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Takapau WWTP - Surface Water Assessment of Environmental Effects

Prepared for Central Hawke's Bay District Council

Prepared by Beca Limited

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Contents

Revision History

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Executive Summary

Beca Ltd (Beca) have been engaged by Central Hawke's Bay District Council (CHBDC) to undertake an assessment of effects of the current and future discharges from the Takapau Wastewater Treatment Plant (WWTP) to the Makaretu River. The proposed wastewater scheme will divert the treated wastewater, which currently discharges to the Makaretu River through a wetland to an alternative, staged discharge methodology. The new methodology is proposed to be to irrigate the adjacent farmland whereby the majority of treated wastewater will eventually be discharged to land in a staged manner. The final stage would include some treated wastewater discharge indirectly to the Makaretu River through a High Rate Land Passage (HRLP) when soil conditions prevent irrigation.

This assessment addresses the river water quality effects of the current discharge and the future staged discharge to land and surface water through mass-balance and mass-load analyses in the context of the Hawke's Bay Regional Resource Management Plan, Policy Plan Change 6 (HBRC RRMP PC6)

The Takapau WWTP currently consists of a single oxidation pond with a screened inlet and single surface aerator. Discharge is through a small wetland before flowing into the Makaretu River approximately 2 km north east of the Takapau township.

The Makaretu River sub-catchment sits within PC6 Tukituki Catchment Management Zone 3 (MZ3) – Ruataniwha South – and is subject to the catchment-specific management objectives, limits and targets set out in Tables 5.9.1A and 5.9.1B in the RRMP PC6 document.

This investigation included a review of relevant historical reports, analysis of historical measured water quality data to assess the current discharge effects, and analysis of future discharge scenarios relating to the proposed staged development of the WWTP. The designed future discharge includes a three-stage development to transition the discharge from the Makaretu River to adjacent farmland for the majority of the time. Water quality data was assessed based on summary statistics from points upstream and downstream of the oxidation pond discharge, a mass-balance downstream prediction methodology, and calculation of the mass-load nutrient contribution to the Makaretu River and wider Tukituki catchment.

The Makaretu River is considered to be in a good state relative to the wider Tukituki River catchment zone and national bottom lines. Water quality monitoring carried out by Central Hawkes Bay District Council (CHBDC) upstream of the discharge point demonstrate that the Makaretu River has phosphorus (total and dissolved) concentrations generally elevated above HBRC RRMP PC6 and Australian and New Zealand Environmental Conservation Council (ANZECC) physical and chemical stressor guidelines. All other contaminants are below their respective guidelines.

Historical ecological investigations undertaken with regard to the consent conditions indicate that the Makaretu River has generally low levels of periphyton and algal cover both upstream and downstream of the treated wastewater discharge. MCI results indicate that the Makaretu River is representative of a good ecological habitat (MCI >100). However, it consistently scores below the HBRC RRMP PC 6 target score of 120.

Monthly water quality and flow data over the last five hydrological years (July 1 2015 to June 30 2020) was reviewed. Measured contaminant concentrations between upstream and downstream of the oxidation pond discharge indicate an immaterial increase in the medians of most contaminants. The discharge itself does not result in the downstream exceedance of relevant guidelines that are not already exceeding upstream (TP and DRP).

Box plot comparisons of the contaminants that were identified as statistically increasing between 50 m upstream and 50 m downstream of the discharge are compared to monitoring results taken at a 400 m downstream location. These box plots indicate that while there may be a low increase in the concentrations of these contaminants directly downstream of the discharge, this is not reflected in the monitoring results at the 400 m downstream location. The results of the latter appear to be more similar to the 50 m upstream monitoring location.

Desktop mass-balance calculations allowed for a prediction of downstream contaminant concentrations from the existing discharge, after full mixing under median and low-flow (7-day Mean Annual Low Flow) conditions. In agreement with the measured results above, predicted contaminant concentrations in median flow conditions saw less than minor concentration increases and no change to the number of exceeding contaminants. Meanwhile, low-flow scenario contaminant concentration predictions indicate the potential for a moderate increase (assuming no treatment by the wetland) across the contaminant suite and exceedances of *E. coli* and Faecal Coliforms above HBRC RRMP PC 6 guidelines.

Current discharge mass-load estimates of the existing WWTP discharge indicate a contribution of 857 kg/yr of total nitrogen, and 221 kg/yr of total phosphorus. This accounts for 0.1% and 1.3% of the total nutrient catchment loads for the MZ3 catchment, measured at the relevant downstream HBRC water quality monitoring location.

The results of the existing discharge analysis in this report conclude that the discharge from the oxidation pond is predicted to be causing a negligible effect on contaminant concentrations at, and above, median flow conditions, while a moderate increase in nutrient (phosphorus) and microbiological (faecal coliforms and *E.coli*) contaminant concentrations is likely to occur in the Makaretu River downstream of the discharge in low stream flow (MALF) conditions.

The two future development stages allow for treated wastewater to be mainly discharged to the farmland adjacent to the WWTP. This will reduce the quantity of discharge directly to the river, with low-flow discharge limits set at half median and median for stages one and two. This is expected to mitigate the contaminant concentration increases identified in the MALF current discharge effects assessment.

Mass balance predicted downstream concentrations for the two future stages show a significant improvement across all measured contaminants in the downstream Makaretu River receiving environment (when discharge to the HRLP occurs) at realistic worst-case scenarios. This is a function of the reduced discharge volume occurring at generally higher flows resulting in higher dilution factors. Importantly, the discharge to the HRLP will only occur for some of the time when soil conditions prevent irrigation from occurring.

Overall, given the HRLP discharge will be periodic and limited to river flows about median flow at stage 2, overall adverse effects of the proposed discharge on the water quality of the Makaretu River are predicted to be negligible.

When comparing the existing nutrient contribution to catchment loads, the future proposed nutrient load represents a four-fold decrease in phosphorus contributions to the river system. Nitrogen reductions are also reduced, however the contribution of nitrogen to the MZ3 catchment is already minor.

The improvements of the future discharge are likely to contribute to meeting the relevant PC6 water quality targets for the Tukituki Catchment MZ3 – Ruataniwha South. In particular, the reduced phosphorus loads will contribute towards improved water quality outcomes in the Makaretu catchment, in which phosphorus has been identified a contaminant of concern. At times when discharge to land is not possible, the discharge to the HRLP will not cause any relevant water quality guidelines to be exceeded in the Makaretu River.

This indicates that the proposed discharge will contribute towards achieving the PC6 objectives (OBJ TT1 and OBJ TT2) through the diversion of treated wastewater from the river to adjacent farmland. This will contribute towards improved water quality and ecology outcomes for the Makaretu River and wider Tukituki Catchment.

1 Introduction

1.1 Background

Central Hawke's Bay District Council (CHBDC) holds resource consent to discharge treated municipal (domestic) wastewater from the Takapau Wastewater Treatment Plant (WWTP) into or onto land (wetland) in circumstances which will result in that contaminant entering water. Resource consent for the discharge was originally granted by the Hawke's Bay Regional Council (HBRC) on 22 December 1999.

The discharge was re-consented in 2006 subject to a suite of conditions and a maximum discharge rate of 216 cubic metres per day during dry weather. This consent was due to expire in May 2018 when CHBDC applied for a three-year extension to investigate alternative discharge options. This application for extension was granted and will expire on 31 October 2021.

The Takapau WWTP services the community of Takapau (approx. 215 households) and consists of one oxidation pond with an aerator. Discharge is to a wetland which then overflows and/or soaks to the Makaretu River on the downstream side of the Burnside Road bridge approximately 15 km upstream of the Tukipo and Tukituki River confluences. The Makaretu River is generally in a good condition with respect to nutrient and bacterial contamination and ecological indicators. It has a median flow of 1.4 m^3/s and can be subjected to large flood flows in winter months.

