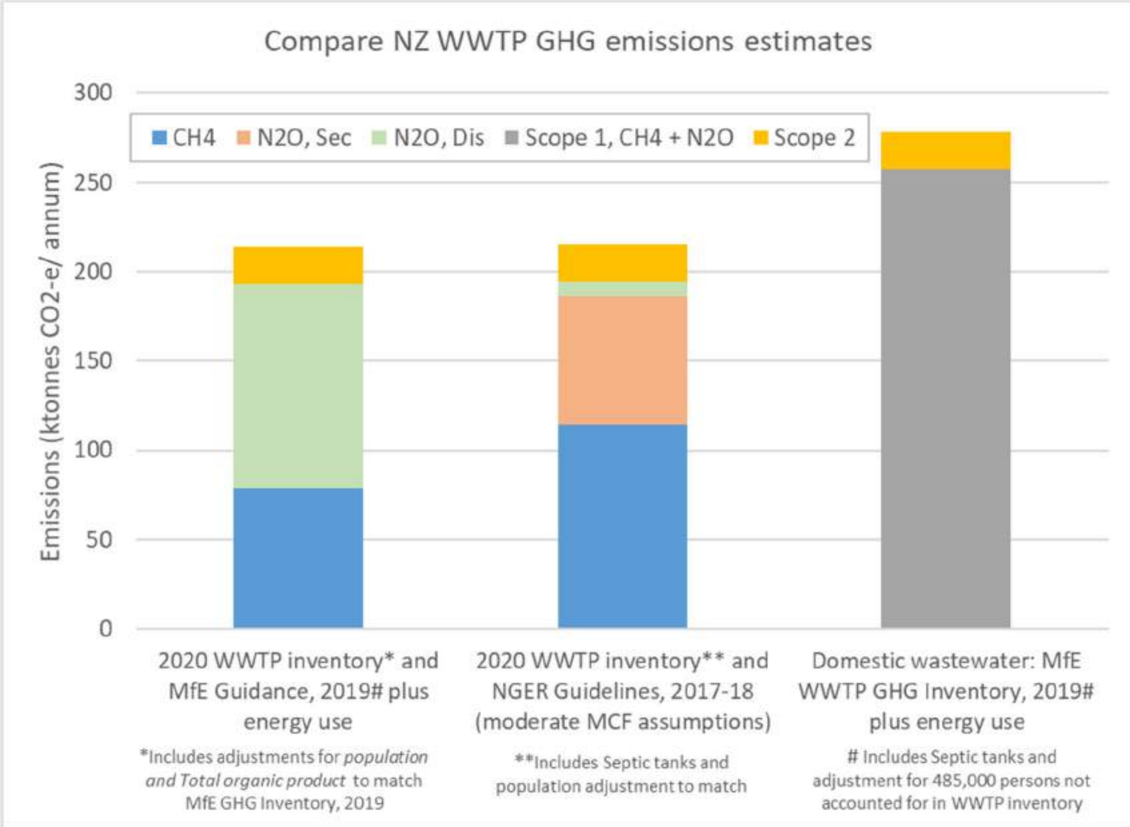

Figure 89: Breakdown of emissions for New Zealand WWTPs, comparing different estimation methods. 'Sec' denotes *Secondary treatment*; 'Dis' denotes *Effluent discharge*.

Note for Figure 89: Scope 1 Domestic wastewater includes both WWTPs and septic tanks, which account for between approximately 10% and 32% of Scope 1 emissions, depending on the emission factors adopted. The Scope 2 CO_2-e emissions result from estimated energy consumption at WWTPs, and is reported as part of the energy sector in the national GHG inventory.

6.4.5 Way forward

Interviews with the NZ wastewater sector and Water NZ have highlighted that an appropriate and consistent approach to GHG testing, measurement and reporting that meets the industry's needs is yet to be confirmed in New Zealand, as discussed in more detail in Appendix A. This can pose an issue when considering future strategies to manage GHG emissions.

As such the following ideas, summarised from the detailed review in Appendix A, can be considered when planning for potential GHG emissions reduction for WWTPs in New Zealand:

- **Think big first** - In New Zealand there are six large WWTPs which are estimated to contribute between 35 and 42% of the total Scope 1 (CH_4 and N_2O) emissions, depending in the reporting method applied. This was determined using methods that considered plant-specific treatment types. These plants provide a good opportunity, with reasonably good economies of scale, to reduce methane emissions. This is less likely to be the case for plants serving smaller more diffuse populations.
- **Refining the methodology** - The current MfE 2019 MEG for reporting GHG emissions from wastewater treatment is reasonably straightforward and aligned with similar protocols around the world, but is relatively simplistic as it was authored to provide basic estimates for small-scale waste generators, not WWTP-scale waste processers. There is an opportunity for the method to be improved and more accurately account for the CH_4 and N_2O emissions produced from different treatment method as well as effluent N_2O emissions. The NGER Technical Guidelines in Australia provide a good starting point for consideration in New Zealand.
- **Decide how to account for septic tanks** - At present, a significant proportion (around 10%) of New Zealand's population is served by wastewater that is treated and disposed of using septic tanks, largely in rural areas. Cumulatively, these systems contribute about 40% of the domestic wastewater emissions according to the national greenhouse inventory and therefore further investigation into improved methods to measure and account for septic tank emissions (CH_4, and N_2O if any) in the New Zealand context would be useful. Relatedly it would also be useful to determine if there are existing or new septic tank technologies with lower emissions.
- Keep in mind the overall objectives – In aiming to minimise GHG emissions associated with WWTPs, there are three main overall objectives:
  - (1) Minimise the potential for release of uncombusted methane to the atmosphere.
  - (2) Minimise the potential for generation of nitrous oxide, both within the plant and in the discharged effluent.
  - (3) Consider and weigh up potentially perverse outcomes whereby process optimisation (e.g, with a view to improving nitrogen removal from the treated effluent and/or reducing electrical energy consumption) leads to higher GHG emissions (refer to Appendix A for examples).

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APPENDICES

APPENDIX A
GREENHOUSE GAS EMISSION

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1. GHG Emissions

This section presents a description of the scope of greenhouse gas (GHG) emissions generated by the domestic waste water sector in the New Zealand context and compares it with the approach taken by the Australian Government. It discusses the overall contribution of the wastewater sector to emissions at a national level and examines two approaches to the measurement and reporting of these emissions. The assessment considers emissions calculations based on a population data set and also relative contribution by treatment plant type[1].

This section includes key considerations for the measurement and management of GHG emissions in the future.

1.1 Scope of emissions

Consistent with IPCC guidelines (IPCC, 2007, 2019), the detailed guide to measuring emissions for organisations in New Zealand (Ministry for the Environment 2019) recognises the dominant greenhouse gas emissions (GHG) from wastewater treatment plants (WWTPs) as methane (CH_4) and nitrous oxide (N_2O). For owners and operators of WWTPs (eg, water utilities, local councils), these are classified as direct (ie, Scope 1) emissions associated with wastewater handling and treatment. These are the emissions considered for discussion purposes in this section of the report.

Other Scope 1 emissions that might be associated with WWTPs might include fossil fuel use (eg, by vehicles directly used for plant operation and maintenance, for standby power generation, or heating) or refrigerant use (eg, hydrofluorocarbons or sulfur hexafluoride) for refrigeration units, air conditioners and heat pumps. However, the emissions from fuel and/or refrigerant use directly related to WWTP operations are typically small relative to those for CH_4 and N_2O. For this reason, fuel and refrigerant use have not been included in this section of the report.

Scope 2 emissions are indirect emissions associated with electricity purchased from a national grid. Since grid electrical energy consumption is significant for most WWTPs, Scope 2 emissions are usually included in GHG emissions inventories for WWTPs, but are separately listed. For comparison against Scope 1 (CH_4 and N_2O), Scope 2 emissions have been considered in this section of the report.

Scope 3 emissions are other indirect emissions that are expected to be reported elsewhere in the economy as direct emissions. Depending on the reporting and financial boundaries for a given organization (eg, a water utility operating one or more WWTPs), some emission sources may be either Scope 1 or Scope 3. Reporting of Scope 3 emissions is voluntary for most organisations. Examples of Scope 3 emission sources include:

- Transmission and distribution losses associated with grid electricity;
- Freight transport (including chemicals consumed at a WWTP or biosolids produced and removed from a WWTP);

[1] The calculations and results presented in this section were developed using available inventory data for New Zealand WWTPs. It is recognised that this inventory has been in development in recent years and might contain some inconsistencies or errors. However, since the same inventory was used for the two GHG estimation approaches compared, the data was considered sufficiently accurate for discussion purposes here.

- Materials production (including chemicals produced outside a WWTP boundary but consumed at the WWTP); and
- Waste (including transport and disposal of biosolids or other solid waste products from a WWTP, if a waste contractor is responsible).

Scope 3 emissions have not been included in this section of the report.

1.2 Approach

A two-fold approach has been taken for discussion purposes in this section of the report: The discussion focused on two methods for estimating GHG emissions from WWTPs treating predominantly domestic wastewater; and testing of those methods and an assessment of their similarities, key differences possible benefits.

Interviews with the NZ wastewater sector and WaterNZ have highlighted that an appropriate and consistent approach to GHD testing, measurement and reporting that meets the industry's needs is yet to be confirmed in New Zealand. The use of the current MfE guidance in New Zealand is compared below with similar guidance produced by the Australian government.

1.2.1 Methods

Firstly, the method for estimating Scope 1 (CH_4 and N_2O) emissions associated with domestic wastewater treatment (or handling), as described in the New Zealand detailed guide to measuring emissions for organisations (Ministry for the Environment 2019a), was reviewed in detail. It was compared to the equivalent method (so-called 'Method 1' for domestic wastewater handling) in the NGER technical guidelines in Australia (Australian Government 2017)[2].

The two methods are similar, but differ on points of detail (refer to Section 1.3.2, Table 3 and Table 4). Both methods reference descriptions of emissions sources provided in the *IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). The New Zealand guide is aligned with *ISO 14064-1:2018* and *the GHG Protocol Corporate Accounting and Reporting Standard*. Both the New Zealand and the Australian guidelines are based on those used by the respective national government departments in preparing the government's annual submissions to the United Nations Framework Convention on Climate Change (UNFCCC) in their respective *National Inventory Report*. The NGER Guidelines also have provision for alternative methods (so-called 'Method 2' or 'Method 3' for domestic wastewater handling). These methods required more detailed data inventories from WWTPs, and the merits of these methods were briefly discussed.

It is important to note that in 2019 the IPCC published *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, including *Volume 5, Waste* that covers wastewater (both domestic and industrial). These IPCC *2019 Refinement Guidelines* include a number of revisions around approach and emission factors that are relevant to the discussion in this report. Reference is made to the IPCC *2019 Refinement Guidelines* in Section 1.4 below. However, the IPCC *2019 Refinement Guidelines* approach and emission factors were not used in the methods tested for this report (refer to Section 1.2.2) since they had not been incorporated in the New Zealand detailed guide to measuring emissions for organisations (Ministry for the Environment 2019a), nor the NGER 2017-18 Guidelines (Australian

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[2] As at the time of drafting calculations for this report (March-April 2020), the 2017-18 NGER Technical Guidelines were the most recent in use in Australia, as published on the relevant Australian Government Dept. of Industry, Science, Energy and Resources website https://publications.industry.gov.au/publications/climate-change/climate-change/climate-science-data/greenhouse-gas-measurement/nger/technical-guidelines.html. Since then (July 2020) a revision of the NGER Determination has been published by the Australian Government. These latest amendments have not been included in this report.

Government 2017). Both sets of these guidelines depend on their respective National Inventories, which in turn depend on decisions at the UNFCCC which has not yet adopted the IPCC *2019 Refinement Guidelines*.

1.2.2 Testing

Secondly, as a way of testing and discussing GHG emissions estimates using the two methods mentioned above, a sample dataset containing a basic inventory of New Zealand WWTPs was used. The data was originally sourced from the currently available Water NZ database and, as far as possible, was updated to 2020 for wastewater treatment plants treating predominantly *domestic wastewater*[3]. This dataset was used to apply the two GHG estimation methods, named with abbreviations below as follows:

- **MfE 2019 MEG**: New Zealand detailed guide to measuring emissions for organisations (Ministry for the Environment 2019a).
- **NGER 2017-18 Guidelines**: NGER technical guidelines in Australia (Australian Government 2017 (refer to footnote 1 on page 32 **Error! Bookmark not defined.**).