The current Takapau WWTP consent has conditions relating to volume, organic load (BOD_5) and total suspended solids (TSS). There are no conditions set for nutrient concentrations (nitrogen and phosphorus) or microbiological quality. Further conditions include regular monitoring of the oxidation pond discharge, as well as at downstream and upstream monitoring locations. The CHBDC produces an annual monitoring and compliance report for the oxidation pond. The discharge has struggled to meet consent compliance conditions set for maximum daily flow and TSS over the last five years. Conditions for $cBOD_5$ were not met in 2018.

Recent investigations have been made to identify a number of future treatment and discharge options. In summary, a staged approach has been chosen to transition the discharge from the Makaretu River to a land discharge to adjacent farmland. The final design is for full discharge to farmland as a supplement to fertiliser and irrigation while allowing for a contingency discharge to the river when the soil conditions prevent irrigation.

1.2 Purpose of this Report

This report is set out in the following sections:

- A description of the receiving environment of the Makaretu River and surrounding catchment;
- A review of background information on the Takapau WWTP including investigations undertaken for the previous consent application;
- A review of existing water quality data from HBRC to assess the current state of the receiving environment of the Makaretu River;
- A review of existing treated wastewater data and CHBDC water quality monitoring results from the Makaretu River;
- An assessment of effects of the existing discharge on the water quality of the Makaretu River; and
- An assessment of potential discharge effects of future development stages for the Takapau WWTP on the water quality of the Makaretu River and the wider Tukituki catchment.

The overall purpose of this report is to assess the effects on the water quality of the Makaretu River of the proposed wastewater discharge for which new consents will be sought. An assessment of groundwater considerations is provided in **Appendix A.**

2 Description of the Environment

2.1 Catchment Overview

The Makaretu River sub-catchment is approximately 80 km^2 and located in the south-western, inland area of the Hawke's Bay Region (Figure 1). The sub-catchment is a linear feature draining from the southwest in the foothills of the Ruahine Ranges (~400 m above sea level (asl)) onto the Ruataniwha Plains. The general physical geography within the sub-catchment is characterised by flat plains, flood plains and gently undulating plains of alluvial origins. Intermediate river terraces of around 10,000 years old are a feature across the wider Ruataniwha Plains, while low terraces generally follow the course of the Makaretu River[1].

The Makaretu River sub-catchment is bordered to the north and south by similarly defined, linear sub-catchments – Tukipo and Porangahau respectively – all of which are contained within the wider Tukituki catchment management zone. The Makaretu River, along with the Tukipo River and Porangahau Stream (via the Maharakeke River), converge with the Tukituki River approximately 5 km upstream of Waipukurau.

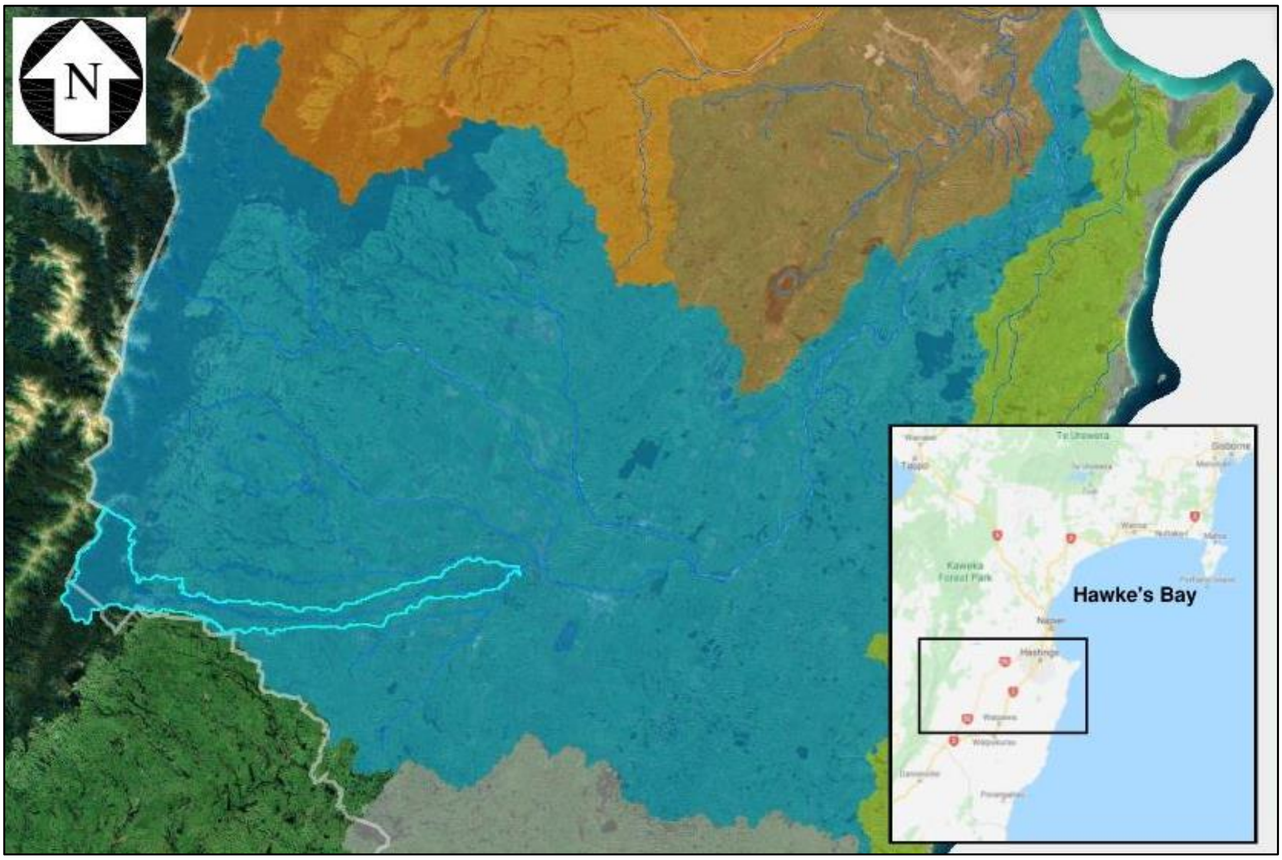

Figure 1. Makaretu River sub-catchment (aqua polygon), Tukituki catchment management zone (blue fill). Inset - Location of catchment in Hawke's Bay region. Source: HBRC Map Viewer.

2.1.1 Climate

The climate in Central Hawke's Bay is significantly influenced by the mountain ranges to the west. The ranges provide a sheltering effect from the predominantly westerly winds, which affect the climate patterns in

[1] Forbes, A., et al. (2011) *Tukituki Catchment Terrestrial Ecology Characterisation*. Prepared for HBRC Plan No.4294 by MWH

New Zealand. This results in a temperate climate with lower than average rainfall. In summer, droughts are not uncommon and this has a significant influence on the waterways in Central Hawke's Bay.

The Makaretu sub-catchment typically features warm temperatures, high solar radiation, and moderate to low annual water deficits. Median annual total rainfall in the sub-catchment trends from ~1,600 mm in the Ruahine foothills to <800 mm west of Waipukurau[2].

2.1.2 Geology and soils

Geology within the sub-catchment is greywacke basement overtopped by late Quaternary alluvium and colluvium consisting of unconsolidated to poorly consolidated mud, sand, gravel and peat. Localised areas of limestone are present to the south of the sub-catchment toward the eastern hills[3].

Soils in the Makaretu catchment are predominantly well-drained, allophanic soils in the upper extents. Allophanic soils have a large affinity for phosphate, are porous and have a low-density structure with weak strength. Moderately well-drained and poorly drained areas are present in the lower areas of the catchment. Soil classification varies between pallic (loess), and gley (saturated) in these areas[4].

2.1.3 Land cover and management context

Land use in the Makaretu River catchment appears to be predominantly sheep and beef farming with a small amount of forestry near the headwaters. Over 90% of the sub-catchment is occupied by high producing exotic grassland associated with the aforementioned agriculture. Other land uses, each making up about 1% of the sub-catchment land cover, include orchards, perennial crops, short rotation cropland, riparian edge protection plantings and riparian forests[1].