The results from the above-mentioned two methods were compared with those published in *New Zealand's Greenhouse Gas Inventory,* using data for the year 2017 (Ministry for Environment 2019b), abbreviated below as **MfE WWTP GHG Inventory, 2019. The assessment undertaken provides context in the form of the Wastewater Sector's relative contribution to the National GHG emissions estimates and provides commentary on the potential implications of policy which aims to manage and reduce these emissions.** Note that the estimates for domestic wastewater as reported in the GHG Inventory include estimates for septic tanks, which contribute about 40% of the total for domestic wastewater.

1.2.3 Types and Sizes of WWTP

In discussing GHG emissions estimates, it is useful to group WWTPs according to similarities in the types of treatment processes applied, and the size of the treatment plants (ie, nominally how many persons served by each plant). The benchmarking approach[4] applied by WSAA and its members (de Haas *et al.,* 2018) was followed. The classification of types of treatment plant was based on the description of the plants in the inventory dataset (refer to Section 1.2.2). Table 1 lists the types of WWTP in the classification.

Table 1: Types of wastewater treatment plant (based on de Haas et al., 2018)

Types	Short description
Type 1	Primary sedimentation tanks, followed by secondary treatment (e.g. Activated sludge) with anaerobic digestion of sludge, biogas capture with cogeneration
Type 2	Same as Type 1, but without cogeneration from biogas
Type 3	All extended activated sludge plants, including membrane bioreactors and those with aerobic sludge digestion

[3] Industrial wastewater treatment plants were not included in the assessment for this section of the report. To the extent that commercial waste, or trade waste, is co-treated with domestic wastewater, those wastes are included in the dataset. Refer to the discussion of results in Section 1.3, for example, in relation to total organic waste (product) that forms part of the WWTP inventory used to estimate GHG emissions.

[4] The last round of WWTP energy benchmarking was conducted in 2015-16 by GHD on behalf of Water Services Association of Australia and the Intelligent Water Network. It covered 245 no. WWTPs, mainly in Australia, but included two WWTPs in the Auckland region of New Zealand.

Types	Short description
Type 4.1	Trickling filters[5]
Type 4.2	Trickling filters and activated sludge combinations
Type 5.1	Aerated lagoons or aerated oxidation ponds
Type 5.2	Unaerated lagoons or unaerated/ facultative oxidation ponds and/or wetlands
Type 6	Rotating biological contactors or other recirculating on-site systems including textile or similar media filters
Other	All other types, including septic tanks

Similarly, the size of treatment plant was classified according to the nominal population served by each WWTP, and the size classes listed in Table 2.

Table 2: Size Classes of wastewater treatment plant (based on de Haas et al., 2018)

Size Class (SC)	Range
SC1	≤ 1000 EP
SC2	1001 - 5000 EP
SC3	5001 - 10,000 EP
SC4	10,001 - 100,000 EP
SC5	>100,000 EP

1.3 Testing results

1.3.1 Wastewater treatment vs. national gross emissions

Figure 1 shows the **MfE WWTP GHG Inventory, 2019** values for domestic wastewater treatment (including septic tanks)[6] plotted against the total gross emissions[7] for New Zealand (all gases) in the same reporting period (2017). Also shown is the estimated Scope 2 emissions, based on test dataset used for this report (refer to Section 1.2.2) and the average results for specific energy use by plant type and size from the WSAA benchmarking reference study (Section 1.2.3).

By these estimates, the results in Figure 1 illustrate that direct emissions from domestic wastewater treatment contributes a small proportion (approximately 0.3%) of the total gross GHG emissions in New Zealand. Similar proportions have been reported in other countries, for example Australia (Australian Government 2018). The error bar in figure illustrates the uncertainty in the domestic wastewater direct emissions. However, including uncertainty at the highest range, the domestic wastewater direct emissions are unlikely to exceed approximately 0.5% of the total gross GHG emissions in New Zealand.

The Scope 2 emissions, associated with grid electricity use, for New Zealand WWTP were also estimated[8] and found to be in the order of 21 kilotonnes/ annum CO_2-e (ie, around one-tenth or less of the WWTP direct emissions). These Scope 2 emissions will be reported as direct CO_2 emissions by the electricity generators in New Zealand that burn fossil fuels, and as such will be included in the national total gross emissions under the energy sector. However, it is useful to

[5] Note: Trickling filter plants usually have primary sedimentation tanks. If these plants also have anaerobic digestion of sludge, with biogas capture and cogeneration, then the plants were classified as Type 1 by default

[6] Ministry for Environment 2019b, Table 7.5.1, p 354.

[7] Ministry for Environment 2019b, Table ES 3.1, p 5.

[8] Estimates derived in this study by extrapolation of WSAA benchmarking energy data (de Haas et al. 2018) to New Zealand WWTPs, based on available inventory data, estimated equivalent population loading and type of treatment process.

note that New Zealand's Scope 2 emission factor for grid electricity is relatively low (0.0977 $kgCO_2$-e/ kWh)[9] because a large proportion of the nation's electricity comes from renewable energy sources (e.g. hydro). By comparison, a country with electricity generated predominantly from black thermal coal will have a Scope 2 emission factor around 1 $kgCO_2$-e/ kWh.

Key messages from Figure 1 are as follows:

- Efforts to reduce GHG emissions from WWTPs treating predominantly domestic wastewater need to be tempered by an understanding of the relatively small contribution that this sector makes to the national greenhouse inventory. Therefore, capital expenditure on WWTP asset renewal programs that have a GHG-reduction thrust should consider the overall justification for such expenditure, including other benefits (eg, improvement in water quality of treated effluent).
- Efforts to reduce electrical energy use (ie, Scope 2 emissions) at WWTPs (eg, through process re-engineering) that potentially lead to an increase in direct emissions (ie, Scope 1 CH_4 and/or N_2O) need to be carefully considered, given that the Scope 2 emissions are likely to be approximately an order of magnitude lower than the Scope 1 emissions.

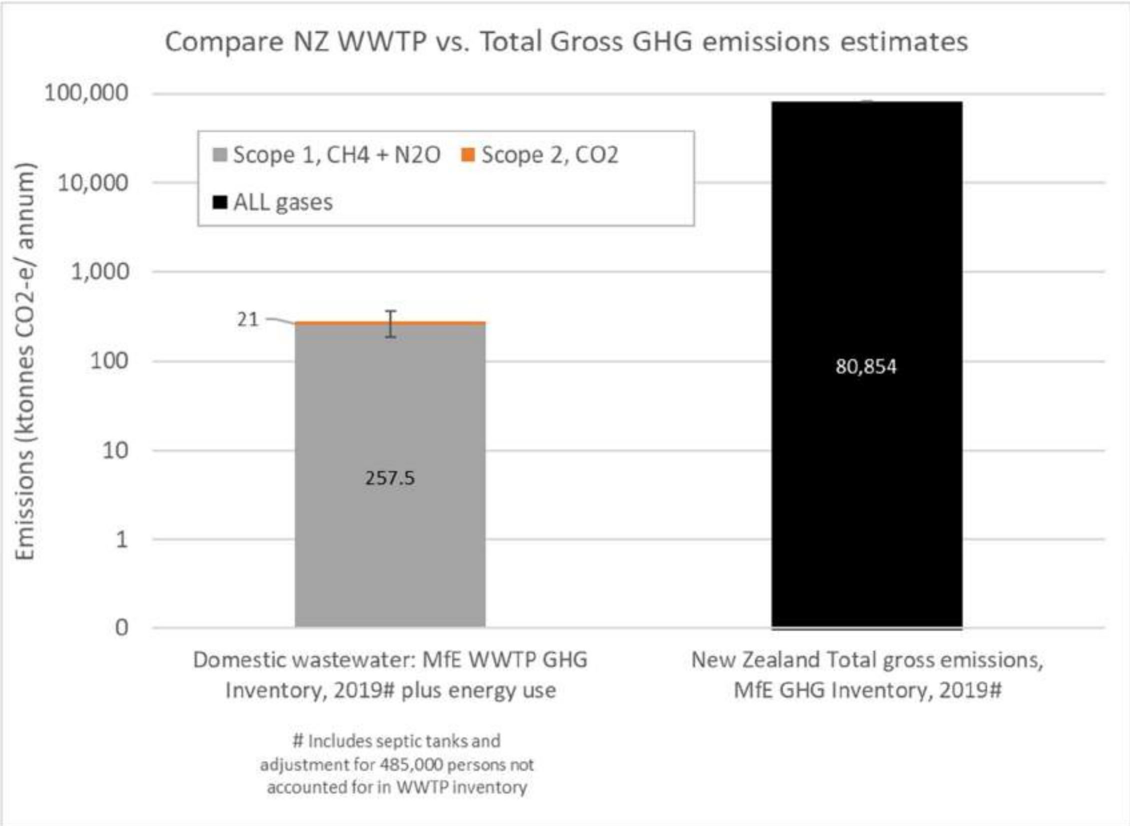


Figure 1: MfE WWTP GHG Inventory estimates compared with total gross emissions for New Zealand (Ministry for the Environment, 2019b).

1.3.2 Methodology for estimating WWTP emissions

As noted in Section 1.2.2, two methods for calculating WWTP GHG were compared for discussion purposes in this report, namely:

- **MfE 2019 MEG** (Ministry for the Environment 2019a); and

[9] Ministry for Environment 2019a, Table 9, p34.

- **NGER 2017-18 Guidelines** (Australian Government 2017.

To understand the differences and limitations of the two methods, it is necessary to briefly compare and contrast the respective approaches for estimating direct emissions (ie, Scope 1 CH_4 and/or N_2O), as outlined below.

It is noted that the MfE 2019 MEG was not intended to be used to estimate WWTP-level emissions, and that the MfE GHG inventory does consider more detail that was omitted from the MEG. The more detailed approach used in the GHG inventory was not evaluated in this report.

Methane (CH_4)

Refer to Table 3. The key points here are as follows:

- Both methods are relatively simplistic, being primarily based on population data and assumptions of organic load (BOD or COD) per capita rather than actual wastewater inventory data (e.g. flow and measured BOD or COD loads). The **NGER 2017-18 Guidelines** do have provision for alternative methods (Methods 2 or 3), which are based on actual measured raw wastewater inventory data, whereas **MfE 2019 MEG** does not.
- Although the two methods use different parameters as a measure of total organic waste load (BOD vs. COD, refer to definitions Table 3), the ratio of the allowance per capita (COD/ BOD = 2.25 from Table 3) is reasonable for a typical domestic/ commercial wastewater.
- When expressed in equivalent units, the two methods have a similar conversion factor to maximum methane potential. However, based on a COD/ BOD ratio of 2.25 (see above), the **MfE 2019 MEG** value is slightly more conservative (ie, 0.625 kg CH_4/ kg BOD vs. 0.563 kg CH_4/ kg BOD equivalent in the **NGER 2017-18 Guidelines**).
- **MfE 2019 MEG** applies one weighted average value for the Methane correction factor (MCF) to all WWTPs. The value is relatively low, implying that the guidance considers most WWTPs in New Zealand, on balance, to have predominantly 'managed aerobic treatment' (i.e. tending to the IPCC default MCF value of zero for such systems). It is noted that the MfE 2019 MEG is based on the average from the MfE GHG inventory, which prescribes an MCF between 0 and 0.65 to different treatment types, from which the weighted average is derived. The **NGER 2017-18 Guidelines** require each WWTP process to be considered, and for the MCF to be allocated (from the IPCC default list of values – refer to Table 3) on case-by-case basis, for the mainstream (liquid) and sludge treatment streams respectively. In this respect, the **NGER 2017-18 Guidelines** are more conservative and likely to lead to higher estimates of methane emissions, subject to the MCF values chosen for each WWTP.
- Conversely, the **MfE 2019 MEG** makes no provision for subtraction of organic loads for sludge or effluent that leaves the WWTP, whereas the **NGER 2017-18 Guidelines** do make such provision. In this respect, the **MfE 2019 MEG** is more simplistic and likely to lead to comparatively high estimates of methane emissions. It is noted that the MfE 2019 MEG was authored to provide basic estimates for small-scale waste generators, not WWTP-scale waste processers.
- Overall, the **MfE 2019 MEG** lacks detail in respect of WWTP methane emissions estimation. Without some level of detail (eg, as a minimum, the IPCC default list for types of wastewater treatment process), it will not be possible to distinguish treatment options that have higher or lower methane emissions potentials.