The Takapau township is outside of the Makaretu sub-catchment and sits within the Porangahau stream sub-catchment (Figure 2). Takapau has an approximate population of 522 permanent residents according to the 2013 census[5].

The Tukituki catchment is designated into five management zones by the Hawke's Bay Regional Council Regional Resource Management Plan (HBRC RRMP). The Makaretu River sub-catchment sits within Management Zone 3 – Ruataniwha South. Generally, microbiological water quality is good across this catchment area and improving over time. Water clarity is also considered acceptable across the catchment.

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[2] Chappell, P. (2013) *The Climate and Weather of Hawke's Bay. 3rd edition*. NIWA Science and Technology Series 58, 44pp.

[3] Heron D. W. (custodian) (2014) *Geological Map of New Zealand 1:250 000*. Institute of Geological & Nuclear Sciences

[4] Manaaki Whenua (2020) Soils Portal. Soil Data and Maps. https://soils.landcareresearch.co.nz/soil-data/s-map-and-s-map-online/

[5] Stats NZ (2018) 2013 Census Data - http://archive.stats.govt.nz/Census/2013-census.aspx#gsc.tab=0

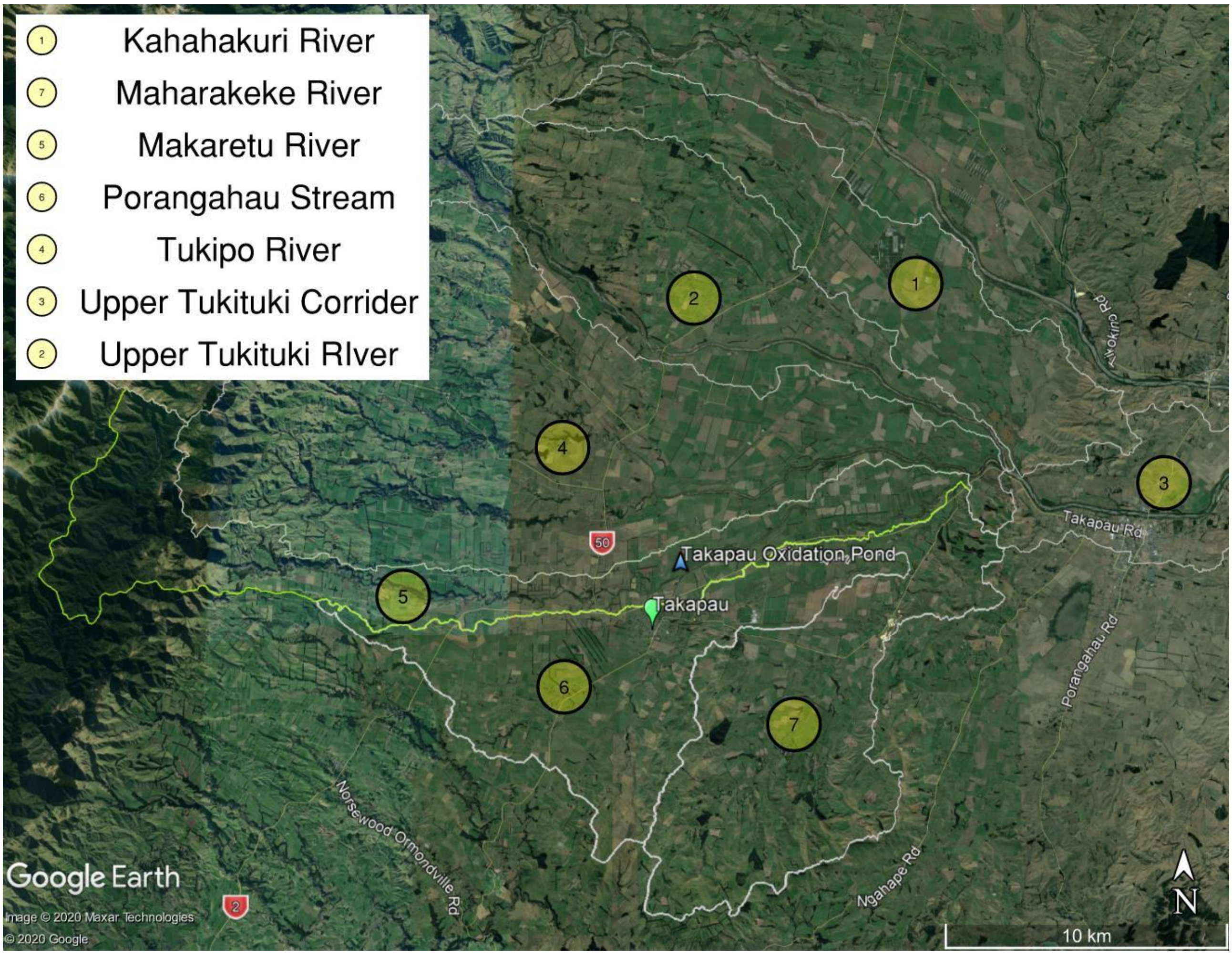

Figure 2. HBRC RRMP PC6 Water Quality Management Zone 3 – Ruataniwha South divided into seven sub-catchments.

2.1.4 Tukituki Catchment

The largest issue in the wider Tukituki catchment is understood to be nutrient enrichment and associated periphyton growth, with a general degradation from upstream to downstream in the catchment[6]. Macroinvertebrate communities also follow a pattern of degradation further downstream in the catchment.

Dissolved Reactive Phosphorus (DRP) and Dissolved Inorganic Nitrogen (DIN) have been identified as notable contaminants of concern, with a significant portion of DRP historically attributed to the Waipawa and Waipukurau oxidation pond discharges. Following treatment plant upgrades, non-point source pollution is now thought to be the greatest contributor of nutrients in the upper and middle Tukituki catchment area[7]. Nutrient concentration ratios indicate that the system is likely to be generally co-limited or N-limited during low river flows, meanwhile phosphorus limitation is likely to occur during higher flow rates[6].

[6] Aussiel, O. (2008) *Water Quality in the Tukituki Catchment – State, trends and contaminant loads*. Aquanet Consulting Ltd for Hawke's Bay Regional Council.

[7] Aussiel, O. et al. (2016) *Tukituki River Catchment. State and Trends of River Water Quality and Ecology 2004-2013.* Hawke's Bay Regional Council. Report No. RM16-09 – 4788.

2.2 Makaretu River

2.2.1 Hydrology

The flow in the Makaretu River is a generally low-flow system that reacts quickly to strong rainfall events. HBRC have spot flow gauge records of the Makaretu River at Speedy Road Bridge, approximately 9 km downstream of the treated wastewater discharge. The median flow is 1.4 m^3/s, the highest flow recorded is 54.9 m^3/s. Table 1 gives the summary statistics based on HBRC flow monitoring of the Makaretu River[8].

Table 1. Correlative flow (m^3/s) statistics in the Makaretu River at Speedy Road Bridge*

			% of time flow is less than				
Min	Max	Mean	5%	25%	Median	75%	95%
0.0	54.9	2.2	0.2	0.5	1.4	2.6	7.0

*Makaretu spot gauged flows correlated with continuous Tukituki River at Tapairu Road flow record

The section of the Makaretu River around the treated wastewater discharge is a relatively shallow braided river with a gravel substrate (Figure 3). There are two semi-permanent river braids, each approximately 10 m wide, that join together ~50 m downstream of the treated wastewater discharge. The width of the river gravel plain is approximately 50 m at the point of discharge. Historical imagery from Google Earth indicates that the main branch of the river shifts across the braid plain at a sub-annual timescale.

Figure 3. Makaretu River at point of discharge looking upstream

2.2.2 River Water Quality

HBRC monitor water quality and flow (non-continuously) in the Makaretu River at two locations; the State Highway 50 (SH50) bridge and upstream of the confluence with the Maharakeke Stream (US Maharakeke in Figure 4). HBRC monitoring occurs infrequently, approximately annually to bi-annually. CHBDC monitor water quality on a monthly basis at locations 50 m upstream, 50 m downstream and 400 m downstream of the discharge as required under the conditions of the current consent (Figure 4 - inset).

[8] Correlated flow data provided by Hawke's Bay Regional Council

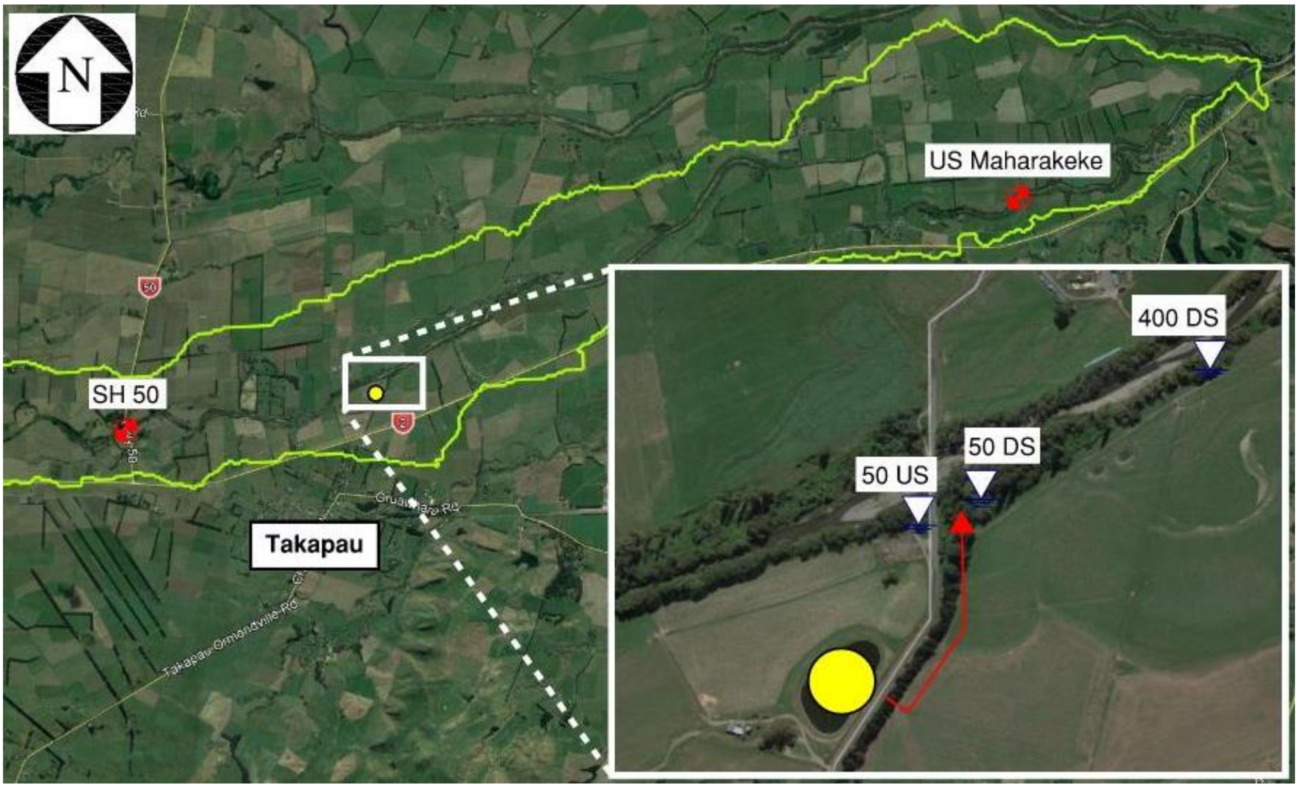

Figure 4. HBRC (red squares) and CHBDC (white triangles - inset) water quality monitoring locations along the Makaretu River with Takapau WWTP (yellow circle), the discharge path (red arrow) and Makaretu sub-catchment (lime green).

A summary of recent water quality results for the Makaretu River 50 m upstream of the treated wastewater discharge is presented in Table 2.

Table 2. CHBDC Water quality monitoring results from 50 m upstream of Takapau WWTP. Approx. 70 samples taken monthly between 2014 and 2020 (June).

Parameter	5%	Median	95%	Criteria	Trigger[2]
$cBOD_5$ (mg/L) *	<1	<1	3		
Chemical Oxygen Demand*	<15	<15	17.0		
Total Ammoniacal Nitrogen (mg/L)	<0.01	0.01	0.02	0.035[5] / 0.05[5] / 0.24[3]	
Nitrate (mg/L)	0.01	0.21	1.16	$3.8_{(a)}$ / $5.6_{(b)}$	
Dissolved Inorganic Nitrogen (mg/L) *	0.01	0.07	0.32	0.8	
Total Nitrogen (mg/L) *	0.04	0.16	0.39	0.281[2]	
Total Phosphorus (mg/L) *	0.016	0.034	0.044	0.023[2]	
Dissolved Reactive Phosphorus (mg/L)	0.007	**0.017**	**0.031**	0.010	
Total Suspended Solids (mg/L)	2	3	182		
Faecal Coliforms (CFU/100ml)	34	110	**600**	200[4]	
E. coli (CFU/100ml) *	22	140	**300**	261-550	>550[1]
Horizontal Visibility (Water clarity)	1.2	3.68	7.424	>3.0	
pH	7.3	7.7	8.0	7.27 – 7.8[2]	
Temperature	6.9	12.0	19.4	Sustain aquatic habitat	
Dissolved Oxygen (ppm)[#]	9.18	10.61	12.09	>80%	82-100
Conductivity (μS/cm)	6.4	9.3	11.5	86[2]	

Parameter	5%	Median	95%	Criteria	Trigger[2]
Note: Orange highlight indicates the ANZECC chemical and physical stressor[2] trigger are exceeded, red highlight indicates the NPS:FM national bottom lines[5], , or relevant toxicity triggers are exceeded, and **bold text** indicates the HBRC RRMP[1] target or regional river guidelines are exceeded[6].					
* Sampling of these analytes began in August 2019 (11 monthly samples)					
# Dissolved Oxygen criteria and trigger values are presented as percentage saturation (%) and should not be compared directly with the datasets (ppm)					
[1] All parameters are Hawkes Bay Regional Resource Management Plan Change 6 (2014) Surface water quality limits, targets and indicators for the Tukituki catchment (Tables 5.9.1B and C) – Zone 3, Mainstem, except where otherwise stated.					
[2] All parameters are ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated					
[3] National Policy Statement for Freshwater Management (NPS-FM) – Attribute States B, 95% species protection level (annual median / maximum)					
[4] Hawke's Bay Regional Resource Management Plan (RRMP) (republished as at 1 October 2015). Note that the faecal coliform surface water guideline value represents the concentration of contaminant in the water body that should not be exceeded after reasonable mixing.					
[5] NPS-FM – Attribute State A, 99% species protection level (annual median / maximum)					

This water quality summary indicates the Makaretu River is generally compliant with regional and national criteria except for TP and DRP. The median values of TP and DRP at the 50 m upstream site are slightly above their respective trigger values. The median concentrations of FC and E. coli, while below their relevant guidelines, are noteworthy. The 95th percentile values of TN, TSS, FC, E. coli and pH exceed their respective trigger values which indicate that the Makaretu River experiences poorer quality, particularly bacterial contamination, only occasionally. This is likely to be related to high-flow events.

Previous investigations and publicly available HBRC monitoring data have classified ecological water quality for the Makaretu River with regular MCI scores of >100[9]. This is indicative of good quality habitat for freshwater macro-invertebrates.

2.2.3 Sensitivity of the Makaretu River Receiving Environment

Identified water quality issues for the Makaretu River – independent of the treated wastewater discharge – include elevated nutrient levels (phosphorus) along with below target macroinvertebrate communities (MCI scores <120) [10].

Similar to the wider Tukituki catchment trends, the Makaretu River both upstream and downstream of the discharge is generally classified as N-limited at low river flows, such that there is more phosphorus present than can be used in a low flow scenario[11]. Consequently, the addition of more nitrogen will tend to stimulate macrophyte and periphyton growth when river flow is low and temperature conditions are favourable to it.