Nitrous oxide (N_2O)

Refer to Table 4. The key points here are as follows:

- Similar to methane (see above), both methods are relatively simplistic, being primarily based on population data. The N_2O methods are based on even more simplistic assumptions of around nitrogen (from protein) average intake per capita, assuming further that all the human nitrogen intake is excreted to the raw wastewater. The **NGER 2017-18 Guidelines** do have provision for alternative methods (Methods 2 or 3), which are based on actual measured raw wastewater inventory data, whereas **MfE 2019 MEG** does not.
- The basic assumptions around protein intake and associated nitrogen content are the same for the two methods compared here. The **MfE 2019 MEG** includes provision for additional correction factors (respectively for non-consumed protein and for industrial and commercial co-discharged protein added to the wastewater). In combination, these factors increase the wastewater nitrogen load by 75% compared with the base load from the population protein consumption.
- The **MfE 2019 MEG** does not have provisions for nitrogen fraction removal via sludge generated in the WWTP (which typically removes around 15% to 30% of the influent nitrogen from the liquid to the solids stream), whereas the **NGER 2017-18 Guidelines** do. However, the **NGER 2017-18 Guidelines** have a higher N_2O emission factor (relative to N *removed*) than the **MfE 2019 MEG,** in which the N_2O emission factor is applied to the influent N load. Overall, taking into account the above-mentioned correction factors for additional protein addition to the wastewater (in the **MfE 2019 MEG**), the two methods are closely similar in terms of N_2O emission factor, when expressed in equivalent terms (i.e. around 0.85% (±0.025%) of influent N load from base population and average human protein intake, without correction for additional loads, assuming an average of 80% N removal from the mainstream liquid treatment process).
- The **NGER 2017-18 Guidelines** include N_2O emission factors for nitrogen in treated effluent discharged to rivers or estuaries, whereas the **MfE 2019 MEG** does not distinguish between the receiving environments. In this respect, the are likely to give somewhat higher N_2O emissions estimates, particularly for river discharge, than the **MfE 2019 MEG.** However, where WWTPs for major cities discharge to the ocean (as in New Zealand), the **NGER 2017-18 Guidelines** will give lower N_2O emissions estimates in total (see below).
- Following the **NGER 2017-18 Guidelines**, regardless of the extent to which a WWTP process removes nitrogen, if it discharges effluent to a river system, it will have similar N_2O emissions estimates for a given population loading (refer to similar emission factors in Table 4 for treatment vs. river discharge).
- The **NGER 2017-18 Guidelines** assume zero N_2O emissions for ocean discharge (because the oceans are considered outside the operational control of a given country[10]). Therefore, if a given plant discharges a given effluent N load to either an estuary (or the ocean), it will have a lower N_2O emissions estimate than an equivalent plant that discharges to a river.
- Both methods have fixed emission factors for the wastewater treatment process. Therefore, neither method distinguishes between different types of treatment process that emit significantly different amount of N_2O for a given site. This means that there is no incentive (under the current estimation methods) for WWTPs to move towards process configurations that emit less N_2O (de Haas 2018; Yuan and de Haas 2019).

[10] The accounting issues around GHG emissions from the oceans and international waters is a matter to be resolved by the IPCC.

It is important to note the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2019) have a revised approach and updated emission factors not reflected in Table 3 or Table 4. There is potential for these revisions to be included in future MfE guidance and NGER guidelines.

Table 3: Comparison of methods for estimation of WWTP methane emissions

Component of GHG estimation method	MfE 2019 MEG	NGER 2017-18 Guidelines Division 5.3.2 'Method 1' Methane released from wastewater handling (domestic and commercial)
Primary inventory data for WWTP	Population served (no. of persons)	Population served (no. of persons)
Total organic waste (TOW) (or product) load calculated from	26 kg BOD/ capita/ year (71 g BOD/ capita/ day) BOD = biological (biochemical) oxygen demand	58.5 kg COD/ capita/ year (160 g COD/ capita/ day) COD = chemical oxygen demand
Conversion factor to maximum methane potential	0.625 kg CH_4/ kg BOD	6.3 kg CO2-e per kg COD (ie, 0.25 kg CH_4/ kg COD)
Correction factor for additional industrial and commercial BOD	Default 1.25 or 1.0 for septic tanks, but varies for several sites	
Global Warming Potential (GWP)	25 kg CO-e/kg CH_4	25 kg CO-e/kg CH_4
Provision for biogas methane capture and combustion/ flaring or transfer out of WWTP	No	Yes (subject to inventory data of biogas volumes metered and minimum 75% test against maximum methane generated from calculation) (Note 2)
Provision for subtraction from total organic waste load portions generated and removed as sludge and/or residual effluent organics	No	Yes
Methane correction factor applied separately to WWTP mainstream liquid treatment and sludge treatment streams	No	Yes
Methane correction factor (MCF)	0.02425 Single constant value applied to all WWTPs ie, the weighted-average methane correction factor (MCF) for wastewater treatment plants in 2016 (based on the MfE 2018 GHG inventory data)	Varies according to type of treatment. IPCC default MCF applied: • managed aerobic treatment: 0 • unmanaged aerobic treatment: 0.3 • anaerobic digester/reactor: 0.8 • shallow anaerobic lagoon (<2 m): 0.2 deep anaerobic lagoon (>2 m): 0.8.
Septic tanks	Same method applied as for WWTP except MCF = 0.4; and correction factor for additional	Not separately considered

Component of GHG estimation method	MfE 2019 MEG	NGER 2017-18 Guidelines Division 5.3.2 'Method 1' Methane released from wastewater handling (domestic and commercial)
	industrial and commercial BOD = 1 (see above)	Same method as for WWTPs applies (Note 1)

Note 1: Small wastewater treatment systems (e.g. septic tanks) are unlikely to trigger thresholds for reporting under the NGER Act in Australia. Septic tanks are included here for comparative purposes only.

Note 2: For testing methods here, under the NGER 2017-18 Guidelines, WWTP Types 1 and 2 were assumed to achieve 85% recovery and combustion of methane (ie, by biogas capture, flaring and/or transfer out).

Table 4: Comparison of methods for estimation of WWTP nitrous oxide emissions

Component of GHG estimation method	MfE 2019 MEG	NGER 2017-18 Guidelines Division 5.3.2 'Method 1' Methane released from wastewater handling (domestic and commercial)
Primary inventory data for WWTP	Population served (no. of persons)	Population served (no. of persons)
Total nitrogen load calculated from	Protein consumption (36 kg/ capita/ year) and fraction of nitrogen in protein (0.16, IPCC default)	Protein consumption (36 kg/ capita/ year) and fraction of nitrogen in protein (0.16, IPCC default)
Correction factor for non-consumed protein added to the wastewater	Default 1.4 (IPCC default)	No
Correction factor for industrial and commercial co-discharged protein into the sewer system	Default 1.25 (IPCC default)	No
Global Warming Potential (GWP)	298 kg CO-e/kg N_2O	298 kg CO-e/kg CH_4
Provision for nitrogen removed with sludge	No (assumed to be zero, IPCC default)	Yes
Provision for nitrogen removed in mainstream treatment process	No (effluent N load assumed equal to influent N load)	Yes

Component of GHG estimation method	MfE 2019 MEG	NGER 2017-18 Guidelines Division 5.3.2 'Method 1' Methane released from wastewater handling (domestic and commercial)
N_2O emission factors applied separately to WWTP mainstream liquid treatment process and effluent (receiving water environment)	No	Yes
N_2O emission factor (EF)	For Effluent discharge: 0.005 kg N_2O-N/kg N (IPCC default) ie, implies 0.5% of influent total N load (see above)	For mainstream treatment process: 4.9 kg CO-e/ kg N ie, implies 1.05% of total N load *removed* or 0.84% of influent total N load if process removes 80% For effluent discharge (kg CO-e/ kg N discharged): • Enclosed waters: 4.7 • Estuarine waters: 1.2 • Open coastal waters (ocean or deep ocean): 0
Septic tanks	Explicitly assumed to emit zero nitrous oxide	Not separately considered Same method as for WWTPs applies (Note 1)

Note 1: Small wastewater treatment systems (e.g. septic tanks) are unlikely to trigger thresholds for reporting under the NGER Act in Australia. Septic tanks are included here for comparative purposes only.

1.3.3 Breakdown of WWTP emissions

Figure 2 shows the breakdown of Scope 1 (CH_4 and N_2O) emissions estimates for New Zealand WWTPs, comparing the **MfE 2019 MEG** and **NGER 2017-18 Guidelines** methods using the test dataset (refer to Section 1.2.2) with the total from the MfE WWTP GHG Inventory (2019b). The estimated Scope 2 emissions (based on the test dataset, and energy benchmarking data - refer to Sections 1.2.2 and 1.2.3) are shown for comparative purposes.

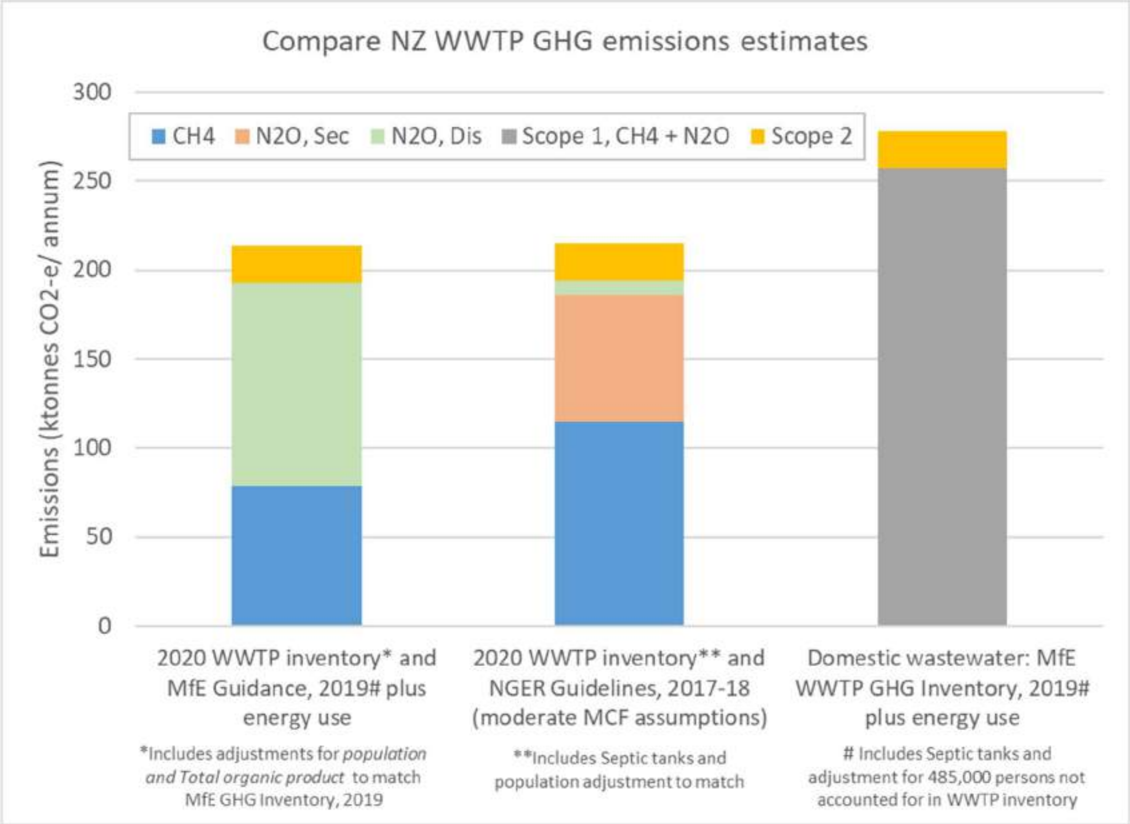


Figure 2: Breakdown of emissions for New Zealand WWTPs, comparing different estimation methods. Refer also to Figure 8 in Section 5.4.4, which shows a breakdown of N2O emissions (secondary treatment vs. effluent discharge).

In total, the two methods gave similar CH_4 and N_2O emissions estimates, although the **NGER 2017-18 Guidelines** gave a higher proportion of CH_4 and a lower proportion of N_2O, relative to the **MfE 2019 MEG**. This outcome is heavily dependent on a number of embedded assumptions, particularly around methane correction factors for different treatment processes (as discussed below) and N_2O emissions factors for effluent discharge to receiving waters (refer to Section 1.3.2).

It is also important to note that for both methods tested here, using both the **MfE 2019 MEG** and **NGER 2017-18 Guidelines**, the emissions estimates shown in Figure 2 included proportional increases such that the connected population the matched the total population numbers in the MfE WWTP GHG Inventory (2019b), as summarized in Table 5. Similarly, for the **MfE 2019 MEG** estimates, the total organic waste (TOW, expressed in tonnes of BOD per annum) was adjusted to match that reported in the MfE WWTP GHG Inventory (2019b) – refer to Table 5. The population and TOW numbers adopted included allowances for rural septic tanks and the disparity is connected ('remainder') population.

Table 5: Comparison of total organic waste and population data underlying MfE 2019 MEG method for emissions estimates

Parameter	Total Organic Waste (Product) (kilotonnes/ annum as BOD)		Population (no. of persons)	
	2020 WWTP inventory* and MfE MEG, 2019	MfE GHG Inventory, 2019#	2020 WWTP inventory* and MfE MEG, 2019	MfE GHG Inventory, 2019#
Connected Population (from WWTP inventory)	132.0	156.7	4,079,194	3,888,400
Rural Septic Tanks Population (Note 1)	15.3	19.0	471,000	471,000
Population Remainder (allowance, from data disparity)	47.90	19.5	294,206	485,000
Total	195.2	195.2	4,844,400	4,844,400
Connected Population (from WWTP inventory)	132.0	156.7	4,079,194	3,888,400

Note 1: from MfE WWTP GHG Inventory (2019b), Table 7.5.2

It is not clear why emissions estimates in Figure 2, based on the test dataset (nominal 2020 WWTP inventory) using both the **MfE 2019 MEG** and **NGER 2017-18 Guidelines**, were lower than those reported in the MfE WWTP GHG Inventory (2019). Further investigation would be required to resolve this. Most likely, the differences are largely attributable to differences in the underlying WWTP inventory data. For example, all estimates for this study accounted for rural septic tanks, but the methodology applied for these systems and associated emission factors have a number of uncertainties.

To illustrate the sensitivity of estimates to underlying assumptions, the effect of the methane correction factor (MCF) in the **NGER 2017-18 Guidelines** can be considered.

In Figure 2, the estimates using **NGER 2017-18 Guidelines** adopted 'moderate' MCF values, namely: MCF = 0 ('managed aerobic treatment' according to IPCC definitions) for unaerated oxidation ponds/ wetlands and 'other' liquid stream treatment processes; and MCF = 0.2 ('shallow anaerobic lagoon' according to IPCC definitions) for the sludge treatment fraction in all types of oxidation pond (i.e., aerated or unaerated/ wetlands)[11].The weighted average[12] MCF applied across all the WWTPs in Figure 2 using the **NGER 2017-18 Guidelines** was 0.13 (compared with the single MCF of 0.02425 for all WWTPs in the **MfE 2019 MEG**). Furthermore, using the **NGER 2017-18 Guidelines,** allowance was made for sludge transfer out of all the plants (including septic tanks), noting that this removes a portion of the organic load that otherwise would add to the estimates of methane generated (refer to Table 3).

In Figure 3, the estimates using **NGER 2017-18 Guidelines** adopted 'conservative' MCF values, namely: MCF = 0.3 ('umanaged aerobic treatment' according to IPCC definitions) for unaerated oxidation ponds/ wetlands and 'other' liquid stream treatment processes; and MCF = 0.8 ('deep anaerobic lagoon' according to IPCC definitions) for the sludge treatment fraction in

[11] Refer to Table 1 for definition of WWTP types.
[12] Weighted according to influent COD load and the fraction treated in the mainstream liquid vs. sludge streams.

all types of oxidation pond (i.e., aerated or unaerated/ wetlands)[13]. The weighted average[14] MCF applied across all the WWTPs in Figure 2 using the **NGER 2017-18 Guidelines** was 0.40. Furthermore, no allowance was made for waste sludge to be generated or removed from the liquid treatment fraction of septic tanks (usually disposed to soil soak-away trenches). Due to these more 'conservative' assumptions, the methane emissions calculated using the **NGER 2017-18 Guidelines** increased by 63 tonnes CO2-e/ annum (compare Figure 2 with Figure 3). The total Scope 1 emissions (CH_4 and N_2O) using the **NGER 2017-18 Guidelines** closely match those of the MfE WWTP GHG Inventory (2019b) in Figure 3.

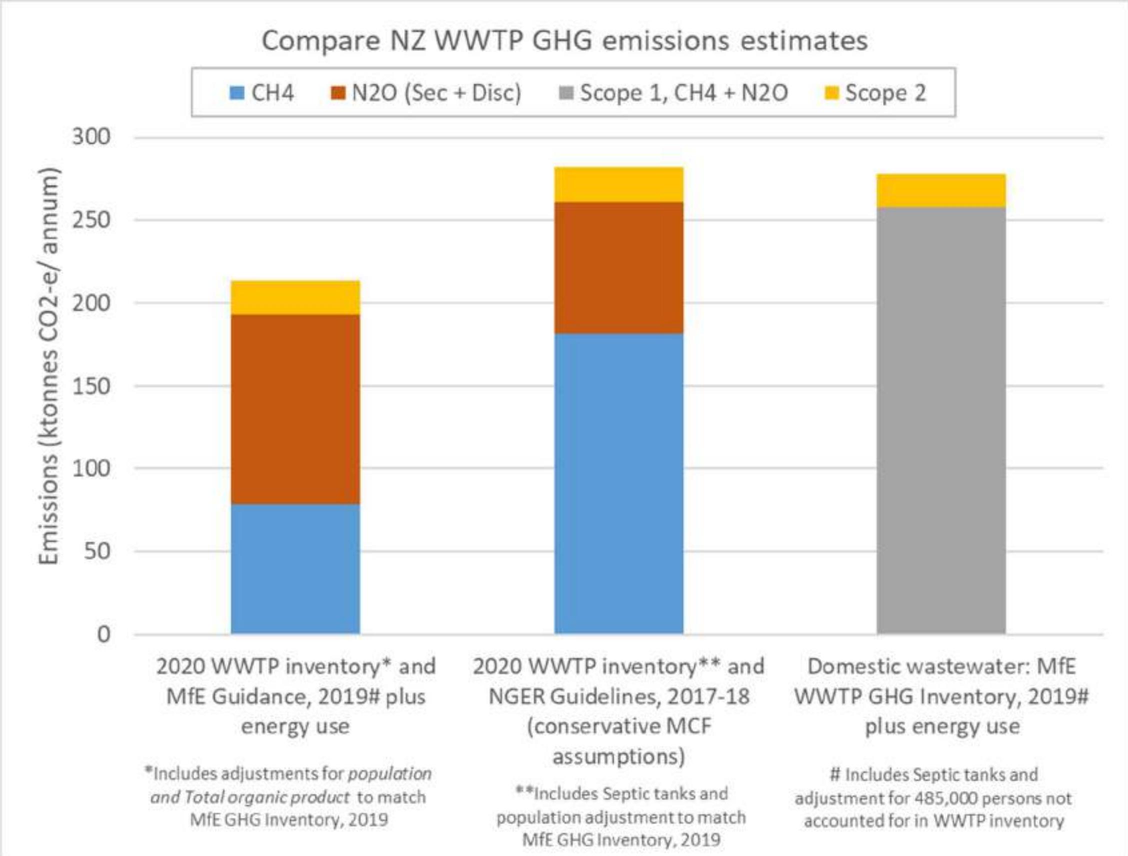


Figure 3: Breakdown of emissions for New Zealand WWTPs, comparing different estimation methods, including *conservative* methane correction factor assumptions using the NGER 2017-18 Guidelines.

1.3.4 Types of WWTP

Figure 4 and Figure 5 respectively show a further breakdown of CH_4 and N_2O emissions estimates according to plant type, using the test dataset (refer to Section 1.2.2) for both the **MfE 2019 MEG** and **NGER 2017-18 Guidelines** methods (the latter using 'moderate' methane correction factors and related assumptions, as per Figure 2, and the discussion in Section 1.3.3)

The error bars in these figures show the indicative aggregated uncertainty ranges of the estimates, using the default uncertainties from the **MfE 2019 MEG**[15]namely: ±40% for methane

[13] The argument here would be that whereas the surface of aerated lagoons might be aerobic, the bottom sludge layers may be anaerobic. Furthermore, many aerated oxidation ponds are preceded by anaerobic/ facultative ponds that remove a significant fraction (indicatively 30-50%) of the influent organic load and therefore increase the potential for methane to be generated.
[14] Weighted according to influent COD load and the fraction treated in the mainstream liquid vs. sludge streams.
[15] Ministry for the Environment (2019b), Table 59

emission factors; ±90% for nitrous oxide emission factors; and ±10% for activity data (both gases). Note, for example, that the higher CH_4 emissions, for the estimates using **NGER 2017-18 Guidelines** that include more conservative assumptions (refer to Figure 3) correspond reasonably closely to the cap of the upper error bar in Figure 4. It is also worth noting that the error bar ranges overlap for the estimates using the **MfE 2019 MEG** and **NGER 2017-18 Guidelines** methods; this implies that the two sets of estimates cannot be relied upon to be statistically different.

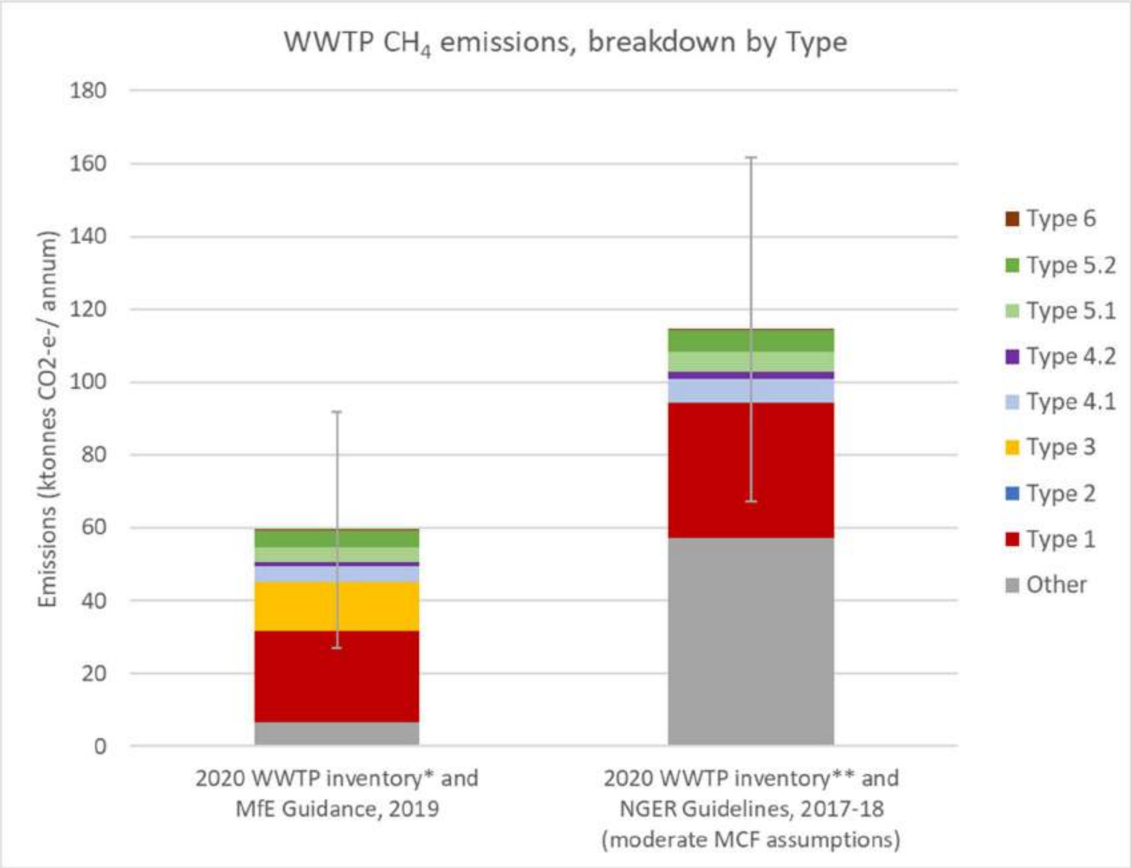


Figure 4: Breakdown of estimated methane emissions from New Zealand WWTPs, according to plant type (as defined in Table 1). Note: 'Other' includes septic tanks.