2.3 Existing Wastewater Treatment System

2.3.1 Site Location and Description

The Takapau WWTP system is a single pond treatment system located on Burnside Road adjacent to Makaretu River Bridge in the Central Hawkes Bay, approximately 600 m north of the Takapau township

[9] Ausseil, et al. (2017) *Takapau WWTP discharge to the Makaretu River: Summary of Current Effects on Freshwater Quality and Ecology*. By Aquanet Consulting Ltd for CHBDC.

[10] Death, F. & Egan, A. (2019) *Takapau Wastewater Discharge to the Makaretu River: Annual Ecological Monitoring.* Prepared for CHBDC by Aquanet Consulting Ltd.

[11] Ausseil, O., Feck, A. & Death, F. (2018) *Takapau WWTP discharge to the Makaretu River: Assessment of Effects on Freshwater Quality and Ecology.* Prepared for CHBDC by Aquanet Consulting Ltd.

(Figure 4). The adjoining land use is predominantly pastoral. Treated wastewater is discharged, via an effluent chamber, to a natural wetland before flowing freely into the Makaretu River.

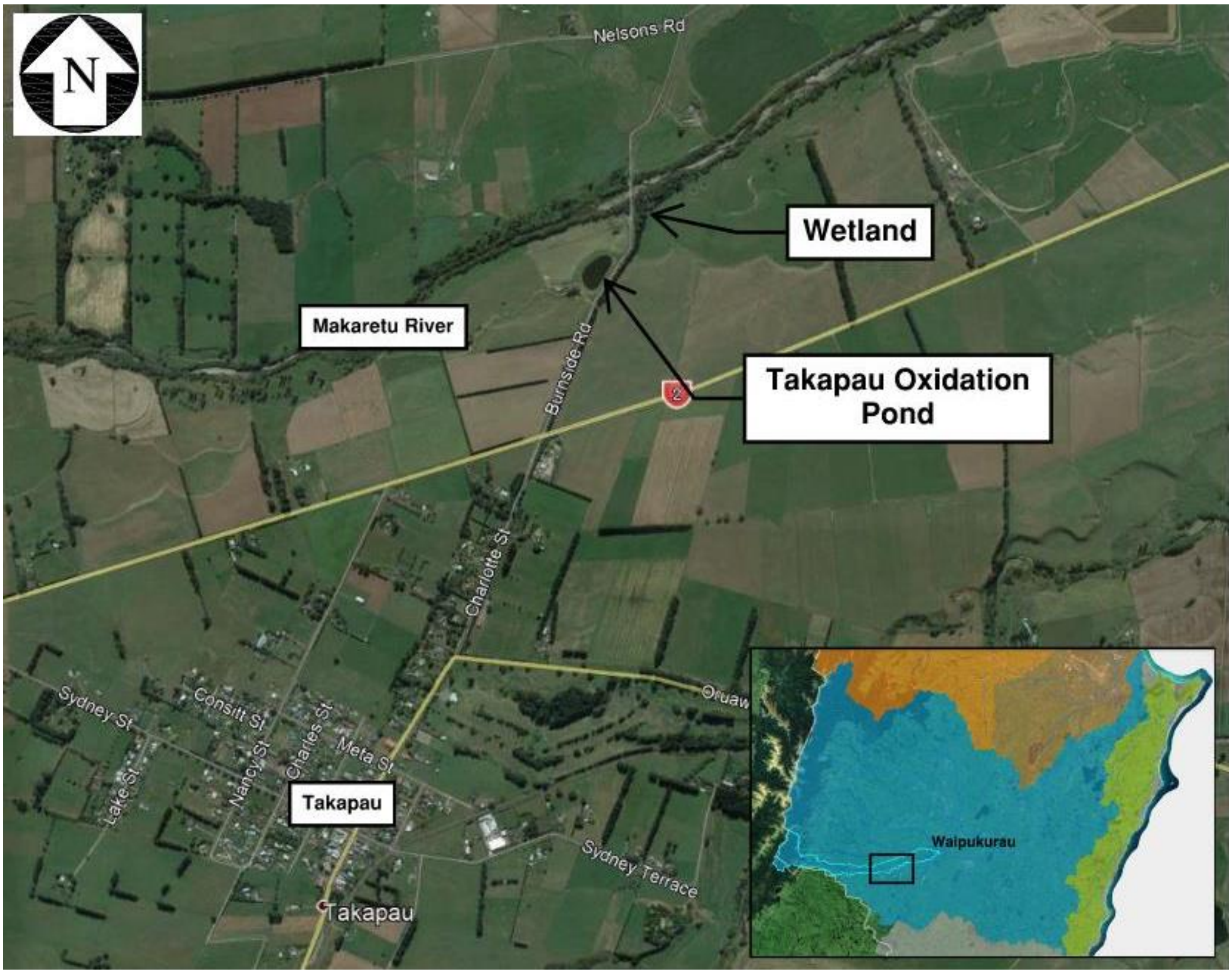

Figure 5. Location of the Takapau WWTP that services the Takapau Township. Inset - Tukituki and Makaretu watersheds. Source: Google Earth and HBRC Map Viewer.

The system consists of a single clay-lined oxidation pond approximately 0.6 ha in size. Aeration for the treatment process is provided by algae and one mechanical surface aerator. The pond services an estimated 215 households with an approximate population of 530 people contributing to the sewerage scheme. The wastewater received at the WWTP is predominantly of domestic origin.

2.3.2 Relevant Consent Limit Conditions

In accordance with the provisions of the Resource Management Act 1991 (RMA), and subject to its conditions, the Hawke's Bay Regional Council granted the resource consent on the 10th of December 2018 (Consent No. DP180115W and DP180124a) for CHBDC to discharge treated municipal (domestic) wastewater from the Takapau WWTP into or onto the land (via wetland) in circumstances which will result in that contaminant entering water.

Details of the Resource Consent include:

- Effluent to be discharged – Treated municipal sewage
- Rate of discharge – max 2.5 L/s (216 m^3/day) based on dry weather flow (calculation method not stated in consent)
- Consent duration – expires 31 October 2021

The discharge consent includes conditions summarised as follows:

- General – outlines the physical works to be undertaken on the plant
- Performance – the maintenance of the wetland and the following effluent quality parameters (Table 3):

Table 3. Takapau WWTP discharge consent conditions

Parameter	Maximum Value	Failures Allowed
Dry weather flow	2.5 L/s (216 m^3/d)	0
Total suspended solids	100 mg/L	0
Carbonaceous Biochemical Oxygen Demand – 5 day ($cBOD_5$)	60 mg/L	0

- Monitoring – outlines the incoming and outgoing flow monitoring requirements
- Discharge quality sampling – outlines the requirements for the sample type, constituents to analyse for and the monitoring frequency
- Receiving Water Quality Monitoring – outlines the requirements for sampling at Makaretu River
- Aquatic Ecology Monitoring – outlines the requirements for macroinvertebrate sampling in Makaretu River
- Groundwater Monitoring – outlines the requirements for a Groundwater Monitoring Plan (GMP)
- Non-compliance – outlines the steps to be taken in the event of the exceedance of the effluent standards
- Reporting – outlines the Reporting requirements and dates.

2.3.3 Current System Performance

Flows from the system are monitored by CHBDC as part of the current consent conditions. The Takapau WWTP Compliance Report for the year ending 30 June 2019 was provided to Beca for review along with the sampling data Takapau DP180011W – Quality Monitoring and Wastewater Outflow Charts. The latter contains flow data since 2008 and the Quality Monitoring file contains data since 1999.

The Takapau WWTP was given a compliance grade of moderate non-compliance for the 2019 hydrological year (July 2018 to June 2019). Table 4 summarises compliance for 2018-2019, based on the data reported to HBRC, with DWF compared with the generally used seven days without rain. The maximum daily total flow of 749.6 m^3/day was on 6th September 2018, where there was a total of 129 mm of rain the three days leading up to the maximum flow.