Some key observations about CH_4 emissions from Figure 4 are as follows:

- The **MfE 2019 MEG** estimates are lower and break down mostly (except for small differences in methane correction factors applied to septic tanks, refer to Table 3), in direct proportion to the population served in aggregate by each WWTP type. The reason is that the **MfE 2019 MEG** applies the same emission factor and methane correction factor to all WWTPs, regardless of type. Further work would be needed to make a similar comparison using the treatment-specific MCF values as used in the MfE GHG inventory.
- Based on these estimates, Type 1 plants (42% of total CH_4 emissions) should be the focus of efforts to reduce CH_4 emissions. At the same time, the estimates using **MfE 2019 MEG** suggest that Type 3 plants are the next biggest emitters (23% of total CH_4 emissions). This is a misleading outcome for this type of plant (extended aeration with fully aerobic treatment). Effectively, zero methane emissions would be expected for Type 3 plants, as reflected in the estimates using the **NGER 2017-18 Guidelines**, using the IPCC default methane correction factor (MCF=0) for 'managed aerobic treatment' (refer to Table 3). It is noted that the MfE GHG inventory estimates do account for plant-specific

treatment types, and use an MCF varying from 0 to 0.65. Since the MfE 2019 MEG is not tailored for WWTP-level emissions estimates, only a weighted average MCF was published, however it may include more specific MCF values in a future update.

- Under **NGER 2017-18 Guidelines**[16] a more detailed calculation is possible for estimation of methane from biogas (i.e., specifically including the capture of biogas for combustion typically with co-generation in Type 1 plants, or flaring in Type 2 plants). If biogas volumes are measured with a reasonably high degree of accuracy, and can be reconciled through mass balance calculations with the actual measured influent organic loading on the plant (i.e. COD or BOD), then the estimated methane emissions reported can be minimized, or approach zero. For this report, in the absence of the biogas volume inventory data for the relevant plants, it was assumed that only 85% of the theoretical methane generation could be accounted through mass balance reconciliation, including biogas methane volume measurement. Under **NGER 2017-18 Guidelines** Method 1, this results in a relatively large proportion (28%) of the theoretical methane generation reporting as CH_4 emissions. Under Method 2 or 3, for the same measurement data (i.e., at least 85% of biogas methane measured, relative to the theoretical amount), only 15% of the theoretical methane generation would be reported as CH_4 emissions. If 100% or more of the theoretical methane generation is measured as biogas methane, then the reported CH_4 emissions would be zero. That is, there is merit in developing accurate inventory data for large plants with high methane generation potential (e.g. Types 1 and 2 where the biogas is captured and combusted i.e., at least by flaring if not by cogeneration), and applying a more detailed accounting methodology in such cases.
- Type 4.1 plants (incorporating trickling filters) typically will have primary sedimentation and anaerobic digestion i.e., these plant are likely to produce biogas methane. This might also be true of some Type 4.2 plants that might have primary sedimentation tanks for treating at least part of the flow, and/or where waste activated sludge is co-digested anaerobically, yielding methane. It was not possible to definitively resolve potential classification inconsistencies here for all the plants, using the test dataset (refer to Table 1 and Section 1.2.2). However, the available data suggests that there are only four plants in New Zealand classified as Types 4.1 or 4.2 with a nominal contributing population (i.e., unadjusted for rural septic tanks or the 'missing' remainder of the national total population) in the range approximately 50,000 to 75,000 persons. In Figure 4, these four plants contributed around 6% of the estimated total CH_4 emissions using the **MfE 2019 MEG**, or around 4% of the total using the **NGER 2017-18 Guidelines.** There would be merit in performing more detailed assessments of these plants, similar to that described above for the Type 1 (or Type 2) plants.
- Virtually all the CH_4 emissions estimated using the **NGER 2017-18 Guidelines** for 'Other' types of WWTP, which include septic tanks in the approached used here, are due to Septic tanks. The population allocation to these 'Rural Septic Tanks' (see Table 4) was 471,000 persons, versus approximately 44,000 persons from the WWTP inventory allocated to the 'Other' WWTP category. The latter group was made up of a mix of treatment technologies, some including septic tanks or Imhoff tanks, which might be partially anaerobic and emit methane. For the purposes of this report, using the **NGER 2017-18 Guidelines,** an MCF= 0.8 ('anaerobic digester/ reactor) was adopted for sites with septic tanks or Imhoff tanks, including all the rural septic tanks. This compares with MCF = 0.4 for septic tanks in the **MfE 2019 MEG**. No methane capture or flaring was assumed to take place for this type of WWTP. Combined with the uncertainties around

[16] In particular, Methods 2 or 3 for Wastewater Handling (Domestic) (Australian Government, 2017). In this report, only Method 1 was considered as it is closest to the method in New Zealand Guidance 2019 – refer to Table 3.

sludge removal from septic tanks (refer to discussion in Section 1.3.3), these differences account for the large differences in CH_4 emissions for the ‘Other’ WWTP type (Figure 4). Practical means to reduce CH_4 emissions from rural septic tanks are not self-evident. Improved methods to estimate actual CH_4 emissions from septic tanks would be recommended before attempting to implement steps to reduce CH_4 emissions from such systems.

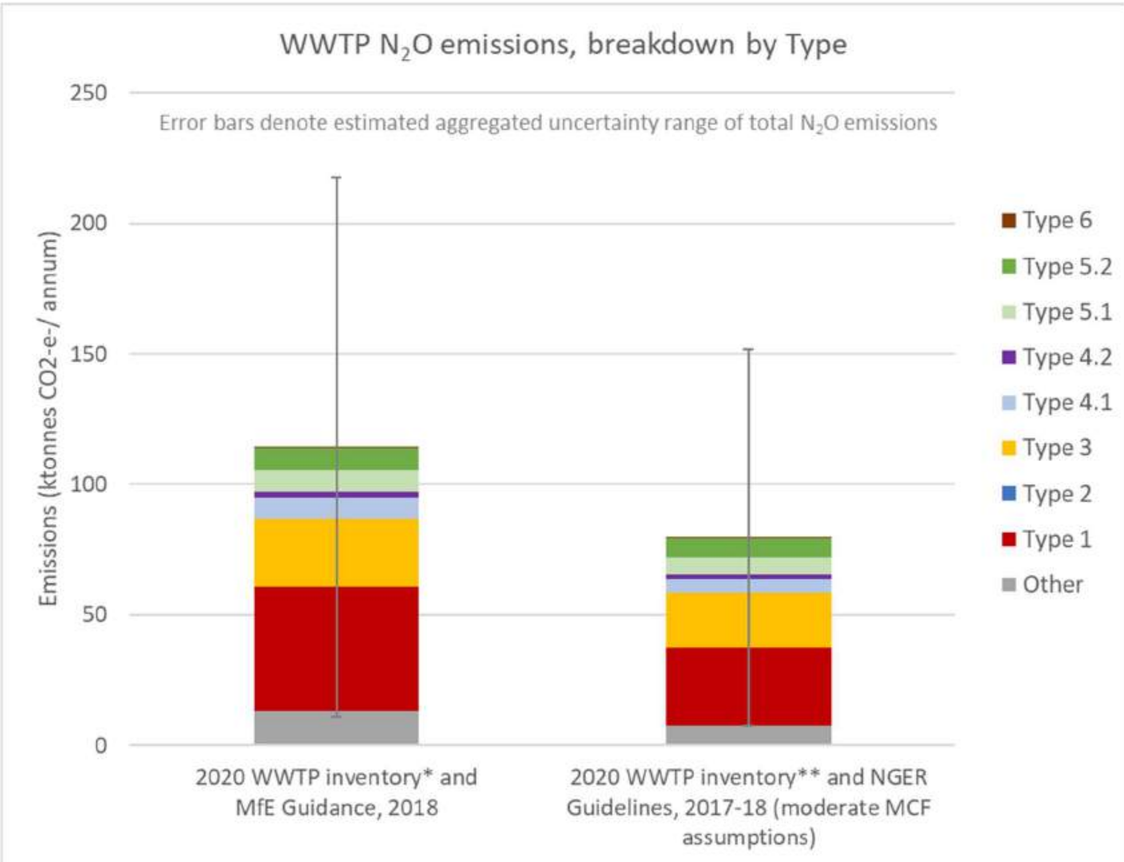
- In New Zealand, there are a large number of WWTPs (indicatively around 205 or nearly two-thirds of all WWTPs, by number) that use oxidation ponds or lagoon-type treatment. These systems may either aerated or unaerated (i.e., classified as Types 5.1 and 5.2 respectively). However, these plants only account for around 15% of the total population served in the WWTP inventory (i.e., excluding adjustments for rural septic tanks and the remaining population – refer to Table 4). As discussed in Section 1.3.3, there are some uncertainties in the appropriate MCF to be applied for these WWTPs (i.e. the extent to which the sludge treatment component might be anaerobic). In that respect, the **NGER 2017-18 Guidelines** approach (using default IPCC values for MCF to broadly distinguish different types of treatment) has some merit. Such an approach could be used to target larger plants (Type 5.1 or Type 5.2) that use deep anaerobic lagoons with a view to capturing and combusting methane (e.g. using covered anaerobic lagoons; or by upgrading primary treatment to include formal anaerobic sludge digestion, with methane capture and combustion).

Some key observations about N_2O emissions from Figure 5 are as follows:

- As previously noted (in Section 1.3.2), both the **MfE 2019 MEG** and the **NGER 2017-18 Guidelines** apply a single fixed emission factor for N_2O emissions from the wastewater treatment process. Taking into account correction factors and differences in the way the respective methods apply the emission factors, the **MfE 2019 MEG** method is more conservative, mainly because it does not take into account sludge production, which typically removes a significant portion of the influent nitrogen load from the treatment process and reduces the N_2O emission potential. N_2O emissions estimates under **MfE 2019 MEG** are therefore largely in direct proportion to the underlying population data. Conversely, the **NGER 2017-18 Guidelines** do account for sludge production, but also include emissions factors for effluent nitrogen discharged to receiving waters (although ocean waters are allocated a zero emission factor).
- The net effect of the above-mentioned methodological differences, based on the test dataset applied here, is that the N_2O emission estimates in aggregate are higher using **MfE 2019 MEG** than those using the **NGER 2017-18 Guidelines**. However, this outcome is strongly dependent on the fact that four of the five largest WWTPs in New Zealand (i.e. Size Class 5, each serving a population of >100,000 persons), representing nearly half (44%) of the total connected population (excluding adjustments for rural septic tanks or the ‘missing’ remainder population), discharge to the ocean. These plants get a zero effluent N_2O emissions estimate under **NGER 2017-18 Guidelines**. Actual N_2O emissions from these plants might be higher under a different accounting protocol (eg, by default the **MfE 2019 MEG**).
- Similarly, the appropriate effluent N_2O factor to be applied for septic tanks under **NGER 2017-18 Guidelines** is unclear. A single septic tank (or relatively small communal septic tanks) would not trigger the GHG reporting thresholds in Australia. As discussed in Section 1.3.3 septic tanks were included for discussion purposes in this report, due to the relatively large proportion of the population in New Zealand served by such wastewater systems. In applying the **NGER 2017-18 Guidelines** here, the lower effluent N_2O

emission factor for estuaries (refer to Table 4) was assumed to apply for septic tank effluent disposal to land via soakage trenches.

- Actual N_2O emissions from WWTPs are inherently uncertain. These emissions are known to vary both over time (eg, in response to plant loading), spatially (eg, with reactor configuration, aeration, and internal recycles) and between plants (i.e., in response to design and loading differences) (de Haas 2018; Pan *et al*. 2016; Law *et al*., 2012; Foley et *al.* 2010, Kampschreur *et al.* 2009). This is reflected in the wide range spanned by the error bars in Figure 5). There are on-going efforts on the part of some water utilities in Australia and overseas to fund further research in this area, including the measurement actual N_2O emissions from WWTPs, particularly in the context of pursuing 'energy-neutral' or 'carbon-neutral' operational goals (eg, Varga 2017; Melbourne Water 2020).
- There have been calls for improved methodologies to measure and account for actual N_2O emissions from different WWTP processes including an overhaul of the current reporting protocols (Yuan and de Haas, 2019). To date, there are no internationally agreed protocols for direct measurement and reporting of N_2O emissions from WWTPs. A possible reason is the relatively small contribution that wastewater handling emissions typically make to national greenhouse inventories (refer to Section 1.3.1). Existing reporting protocols (eg, refer to Section 1.2.1) rely on a single emission factor for all types of WWTP process, and therefore provide little or no incentive for design and operation of low N_2O-emitting plants[17].



[17] The recent IPCC (2019) refinement guidelines similarly apply a single N_2O emission factor for WWTP processes, based on an average from literature data, and that factor is about 60% higher than in earlier IPCC guidelines.

Figure 5: Breakdown of estimated nitrous oxide emissions from New Zealand WWTPs, according to plant type (as defined in Table 1)

1.4 Future strategy considerations

The following ideas should considered when planning future strategies around potential GHG emissions reduction for WWTPs in New Zealand:

- **Think Big First**: There are approximately six major WWTPs, identified from the test dataset in this study as 'Type 1' (including anaerobic digestion with biogas recovery and co-generation) that fall into the two larger size classes (>10,000 to 100,000 persons; and >100,000 persons) that account for approximately 42% of the total population in the WWTP inventory of the dataset. It is estimated these six plants contribute for between 35 and 42% of the total Scope 1 (CH_4 and N_2O) emissions, depending in the reporting method applied[18] (refer to Section 1.2.1). There are likely to be good opportunities, with reasonably good economies of scale, to reduce methane emissions from these plants. However, the extent which the actual vs. reported emissions can be reduced will depend partly on the reporting method applied (see below). There might be similar opportunities on a small number of plants with configurations that generally align with Type 1. For example, there are indicatively up to ten of these plants (typed here as Type 4.1 or Type 4.2, and in the second biggest size class i.e., >10,000 to 100,000 persons), accounting for a further 9% of the total population in the WWTP inventory, and 8-9% of the total Scope 1 (CH_4 and N_2O) emissions. These plants might have either been mistyped here (due to inventory data limitations), or might be feasibly modified at reasonable cost to be like Type 1 (eg, by adding/ expanding opportunities for anaerobic digestion, biogas capture and cogeneration), and thereby minimize methane emissions. Co-generation also brings with it the opportunity to reduce grid electricity consumption and hence reduce Scope 2 emissions as well. However, the main focus should remain on Scope 1 emissions, given that most of New Zealand's grid electricity is sourced from renewable (greenhouse neutral) energy sources.
- **Revisit the methodology**: The current **MfE 2019 MEG** for reporting GHG emissions from wastewater treatment is reasonably straightforward and aligned with similar protocols around the world, but is relatively simplistic. In respect of methane emission, the **MfE 2019 MEG** makes no provision for sludge treatment or removal and does not require mass balance considerations around biogas capture and combustion or transfer out of the WWTP (e.g. future potential for sale of biogas to third parties for cogeneration etc). Furthermore, it applies a single methane correction factor to all WWTPs, regardless of configuration. It is noted that the MfE 2019 MEG is based on the MfE GHG inventory which uses a range of MCF values from 0 to 0.65 and these may be incorporated into the next version of the MEG document. In respect of nitrous oxide, the **MfE 2019 MEG** is somewhat similar to other protocols around the world. These protocols largely rely on a single emission factor for all wastewater treatment processes (a significant shortcoming eg, as argued by Yuan and de Haas, 2019). This issue hinges on the lack of international consensus or guidance on N_2O emissions factors for different processes Nevertheless, there is potential to improve the **MfE 2019 MEG** by taking into account the nitrogen content of sludge production and removal from the WWTP, as well as effluent nitrogen and the potential for N_2O emissions from receiving waters. The NGER Technical

[18] These percentages include adjustment for 'missing' (unaccounted) population in WWTP inventory. Without this adjustment, the six largest WWTPs are estimated to account for between 36% and 47% of the total Scope 1 (CH_4 and N_2O) emissions, depending in the reporting method applied.

Guidelines in Australia include these provisions and might be a starting point for similar consideration in New Zealand. Furthermore, the 2019 IPCC *Refinement Guidelines* (IPCC, 2019) have a number of new provisions and updated emission factors that deserve consideration in future guidance adopted for the New Zealand wastewater sector.

- **Decide how to account for septic tanks**: At present, a significant proportion (around 10%) of New Zealand's population is served by wastewater that is treated and disposed of using septic tanks, largely in rural areas. The existing **MfE 2019 MEG** accounts for methane emissions (but not nitrous oxide) from these systems in a similar way to all other WWTPs, except for the minor adjustments to some factors in the calculations. The NGER Technical Guidelines in Australia do not mention septic tanks, probably because of the small scale of such systems placing them below the relevant reporting thresholds. However, given the relative predominance of septic tanks in New Zealand, depending on how their emissions are accounted for, these systems are estimated to contribute about 40% of domestic wastewater emissions in the national greenhouse inventory. This alone might justify further investigation into improved methods to measure and account for septic tank emissions (CH_4 and N_2O) in the New Zealand context. In this respect, the 2019 IPCC *Refinement Guidelines* (IPCC, 2019) have a provisions and emission factors for septic tanks that deserve consideration in future guidance adopted for the New Zealand.
- **Keep in the mind the overall objectives**: In aiming to minimise GHG emissions associated with WWTPs, there are three main overall objectives:
    - (1) Minimise the potential for release of uncombusted methane to the atmosphere (once captured and combusted, the resultant emissions will consist largely of greenhouse neutral carbon dioxide);
    - (2) Minimise the potential for generation of nitrous oxide (this will hinge mainly around process optimization for nitrogen removal in biological treatment processes; however, the research evidence in this area is large and sometimes confusing, likely necessitating direct measurement, where feasible eg, on larger plants);
    - (3) Consider and weigh up potentially perverse outcomes whereby process optimisation (eg, with a view to improving nitrogen removal from the treated effluent and/or reducing electrical energy consumption) leads to higher GHG emissions (perhaps inadvertently). One example here might be conversion of nutrient removal activated sludge processes to incorporate so-called 'short-cut' nitrogen removal pathways, which appear to carry higher risks of nitrous oxide emissions (de Haas 2018). Another example might be conversion of Type 3 (extended aeration) plants to Type 1 or Type 2 (by adding primary sedimentation and anaerobic digestion, generating methane). The benefits of Type 1 plants might be obvious particularly for larger plants when taking into account economies of scale (eg, smaller bioreactors, lower energy use with the potential for co-generation, and better use of capital). Minimising Scope 1 emissions from these plants will hinge on methane capture and combustion or process design/ operation for nitrogen removal. However, New Zealand has a large number of small to medium-sized plants. For these plants, aside from capital cost considerations around relatively poor economies of scale, wide-scale conversion to configurations that add anaerobic digestion might not be appropriate from an energy and greenhouse perspective. In both of the above examples, a key trade off will be the potential for methane emissions (actual or as accounted for under the relevant protocol – see above) versus grid electricity use. Where grid electricity is already predominantly of renewable origin (i.e. a low Scope 2 emission factor, as in

New Zealand), WWTP process conversions that potentially risk Scope 1 emissions (CH_4 and/or N_2O) in order to reduce grid electricity use might be misguided and lead to higher overall actual emissions profiles (i.e., Scopes 1 and 2).

1.5 Summary

Within the water sector, WWTP direct emissions are likely to be among the dominant greenhouse gas emissions. However, efforts to reduce GHG emissions from WWTPs treating predominantly domestic wastewater need to be tempered by an understanding of the relatively small contribution that this sector makes to the national greenhouse inventory (indicatively, less than 0.5% in New Zealand). Therefore, capital expenditure on WWTP asset renewal programs that have a GHG-reduction thrust must consider the overall justification for such expenditure, including other benefits (eg, improvement in water quality of treated effluent).

In New Zealand, the emission factor for Scope 2 is relatively low, given that the country has grid electricity sourced predominantly from renewable sources. Therefore, efforts to reduce grid electrical energy use (i.e., Scope 2 emissions) at WWTPs (eg, through process re-engineering) that potentially increase direct emissions (i.e., Scope 1 CH_4 and/or N_2O) might not meet expectations, given that the Scope 2 emissions are likely to be approximately an order of magnitude lower than the Scope 1 emissions.

The current estimation methods for WWTP direct emissions in New Zealand, taken from the **MfE 2019 MEG** (Ministry for the Environment 2019a), are relatively simplistic, but aligned with international protocols and broadly similar to the 'Method 1' in the Australian **NGER 2017-18 Guidelines** (Australian Government 2017). Compared with the **NGER 2017-18 Guidelines** , the **MfE 2019 MEG** is additionally simplified in several respects, notably that: it does not make allowance for different types of treatment process (related to methane emissions correction factors); it applies a single emission factor for methane to all WWTPs (this may be amended in a future update); it does not allow for sludge production and removal (relevant to both methane and nitrous oxide emissions); and it does not take into account effluent nitrogen or the receiving water environment (relevant to oxide emissions). The **MfE 2019 MEG** also does not make possible the measurement of actual plant loads (i.e.., measures of organic material or nitrogen) and it does not allow for mass balance checks of actual biogas methane production (where relevant) against WWTP organic loads; nor does it account for different extents of nitrogen removal in different WWTPs. Rather, the **MfE 2019 MEG** allocates fixed influent wastewater loads per capita for organic and nitrogen load parameters.

A more detailed approach to emissions estimates, on a case-by-case basis (eg, for major WWTPs), would go some way towards improving understanding of the potential for emissions reduction. Methods 2 and 3 in the **NGER 2017-18 Guidelines** enable a more detailed inventory approach to WWTP emissions estimates, at least to some extent (eg, for methane emissions). However, the **NGER 2017-18 Guidelines** are silent on emissions estimation from septic tanks, whereas the **MfE 2019 MEG** specifies factors for methane emissions from septic tanks. Given that around one-tenth of New Zealand's total population relies on wastewater treatment through septic tanks (based on available inventory data), this aspect merits further investigation to confirm the accuracy of the emissions factor(s) applied.

Similarly, most reporting protocols (including **MfE 2019 MEG** and the **NGER 2017-18 Guidelines**) rely on a single emission factor for nitrous oxide from all wastewater treatment processes, which is arguably a significant shortcoming. This issue hinges on the inherent variability of N_2O emissions from WWTPs, and a lack of international consensus or guidance on N_2O emissions factors for different processes. Effectively, under current reporting protocols, there is no driver to reduce N_2O emissions factors from wastewater treatment processes (eg, through process engineering). Under **NGER 2017-18 Guidelines** (but not **MfE 2019 MEG**), in respect of reducing reported N_2O emissions, the only significant driver is to direct WWTP nitrogen loads as far as possible to effluent discharge via estuaries (or to the ocean). The reason is the N_2O emission factors tabled in the NGER Guidelines for receiving waters are lower for estuaries than for rivers (or zero in the case of the oceans, the latter partly due to lack of international consensus).

Hence, in a number of ways, both in New Zealand and internationally, it will be necessary to revisit the reporting methodology for wastewater treatment in order to provide more comprehensive and sensible guidance to the water sector in respect of GHG emissions reduction. Including methodological issues, this report identified ideas that provide a basis for guiding future strategies around potential GHG emissions reduction for WWTPs in New Zealand.