Table 4. Takapau WWTP discharge consent compliance 2018/19

Parameter	Consent Limit	Permitted Exceedance	Reported Exceedance[1]	DWF Exceedance[1]	Maximum Value
DWF L/sec	<2.5	0/365	164/365	11/34	9.05
m^3/day	<216		140/365	4/34	749
TSS (mg/L)	<100	0/12	1/12	-	105
Filtered $cBOD_5$ (mg/L)	<60	0/12	0/12	-	37

[1] Reported exceedance is a count of any day where flow exceeds consent limits

[2] DWF Exceedance is based on flow exceedance coincident with 7-days of no rain.

Table 5 summarises compliance for flow, $cBOD_5$, and TSS for the last five years.

Table 5. Summary of resource consent compliance - red non-compliance, green fully compliant - by reporting year (July).

Parameter	15/16	16/17	17/18	18/19	19/20 YTD
Flow	(red)	(green)	Unknown#	(red)	(red)
TSS*	1/14 (red)	3/14 (red)	2/13 (red)	1/13 (red)	(green)
$cBOD_5$*	(green)	(green)	1/13 (red)	(green)	(green)

* Number of failing samples vs number of samples taken
\# Unknown – HBRC audit not available (17/18)

The oxidation pond discharge was generally non-compliant for consent conditions related to flow and TSS over the last five years. Exceedances in effluent total suspended solids tend to relate to the summer months when algae concentrations are at their highest in the pond. The condition related to $cBOD_5$ is generally compliant but was non-compliant in 2017/18.

General treated wastewater quality monitoring of the pond discharge is presented in Table 6. Treated wastewater quality samples are collected once every month at the outlet of the oxidation pond, prior to discharge through the wetland. These parameter concentrations represent the discharge prior to reasonable mixing with the Makaretu River.

Table 6. HBRC water quality monitoring results of the Takapau WWTP discharge: July 2014 to June 2020.

Parameter	5%	Median	95%
$cBOD_5$ (mg/L)	10	26	54
Chemical Oxygen Demand	51	113	196
Total Ammoniacal Nitrogen (mg/L) *	0.01	0.33	19.97
Nitrate (mg/L) *	0.05	0.29	7.58
Dissolved Inorganic Nitrogen (mg/L) *	0.67	5.80	20.06
Total Nitrogen (mg/L) *	6.0	14.1	24.6
Total Phosphorus (mg/L) *	2.14	3.82	5.36
Dissolved Reactive Phosphorus (mg/L) *	1.71	2.67	3.81
Total Suspended Solids (mg/L)	13	79	155
Faecal Coliforms (CFU/100ml)	2,090	27,000	160,000
E. coli (CFU/100ml) *	636	18,000	76,850

* Sampling of these analytes began in February 2019 (16 monthly samples)

2.4 Summary

The Makaretu River drains a catchment of approximately 80 km^2 in the south-western corner of Hawkes Bay. The catchment headwaters originate in the foothills of the Ruahine Ranges and flow onto the Ruataniwha Plains. Pastoral agricultural land uses are present in the catchment, with sheep and beef farming prevalent.

The climate in the area is warm and dry, prone to long dry spells in the summer as well as heavy rainfall events in the winter. The Makaretu River reflects this by having generally low median and 95^{th} percentile flow rates but with a high maximum flow rate in response to rainfall events.

The Makaretu River, upstream of the Takapau WWTP discharge, has consistently elevated levels of TP and DRP. Nitrogen, total suspended solids and microbial contaminants (*E. coli* and Faecal coliforms) occasionally exceed trigger values (95^{th} percentiles).

The Takapau WWTP discharge has consent conditions based on maximum daily flow volumes, total suspended solids and chemical biological oxygen demand. The discharge over the last five years has been largely non-compliant with respect to flow (3/5 yrs.) and TSS (4/5 yrs.). Conditions set for $cBOD_5$ were not met for just one of the last five years. “No exceedance” conditions are generally considered to be too stringent and, more recently, since the Wastewater Monitoring Guidelines were published in 2002 which recommended against maximum consent limits, are being replaced with conditions that allow a small number of exceedances or set an upper percentile as a consent condition. While the water quality conditions for the Takapau WWTP consent are overall non-compliant, actual exceedances are infrequent.

3 Historical Reporting and State of the Environment Documents

A number of investigations exist that relate to the discharge of treated wastewater to the Makaretu River. These investigations are largely related to ongoing consent monitoring and reporting conditions, while some reference to the state of the environment in the Tukituki catchment is also included. These reports are summarised below and referred to as footnote references throughout the rest of this document where applicable.

3.1 Takapau Wastewater Discharge to the Makaretu River: Ecological Monitoring 2010 to 2019[9] [12] [13]

A number of reports are available reporting on the effects of the discharge with respect to water quality and ecological indicators. The most recent of which was provided to CHBDC in 2019, after the 2018 consent renewal. The summary of ecological monitoring presented below is an amalgamation of the annual monitoring reports provided to HBRC by CHBDC in accordance with the discharge consent conditions.

This review of water quality and ecological monitoring of the Takapau WWTP discharge includes statistical comparisons of historical consent monitoring and in-stream ecology datasets sourced from both CHBDC and HBRC. More recent macroinvertebrate investigations are also regularly reported on in accordance with the discharge consent conditions.

3.1.1 Methodology

A summary of monitoring results spanning the last decade from repeat Makaretu River sampling locations at 50 m upstream, 50 m downstream and 400 m downstream of the WWTP discharge is presented in these reports. The analysis of ecological data is assessed against the provisions of:

- The resource consent conditions (2006-2018);
- HBRC RRMP Plan Change 6 (2014); and
- The National Policy Statement for Freshwater Management (NPSFM) (2014, 2017 amendments) relevant numeric Attribute States.

3.1.2 Water quality

- HBRC RRMP Plan Change 6 (2014) limits for nitrogen were complied with both upstream and downstream of the Takapau WWTP discharge, while concentrations of phosphorus were generally above Plan Change 6 targets at both sites;
- NPS:FM assessments were carried out on ammoniacal nitrogen, nitrate nitrogen and dissolved oxygen instream data. Both sites generally fell within Attribute State A of the NPSFM for each parameter, which corresponds to the highest species protection level. It is noted that the instream Dissolved Oxygen (DO) data available are daytime 'spot' measurements, which do not provide any indication of night-time minima;
- Nutrient concentration ratios indicate that the growth of periphyton in the Makaretu River both upstream and downstream of the discharge are generally nitrogen limited at low river flows, with a shift towards co-limitation and then P-limitation conditions as stream flows increase.

[12] Strong, J. (2017) *Assessment of Biological Effects of Takapau WWTP Discharge to the Makaretu River, Central Hawke's Bay*. By EAM NZ Ltd for CHBDC.

[13] Death, F. & Egan, A. (2019) *Takapau Wastewater Discharge to the Makaretu River: Annual Ecological Monitoring*. By Aquanet Consulting Ltd for CHBDC.

3.1.3 Ecological Indicators

- Macroinvertebrate communities in the Makaretu River upstream and downstream of the discharge had biotic indices of fair to good water quality.
- Differences were apparent between upstream and downstream sites for most indices, but no statistically significant differences were observed between sites.
- Macroinvertebrate communities were similar upstream and downstream of the treated wastewater discharge with no statistically significant differences between sites. Average MCI scores for each site were below the HBRC RRMP Plan Change 6 (2014) minimum target of 120 in 2019 and have been since 2010. It is important to note that average MCI scores at all three monitoring locations and in the Makaretu River in general are above 100, indicative of good water quality habitat.
- There has historically been a general reduction in QMCI scores between upstream and downstream of the discharge, and the Plan Change 6 (2014) limit of no more than a 20% reduction in QMCI between upstream and downstream was exceeded in 2013 and 2014 between the upstream and 50m downstream sites, as well as in 2014 and 2015 between the upstream and 400m downstream sites. Conversely, a 31% increase (improvement) in QMCI downstream of the discharge was observed in 2019.
- Periphyton biomass was well below the HBRC RRMP Plan Change 6 (2014) target of 120 mg/m^2 at all three sites.
- Visual assessments of periphyton communities in 2019 showed cover by thick mats (consisting mostly of cyanobacteria) to be well below the HBRC RRMP PC6 target (and MfE guidelines) of 60% cover; and cover by very small amounts of long green filamentous algae at all three sites also well below the HBRC RRMP PC6 target (and MfE guidelines) of 30% cover (as has been the case since 2010). No bacterial or fungal growths (sewage fungus) were observed at any of the sites in 2019.
- The Autotrophic Index (AI), which represents the ratio of AFDW (ash-free dry weight) to Chlorophyll a and can be considered a measure of organic enrichment, indicated only mildly polluted waters for sites sampled on the Makaretu River in February 2019.
- Biomonitoring undertaken in 2019 suggests that the discharge from the Takapau WWTP does not appear to be having adverse effects on the aquatic ecology in this stretch of the Makaretu River.

3.1.4 Conclusion

Water quality parameters measured over the last decade indicate the Makaretu River is in a relatively good condition both upstream and downstream of the Takapau WWTP discharge. There is no evidence of the discharge causing any significant adverse effect on concentrations of key in-stream water quality determinants when upstream and downstream monitoring locations are compared. Furthermore, the most recent 2019 summer biological monitoring data indicates an improvement in QMCI results downstream of the discharge and does not show an effect of the Takapau WWTP treated wastewater on the macroinvertebrate community or on algal growth in the Makaretu River. Biological monitoring is undertaken in the summer months (Jan - Mar), at least three weeks after any significant rainfall events, in order to understand the effects of the discharge on biological indicators at low flows (i.e. worst-case).

4 Assessment of Effects of the Existing Discharge of Treated Wastewater

4.1 Introduction

This section describes an assessment of effects of the existing discharge of the treated wastewater discharge on the water quality of the Makaretu River. The effects are evaluated for the current discharge, based on both measured and predicted results. The measured effects use monitoring data from both upstream and downstream of the discharge to obtain a direct assessment of changes in water quality within the Makaretu River. The predicted effect is based on a combination of measured and estimated wastewater and receiving water flows and contaminant concentrations.

4.2 Assessment Methodologies

4.2.1 Water Quality Criteria

Effects of the treated wastewater discharge on the water quality of the Makaretu River were made against a range of relevant guidelines. Available guidelines include those from the HBRC Regional Resource Management Plan, Plan Change 6 (HBRC RRMP PC6, 2014). Surface water quality limits targets and indicators for the Tukituki River catchment are specific to five zones. The Makaretu River is a sub-catchment in Zone 3. The limits, targets and indicators, which have been used in this assessment are provided in the HBRC RRMP Tables 5.9.1A and 5.9.1B.

Additional guidelines and criteria have been sourced from the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2018), the Ministry for the Environment National Policy Statement for Freshwater Management (NPS-FM), the Ministry for the Environment Microbiological Assessment Categories (MAC) and the New Zealand Guidelines for Recreational Water Quality (Ministry for the Environment, 2003).

ANZECC presents a preferred hierarchy of types of guidelines values for water quality indicators. This hierarchy prioritises site-specific and/or local guidelines over regional and national guidelines. The assessment criteria for this report takes guidance from this preferred hierarchy.

Trigger values indicate that there is a ‘potential risk’ of adverse effects at a site. Trigger values are defined by the 80th percentile of indicators that are harmful at high values and/or the 20th percentile of indicators that cause problems at low values.

ANZECC (2018/2000) chemical and physical stressor and trigger values for the Makaretu River were identified using the MfE River Environmental Classification (REC) guide. The REC accounts for a range of natural factors that influence water quality (e.g., climate, topography and geology) and is widely used to study water quality patterns in New Zealand. The Makaretu River is classified as ‘Warm Dry Low-elevation’ by the REC database. Where applicable, REC (New Zealand) default guideline values (DGVs) for physical and chemical (PC) stressors are presented in Table 7 below, along with guidelines for different water quality parameters where relevant.

Table 7. Water quality assessment criteria

Parameter	HBRC RRMP[1]	ANZECC Stressor[2]	NPS-FM[3]
$cBOD_5$ (mg/L)			
Chemical Oxygen Demand			
Total Ammoniacal Nitrogen (mg/L)		0.24	0.03[5] / 0.05[5]
Nitrate-nitrogen (mg/L)	$3.8_{(a)}$ / $5.6_{(b)}$	0.195	2.4 / 3.5
Dissolved Inorganic Nitrogen (mg/L)	0.8		
Total Nitrogen (mg/L)		0.281	
Total Phosphorus (mg/L)		0.023	
Dissolved Reactive Phosphorus (mg/L)	0.010		
Total Suspended Solids (mg/L)		4.6	
Faecal Coliforms (CFU/100ml)	200[4]		
E. coli (CFU/100ml)	261-550 / >550		
Horizontal Visibility (Water clarity)	3.0		
pH		7.27 – 7.8	
Temperature	Sustain aquatic habitat		
Dissolved Oxygen (%)	>80%	82-100	
Conductivity (µS/cm)		86	
MCI	120		
Periphyton	120 / $30_{(b)}$ / $60_{(c)}$ / $50_{(d)}$		

[1] All parameters are Hawkes Bay Regional Resource Management Plan Surface water quality limits, targets and indicators for the Tukituki catchment (Tables 5.9.1B and C) – Zone 3, Mainstem, except where otherwise stated.

[2] All parameters are ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated

[3] National Policy Statement for Freshwater Management (NPS-FM) – Attribute States B, 95% species protection level (annual median / maximum)

[4] Hawke's Bay Regional Resource Management Plan (RRMP) (republished as at 1 October 2015). Note that the faecal coliform surface water guideline value represents the concentration of contaminant in the water body that should not be exceeded after reasonable mixing.

[5] NPS-FM – Attribute State A, 99% species protection level (annual median / maximum)

4.2.2 Measured Downstream Trends Analysis

Water quality data, collected by CHBDC over the last five years at 50 m upstream, 50 m downstream and 400 m downstream of the treated wastewater discharge, allows for a downstream trend analysis of water quality parameters. Assessing a significant difference of means between sampling locations upstream and downstream of the discharge enables the measured assessment of effects of the Takapau WWTP discharge on river water quality.

The means of 16 parameters – nine parameters from July 2014 to June 2020, seven parameters from July 2019 to June 2020 – were compared using a one-way T-test analysis at the 5% significance interval using the NIWA time trends software. The dataset at the 50 m upstream location was compared to the 50 m downstream dataset. Parameters identified as significantly different downstream of the discharge are then presented as a box plot comparison across all three monitoring locations (50 m upstream, 50 m downstream and 400 m downstream).

4.2.3 Mass Balance Methodology

Contaminant concentrations downstream of the Takapau WWTP discharge were modelled using mass balance calculations. The mass balance calculation is based on inputs from:

- The contaminant concentrations of the existing discharge based upon monthly monitoring between 2014 and 2020;
- The median background water quality in the Makaretu River upstream of the discharge (50 m upstream monitoring location); and
- Dilutions available based on proposed discharge volumes and the flow records of the Makaretu River.

The predicted water contaminant concentration (C_x) at the receiving water downstream of discharge is given by Equation 1:

$$C_x = \frac{(C_d - C_b)}{TD + 1} + C_b$$

Where C_d is the contaminant concentration of treated wastewater; C_b is the background contaminant concentration in the receiving environment; and TD is the total dilution.

The total dilution factor assumes full mixing when the discharge plume is evenly mixed across the full width of the receiving waters. Higher contaminant concentrations will occur within the discharge plume close to the point of discharge. The proposed reasonable mixing zone is discussed in Section 4.2.4.

The mass balance calculations for the predicted water quality downstream of the discharge in the Makaretu River are run under a worst-case low-flow scenario as well as a standard median flow scenario. The low-flow calculation is estimated from the 7-day mean annual low flow (MALF) metric, this is understood to be the absolute lowest weekly flow in the river for any particular year and is therefore uncommon. The MALF is used to estimate the effect of the treated wastewater discharge at lowest river flows because there is a low probability that the monthly sampling has occurred on a day that reflects MALF conditions.