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APPENDIX B
COMMON ABBREVIATIONS AND GLOSSARY

Appendix B Common Abbreviations and Glossary

Common Abbreviations

Abbreviation	Definition
ASP	Activated Sludge Process
BAU	Business As Usual
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BPO	Best Practicable Option
COD	Chemical Oxygen Demand
CEC	Contaminants of Emerging Concern
CSO	Combined sewer overflow
DIA	Department of Internal Affairs
E.coli	Escherichia coli
EDC	Endocrine Disrupting Chemical
GHG	Greenhouse Gas
GIS	Geographical information System
GPR	Gas phase reduction
I/I	Inflow and infiltration
NPS	National Policy Statement
MBR	Membrane Bioreactor
MfE	Ministry for the Environment
PE	Population Equivalent
PFAS	Per- and Poly-fluoroalkyl Substances
RDII	Rainfall Derived Inflow and Infiltration
RMA	Resource Management Act
SBR	Sequencing Batch Reactors
TA/TLA	Territorial Authority /Territorial Local Authority (defined in the LGA as a city or district council)
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TSS	Total Suspended Solids
UV	Ultraviolet

Abbreviation	Definition
WSP	Waste Stabilisation Pond
WW	Wastewater
WWA	Waste Water Authority – used in the model bylaw to define the unit of a TA responsible for the collection, treatment and disposal of sewage
WWTP	Wastewater Treatment Plant

Glossary

Term	Explanation
Actiflo	Actiflo is a proprietary accelerated settlement process. It uses both coagulant and polymer to coagulate and flocculate suspended and dissolved contaminants, along with a fine sand (microsand) which provides a ballast to aid settlement. pH adjustment may be required to optimise coagulation. Settlement occurs in a lamella clarifier, and the microsand is recovered through a hydrocyclone. Removed contaminants require further treatment.
Activated Sludge	Sludge particles produced in raw or settled wastewater (primary effluent) by the growth of organisms in aeration tanks in the presence of dissolved oxygen. These sludge particles contain microorganisms that feed on the incoming wastewater.
Activated Sludge Process	A biological wastewater treatment process that speeds up the decomposition of dissolved organic substances in the wastewater. Activated sludge is added to wastewater and the mixture (mixed liquor) is aerated and agitated. After some time in the aeration tank, the activated sludge is allowed to settle out by sedimentation and is disposed of (wasted) or reused (returned to the aeration tank) as needed. The remaining wastewater then undergoes more treatment.
Aerobic	A condition in which atmospheric or dissolved oxygen is present in the water.
Affected Population	The population served by a WWTP requiring upgrade.
Anaerobic	A condition in which atmospheric or dissolved oxygen is not present in the water.
Anoxic	A condition in which water does not contain dissolved oxygen but does contain chemically bound oxygen, such as in molecules like nitrate.
Aquamats	AquaMats are a high-surface area media which hang down through the depth of WSP's. Biomass, including bacteria, protozoa and a range of higher life forms, grows on the surface of the media. Diffused air aeration is provided to increase the amount of oxygen available for aerobic organisms to break down contaminants, and to aid with water movement through the pond depth. By increasing both oxygen availability and the amount of biomass present in the WSP, the treatment capacity is increased.
Baffles	An artificial obstruction (often a curtain) that directs the flow of water in a WSP. WSP's are prone to short circuiting and baffles can assist with preventing this.
Biochemical Oxygen Demand	A measure of the organic load of a wastewater. Is a measure of the amount of dissolved oxygen consumed by aerobic

Term	Explanation
	microorganisms to break down organic material at a given temperature over a specifc time period.
BioFiltro	In a BioFiltro Plant, WSP effluent is sprayed over the surface of a bed of wood shavings, which is naturally colonised with microorganisms, forming a biofilm. The top layer of the bed is populated with earthworms which both aerate the bed and break down contaminants. The biofilm oxidises dissolved organics and other nutrients, while the worms break down solid organic material. The removal of ammonia is due to nitrification.
Biological Nutrient Removal (BNR)	Biological Nutrient Removal (BNR) is an activated sludge-based process used for nitrogen and phosphorus removal from wastewater.
Biosolids	Solid organic matter produced by wastewater treatment processes that can be beneficially recycled.
Characteristics	The physical, chemical, and biological properties of a wastewater.
Combined sewer overflow (CSO)	Overflows from combined stormwater and wastewater networks.
Compliance	Discharge of treated wastewater in most situations is subject to a Resource Consent that permits the discharge. Resource Consents typically include a number of conditions that must be complied with. Compliance in this report relates to compliance with Resource Consent conditions.
Contaminants of Emerging Concern (CEC)	Pollutants in water bodies that may cause ecological or human health impacts and typically are not regulated under current environmental laws.
Controlled Wet Weather Overflow	Overflows that are designed into a network such that in rainfall events, where system capacity is exceeded, the overflow goes to a designated location – often a stream or river.
Denitrification	An anoxic process that occurs when nitrite or nitrate ions are reduced to nitrogen gas and nitrogen bubbles are formed as a result.
Discharger/Trader/Trade Waste customer	Used interchangeably to describe businesses discharging trade waste to the municipal system
Dry Weather Overflow	Overflows caused by a system failure, which normally would be either a blockage or pump failure.
Effluent	The liquid that comes out of a WWTP after completion of any treatment process.
Endocrine Disrupting Chemical (EDC)	Substances that may interfere with the normal function of the body's endocrine system (i.e. effects hormone production that regulates metabolism, growth and development, tissue function, reproduction, etc.).
Escherichia coli (E.coli)	Escherichia coli (abbreviated as E. coli) are bacteria found in the environment, foods, and intestines of people and animals. E. coli are a large and diverse group of bacteria and are used as an indicator that faecal contamination in water has occurred.
Floating wetlands	Floating Treatment Media or Floating Treatment Wetlands use microbes and bacteria in present within the root zone to remove nutrients in the water.
Grease Trap	A device designed to collect and retain grease and fatty substances usually found in kitchen wastes or similar wastes. Grease traps are installed onsite between the source of grease and the collection line to the reticulation network. They are commonly used in restaurants.
Greenhouse Gas	Gas that contributes to the greenhouse effect by absorbing infrared radiation.

Term	Explanation
Geographical information System (GIS)	GIS is a framework for gathering, managing, and analysing data. GIS integrates many types of data. It analyses spatial location and organizes layers of information into visualizations using maps and 3D scenes.
Household	For this report, the number of households has been determined from population data and it is assumed there are 2.7 people per household.
Infiltration	The seepage of groundwater into the wastewater reticulation network. Seepage occurs through defective or damaged pipes, and through pipe joints and connections.
Inflow	Stormwater that enters the wastewater reticulation network from sources other than regular connections. Sources are often illegal cross connections such as downpipes that drain to the wastewater network.
Influent	Untreated or partially treated water flowing into a treatment process or treatment plant
Membrane Bioreactors (MBR)	MBR is an activated sludge-based treatment processes that uses membrane filtration to separate the treated effluent from biomass, rather than settlement.
Mixed Liquor	A mixture of raw or settled wastewater and activated sludge contained in an aeration basin in an activated sludge process.
Model Bylaw	NZS 9201.23 – standard available to use as the basis for a trade waste bylaw. Use of the model bylaw is not compulsory, and is provided for guidance
Nitrification	An aerobic two-step process in which bacteria oxidize the ammonia in wastewater into nitrite and then nitrate.
Nutrient Sources	In rural catchments nutrients are commonly sourced from animal faeces and excess fertilizer. In the urban environment nitrogen and phosphorus is picked up in stormwater from a range of sources including wildfowl and animal faeces, fertilizers and other garden products.
Nutrients (macro)	Macro nutrients refers primarily to phosphorous and nitrogen. Nitrogen and phosphorus are nutrients that are natural parts of aquatic ecosystems. However, in excess concentrations they can cause adverse effects on water bodies including excess algal growth. Significant increases in algae harm water quality, food resources and habitats, and decrease the oxygen that fish and other aquatic life need to survive.
Partitioned Ponds	Partitioning ponds to create several smaller ponds in series can significantly reduce the effects of short-circuiting and thus improve performance.
Population Category	The study distinguishes between WWTPs based on the following population categories: Large – greater than 100,000 people Major – 10,000 – 100,000 people Medium – 5,000 – 10,000 people Small – 1,000 – 5,000 people Very Small – Less than 1,000 people
Population Equivalent	A means of expressing the strength of organic material in wastewater based on the pollution load produced by an individual producing standard domestic wastewater.
Primary Treatment	A wastewater treatment process that allows substances that readily settle or float to be separated from the wastewater.
Receiving Water	The surface water (stream, river or lake) that the WWTP treated water discharges into.

Term	Explanation
Resource Consent	The authorisation given to certain activities or uses of natural and physical resources required under the Resource Management Act.
Resource Management Act 1991	The main piece of legislation that sets out how the environment should be managed in New Zealand.
Secondary Treatment	A wastewater treatment process used to convert dissolved or suspended materials into a form more readily separated from the water being treated. The process commonly is a type of biological treatment followed by secondary clarifiers that allow the solids to settle out from the water.
Sequencing Batch Reactor (SBR)	Sequencing batch reactors or sequential batch reactors are a type of activated sludge process for the treatment of wastewater.
Septic Tank	A settling tank used to provide basic primary treatment to wastewater sources that is not connected to a collection system/WWTP. Anaerobic bacteria in the tank decompose organic solids.
Short Circuiting	When the actual flow path (and retention time) is reduced by non-deal configuration, e.g. influent flows directly to the outlet of a WSP/ unmixed tank, etc.
Sludge	Waste solids generated from a treatment process step, e.g. chemical coagulation followed by settling or biological process.
Tankered Waste	Wastewater conveyed to a WWTP by vehicle for disposal (excludes domestic wastewater discharged directly from buses, caravans, house buses, or similar).
Tertiary Treatment	Additional treatment step(s) undertaken after secondary treatment to enhance the water quality prior to discharge to the environment. Often involves disinfection processes such as UV treatment to reduce the remaining bacteria.
Total Population	The total population of a region that are served by Territorial Authority owned and operated WWTPs. This includes WWTPs discharging to land and the ocean environments.
Trade Waste	Commercial and industrial liquid waste that is discharged to a wastewater reticulation network or WWTP owned by a Territorial Authority.
Trade Waste Agreement	A written agreement between a Territorial Authority and a person/business discharging trade waste to the wastewater network.
Turbidity	The cloudy/murky appearance of water caused by the presence of suspended and colloidal solids. It is an optical property of water based on the amount of light reflected by suspended particles, measured in NTU.
Ultra Violet (UV) Disinfection	Short-wavelength ultraviolet light applied to the water to retard the ability of microorganisms to reproduce.
Uncontrolled wet weather overflow	Wet weather overflows that occur within a network in places that were not designed to overflow e.g via manhole lids
Waste Stabilisation Pond (WSP)	WSPs are large ponds that utilise a variety of mechanisms to remove pollutants from wastewater. These treatment mechanisms include settlement, and aerobic, anoxic and anaerobic biological processes.
Wastewater Treatment Plant (WWTP)	A facility where a combination of various processes are used to treat wastewater to remove pollutants.
Constructed Wetlands	An artificial wetland that uses the natural functions of vegetation, soil and microorganisms to treat wastewater.

APPENDIX C
WASTEWATER TREATMENT PLANT (WWTP) IDENTIFICATION

Appendix C – Wastewater Treatment Plant (WWTP) identification

Wastewater treatment plant (WWTP) reference numbers.

Reference Number	Operator	WWTP Name
1	Ashburton District Council	Ashburton
2	Ashburton District Council	Methven
3	Ashburton District Council	Rakaia
4	Buller District Council	Little Whanganui
5	Buller District Council	Reefton
6	Buller District Council	Westport
7	Carterton District Council	Carterton
8	Central Hawke's Bay District Council	Otane
9	Central Hawke's Bay District Council	Porangahau
10	Central Hawke's Bay District Council	Porangahau Beach
11	Central Hawke's Bay District Council	Takapau
12	Central Hawke's Bay District Council	Waipawa
13	Central Hawke's Bay District Council	Waipukurau
14	Central Otago District Council	Alexandra
15	Central Otago District Council	Cromwell
16	Central Otago District Council	Naseby
17	Central Otago District Council	Omakau
18	Central Otago District Council	Ranfurly
19	Central Otago District Council	Roxburgh
20	Central Otago District Council	Roxburgh Hydro
21	Christchurch City Council	Akaroa
22	Christchurch City Council	Christchurch
23	Christchurch City Council	Diamond Harbour
24	Christchurch City Council	Duvauchelle
25	Christchurch City Council	Governors Bay
26	Christchurch City Council	Lyttelton
27	Christchurch City Council	Tikao Bay
28	Christchurch City Council	Wainui

Reference Number	Operator	WWTP Name
29	Clutha District Council	Balclutha
30	Clutha District Council	Clinton
31	Clutha District Council	Heriot
32	Clutha District Council	Kaitangata
33	Clutha District Council	Kaka Point
34	Clutha District Council	Lawrence
35	Clutha District Council	Milton
36	Clutha District Council	Owaka
37	Clutha District Council	Stirling
38	Clutha District Council	Tapanui
39	Clutha District Council	Waihola
40	Dunedin City Council	Green Island
41	Dunedin City Council	Middlemarch
42	Dunedin City Council	Mosgiel
43	Dunedin City Council	Seacliff
44	Dunedin City Council	Tahuna
45	Dunedin City Council	Waikouaiti
46	Dunedin City Council	Warrington
47	Far North District Council	Ahipara
48	Far North District Council	East Coast/Taipa
49	Far North District Council	HiHi
50	Far North District Council	Kaeo
51	Far North District Council	Kaikohe
52	Far North District Council	Kaitaia
53	Far North District Council	Kawakawa
54	Far North District Council	Kerikeri
55	Far North District Council	Kohukohu
56	Far North District Council	Opononi
57	Far North District Council	Paihia
58	Far North District Council	Rangiputa
59	Far North District Council	Rawene
60	Far North District Council	Russell
61	Far North District Council	Whatuwhiwhi

Reference Number	Operator	WWTP Name
62	Gisborne District Council	Gisborne
63	Gisborne District Council	Te Karaka
64	Gore District Council	Gore
65	Gore District Council	Mataura
66	Gore District Council	Waikaka
67	Grey District Council	Blackball
68	Grey District Council	Greymouth
69	Grey District Council	Iveagh Bay
70	Grey District Council	Karoro/Paroa
71	Grey District Council	Moana
72	Grey District Council	Runanga
73	Hamilton City Council	Pukete
74	Hastings Dstrict Council	East Clive
75	Hauraki District Council	Kerepehi
76	Hauraki District Council	Ngatea
77	Hauraki District Council	Paeroa
78	Hauraki District Council	Turua
79	Hauraki District Council	Waihi
80	Hauraki District Council	Waitakaruru
81	Hauraki District Council	Whiritoa
82	Horowhenua District Council	Foxton
83	Horowhenua District Council	Foxton Beach
84	Horowhenua District Council	Levin
85	Horowhenua District Council	Shannon
86	Horowhenua District Council	Tokomaru
87	Horowhenua District Council	Waitarere
88	Hurunui District Council	Amberley & District
89	Hurunui District Council	Cheviot
90	Hurunui District Council	Greta Valley
91	Hurunui District Council	Hanmer Springs
92	Hurunui District Council	Hawarden
93	Hurunui District Council	Motunau Beach
94	Hurunui District Council	Waikari

Reference Number	Operator	WWTP Name
95	Hutt City Council	Seaview
96	Invercargill City Council	Bluff
97	Invercargill City Council	Clifton
98	Invercargill City Council	Omaui
99	Kaikoura District Council	Kaikoura
100	Kaipara District Council	Dargaville
101	Kaipara District Council	Glinks Gully
102	Kaipara District Council	Kaiwaka
103	Kaipara District Council	Mangawhai
104	Kaipara District Council	Maungaturoto
105	Kaipara District Council	Te Kopuru
106	Kapiti District Council	Otaki
107	Kapiti District Council	Paraparaumu
108	Kawerau District Council	Kawerau
109	Mackenzie District Council	Burkes Pass
110	Mackenzie District Council	Fairlie
111	Mackenzie District Council	Tekapo
112	Mackenzie District Council	Twizel
113	Manawatu District Council	Awahuri EDS
114	Manawatu District Council	Cheltenham EDS
115	Manawatu District Council	Fielding
116	Manawatu District Council	Halcombe
117	Manawatu District Council	Himatangi Beach
118	Manawatu District Council	Kimbolton EDS
119	Manawatu District Council	Rongotea
120	Manawatu District Council	Sanson
121	Marlborough District Council	Blenheim
122	Marlborough District Council	Havelock
123	Marlborough District Council	Picton
124	Marlborough District Council	Seddon
125	Masterton District Council	Castlepoint
126	Masterton District Council	Masterton
127	Masterton District Council	Riversdale

Reference Number	Operator	WWTP Name
128	Masterton District Council	Tinui
129	Matamata-Piako District Council	Matamata
130	Matamata-Piako District Council	Morrinsville
131	Matamata-Piako District Council	Tahuna
132	Matamata-Piako District Council	Te Aroha
133	Matamata-Piako District Council	Waihou
134	Napier City Council	Awatoto-BTF Plant
135	Nelson City Council	Bells Island
136	Nelson City Council	Nelson North
137	New Plymouth District Council	New Plymouth
138	Opotiki District Council	Opotiki
139	Opotiki District Council	Waihau Bay
140	Otorohanga District Council	Otorohanga
141	Palmerston North City Council	Totara Road
142	Porirua City Council	Porirua
143	Queenstown Lakes District Council	Cardrona
144	Queenstown Lakes District Council	Hawea
145	Queenstown Lakes District Council	Shotover
146	Queenstown Lakes District Council	Wanaka
147	Rangitikei District Council	Bulls
148	Rangitikei District Council	Hunterville
149	Rangitikei District Council	Koitiata
150	Rangitikei District Council	Mangaweka
151	Rangitikei District Council	Marton
152	Rangitikei District Council	Ratana
153	Rangitikei District Council	Taihape
154	Rotorua District Council	Rotorua
155	Ruapehu District Council	Hikumutu
156	Ruapehu District Council	National Park
157	Ruapehu District Council	Ohakune
158	Ruapehu District Council	Pipiriki
159	Ruapehu District Council	Raetihi
160	Ruapehu District Council	Rangataua

Reference Number	Operator	WWTP Name
161	Selwyn District Council	Arthurs Pass(STP) Sunshine Tce
162	Selwyn District Council	Castle Hill (STP)
163	Selwyn District Council	Claremont(STP) Avonie Pl
164	Selwyn District Council	Ellesmere (STP) Leeston
165	Selwyn District Council	ESSS(STP) Pines
166	Selwyn District Council	Lake Coleridge(STP)
167	Selwyn District Council	Upper Selwyn Huts(STP)
168	South Taranaki District Council	Eltham
169	South Taranaki District Council	Hawera
170	South Taranaki District Council	Kaponga
171	South Taranaki District Council	Manaia
172	South Taranaki District Council	Opunake
173	South Taranaki District Council	Patea
174	South Taranaki District Council	Wai-inu
175	South Taranaki District Council	Waverley
176	South Waikato District Council	Arapuni
177	South Waikato District Council	Putaruru
178	South Waikato District Council	Tirau
179	South Waikato District Council	Tokoroa
180	South Wairarapa District Council	Featherston
181	South Wairarapa District Council	Greytown
182	South Wairarapa District Council	Lake Ferry WWTP
183	South Wairarapa District Council	Martinborough WWTP
184	Southland District Council	Balfour
185	Southland District Council	Browns
186	Southland District Council	Edendale Wyndham
187	Southland District Council	Gorge Road
188	Southland District Council	Lumsden
189	Southland District Council	Manapouri
190	Southland District Council	Nightcaps
191	Southland District Council	Oban
192	Southland District Council	Ohai
193	Southland District Council	Otautau

Reference Number	Operator	WWTP Name
194	Southland District Council	Riversdale
195	Southland District Council	Riverton (Townside)
196	Southland District Council	Riverton(Rocks)
197	Southland District Council	Te Anau
198	Southland District Council	Tokanui
199	Southland District Council	Tuatapere
200	Southland District Council	Winton
201	Stratford District Council	Stratford
202	Tararua District Council	Dannevirke
203	Tararua District Council	Eketahuna
204	Tararua District Council	Norsewood
205	Tararua District Council	Ormondville
206	Tararua District Council	Pahiatua
207	Tararua District Council	Pongaroa
208	Tararua District Council	Woodville
209	Tasman District Council	Collingwood
210	Tasman District Council	Motueka
211	Tasman District Council	Murchison
212	Tasman District Council	St Arnaud
213	Tasman District Council	Takaka
214	Tasman District Council	Tapawera
215	Tasman District Council	Upper Takaka
216	Taupo District Council	Acacia Bay
217	Taupo District Council	Atiamuri
218	Taupo District Council	Kinloch
219	Taupo District Council	Mangakino
220	Taupo District Council	Motuoapa
221	Taupo District Council	Motutere (Camp Ground)
222	Taupo District Council	Omori
223	Taupo District Council	Taupo
224	Taupo District Council	Turangi
225	Taupo District Council	Whakamaru
226	Taupo District Council	Whareroa

Reference Number	Operator	WWTP Name
227	Tauranga City Council	Chapel Street
228	Tauranga City Council	Te Maunga
229	Thames Corromandel District Council	Hahei
230	Thames Corromandel District Council	Cooks Beach
231	Thames Corromandel District Council	Coromandel
232	Thames Corromandel District Council	Matarangi
233	Thames Corromandel District Council	Oamaru Bay
234	Thames Corromandel District Council	Onemana
235	Thames Corromandel District Council	Pauanui
236	Thames Corromandel District Council	Thames
237	Thames Corromandel District Council	Whangamata
238	Thames Corromandel District Council	Whitianga
239	Timaru District Council	Timaru Domestic
240	Timaru District Council	Timaru Industrial
241	Waikato District Council	Huntly
242	Waikato District Council	Maramarua
243	Waikato District Council	Matangi
244	Waikato District Council	Meremere
245	Waikato District Council	Ngaruawahia
246	Waikato District Council	Raglan
247	Waikato District Council	Tauwhare
248	Waikato District Council	Te Kauwhata
249	Waikato District Council	Te Kowhai
250	Waimakariri District Council	Fernside
251	Waimakariri District Council	Kaiapoi
252	Waimakariri District Council	Loburn Lea
253	Waimakariri District Council	Oxford
254	Waimakariri District Council	Rangiora
255	Waimakariri District Council	Waikuku
256	Waimakariri District Council	Woodend
257	Waimate District Council	Waimate
258	Waipa District Council	Cambridge
259	Waipa District Council	Te Awamutu

Reference Number	Operator	WWTP Name
260	Wairoa District Council	Tuai
261	Wairoa District Council	Wairoa
262	Waitaki District Council	Duntroon
263	Waitaki District Council	Kurow
264	Waitaki District Council	Lake Ohau Alpine Village
265	Waitaki District Council	Moeraki
266	Waitaki District Council	Oamaru
267	Waitaki District Council	Omarama
268	Waitaki District Council	Otematata
269	Waitaki District Council	Palmerston
270	Waitomo District Council	Bennydale
271	Waitomo District Council	Piopio
272	Waitomo District Council	Te Kuiti
273	Waitomo District Council	Te Waitere
274	Watercare	Army Bay (Whangaparaoa Peninsula)
275	Watercare	Beachlands(Okaroro Road)
276	Watercare	Bombay(Barber Road)
277	Watercare	Clarks Beach(Stella Drive)
278	Watercare	Denehurst (Denehurst Drive,Waimauku)
279	Watercare	Helensville (Mount Rex, Helensville)
280	Watercare	Kawakawaa Bay(Orere Road)
281	Watercare	Kingseat(Buchanan Road)
282	Watercare	Mangere (Island Road)
283	Watercare	Omaha
284	Watercare	Owhanake (Ocean View Road, Waiheke Island)
285	Watercare	Pukekohe (Friedlander Road)
286	Watercare	Rosedale (Albany, North Shore)
287	Watercare	Snells/Algies (Hamatana Rd, Snells Beach)
288	Watercare	Waiuku(Williams Road)
289	Watercare	Waiwera (Weranui Rd)
290	Watercare	Warkworth(Alnwick Street)
291	Watercare	Wellsford

Reference Number	Operator	WWTP Name
292	Wellington City Council	Moa Point
293	Wellington City Council	Western
294	Western Bay of Plenty District Council	Katikati
295	Western Bay of Plenty District Council	Maketu
296	Western Bay of Plenty District Council	Te Puke
297	Western Bay of Plenty District Council	Waihi Beach
298	Westland District Council	Fox
299	Westland District Council	Franz
300	Westland District Council	Haast
301	Westland District Council	Hokitika
302	Whakatane District Council	Edgecumbe
303	Whakatane District Council	Murupara
304	Whakatane District Council	Ohope
305	Whakatane District Council	Taneatua
306	Whakatane District Council	Te Mahoe
307	Whakatane District Council	Whakatane
308	Whanganui District Council	Marybank Scheme
309	Whanganui District Council	Mowhanau Beach
310	Whanganui District Council	Whanganui
311	Whangarei District Council	Hikurangi
312	Whangarei District Council	Ngunguru
313	Whangarei District Council	Oakura
314	Whangarei District Council	Portland
315	Whangarei District Council	Ruakaka
316	Whangarei District Council	Tutukaka
317	Whangarei District Council	Waiotira
318	Whangarei District Council	Waipu
319	Whangarei District Council	Whangarei
320	Central Otago District Council	Bannockburn
321	Taupo District Council	Pukawa
322	Waitaki District Council	Kakanui
323	Waitaki District Council	Weston
324	Ruapehu District Council	Waiouru

GHD

Level 3
138 Victoria Street
T: 64 3 378 0900   F: chcmail@ghd.com

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Prepared for
Ministry for the Environment

Beca

GHD

Boffa Miskell