4.2.4 Catchment Mass Loading Analysis

Estimations of mass load contributions were undertaken to understand the relative contribution of nutrients from the Takapau WWTP, to the wider catchment system. This assessment compares the nutrient load discharged from the WWTP to two downstream HBRC monitoring locations: Tukituki at Tapairu Road and Tukituki at Red Bridge. The Tapairu Road monitoring location can be considered representative of the Tukituki Catchment Zone 3. The Red Bridge location is the most downstream monitoring point on the Tukituki River and provides an understanding of the Takapau WWTP mass-load contribution to the wider Tukituki catchment (as shown in Figure 6).

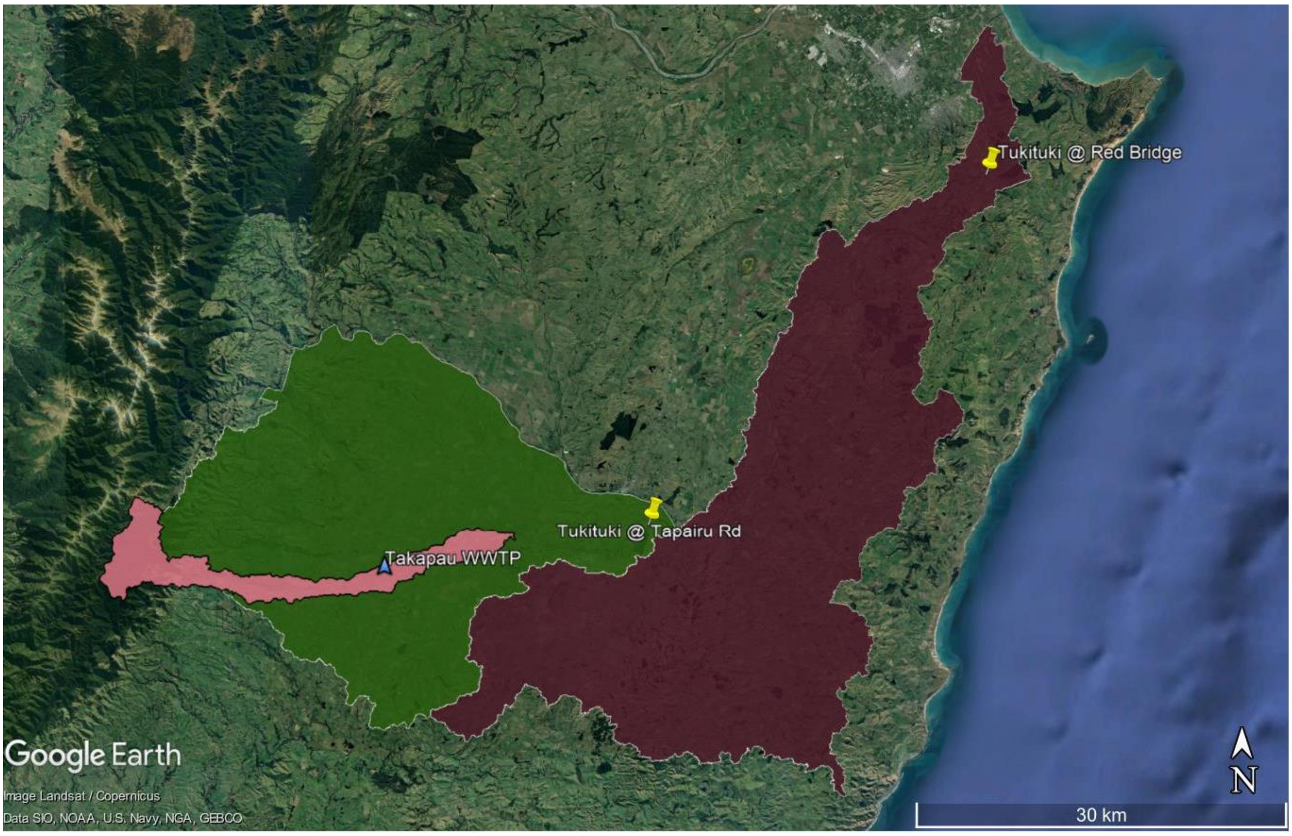

Figure 6. HBRC Monitoring Locations at the bottom of Tukituki PC6 Catchment Zones 3 (Green), and 1 (Maroon). Makaretu sub-catchment (Pink)

Nutrient mass-loads (Total Phosphorous and Total Nitrogen) of the Takapau WWTP treated wastewater discharge and the HBRC monitoring location at Tukituki River at Tapairu Road were calculated using the "Averaging" method[14] to understand the relative nutrient contribution of the Takapau WWTP to the sub-catchment. The mass-load averaging method uses average flow and average contaminant concentrations to estimate the nutrient mass loads across the 2015-2019 hydrological years (July 2015 to June 2020).

4.2.5 Reasonable Mixing

The RMA (1991) requires that any standards imposed through classification of waters or under Section 107 of the RMA should be met "after reasonable mixing". This implies the existence of a zone in which the underlying standards need not be met. The RMA however stops short of giving clear guidance about what constitutes reasonable mixing. It may be implied that the area of water required for "reasonable mixing" should be minimised and any adverse effects within the "reasonable mixing zone" should not frustrate the management objectives for the waters.

Policy 72 in Section 5.4.6 **(a)** of the Hawke's Bay Regional Resource Management Plan states that:

> *For the purposes of this Regional Plan, "reasonable mixing in surface water" of contaminants in surface water will generally be considered to have occurred as follows:*
>
> a. *In relation to flowing surface water bodies, at whichever of the following is the least:*

[14] Ausseil, O. (2008) *Water Quality in the Tukituki catchment – State, Trends and Contaminant Loads*. Prepared for Hawke's Bay Regional Council. Aquanet Consulting Ltd Client Report.

> i. *A distance 200 metres downstream of the point of discharge*
>
> ii. *A distance equal to seven times the bed width of the surface water body, but which shall not be less than 50 metres, or*
>
> iii. *The distance downstream at which mixing of contaminants has occurred across the full width of the surface water body, but which shall not be less than 50 metres.*
>
> *Alternatively, for activities that are subject to resource consents, "reasonable mixing" may be determined on a case by case basis through the resource consent process*.

A review of historical aerials on Google Earth shows that the "bed width" of the Makaretu River at the point of discharge is subject to much variability as a function of braided river channel dynamics. As such, a definition of "reasonable mixing" under Item *ii.* of Section 5.4.6 **(a)** is subject to change and difficult to validate. Further, in the absence of a mixing study to inform Item *iii.* of Section 5.4.6 **(a)**. For the purposes of this report, the point of reasonable mixing is assumed to be 200 m downstream of the treated wastewater discharge.

4.3 Measured Effects on Makaretu River

As discussed in Section 4.2.2, CHBDC carry out monthly monitoring 50 m upstream, 50 m and 400 m downstream of the Takapau WWTP discharge point as part of consent conditions. While there has been no sampling undertaken at the extent of "reasonable mixing" (200 m), it can be assumed that the 50 m downstream location is within the zone of reasonable mixing and, therefore, any analysis undertaken with this dataset can be considered as conservative. Conversely, the 400 m downstream sampling location is understood to be outside the zone of reasonable mixing and should reflect the full downstream effect, if any, of the Takapau WWTP discharge on the Makaretu River.

The following section presents analysis from a five-year record of measured water quality parameters collected at the three monitoring locations. A number of parameters were added to the monthly analysis in June 2019 following updated conditions in the 2018 consent renewal.

4.3.1 Comparison of Upstream and Downstream Monitoring Locations

A comparison of sites directly upstream (50 m) and downstream (50 m) of the discharge point to the Makaretu River is provided in Table 8**,** showing the range and median difference directly upstream and downstream of the discharge. A positive difference represents an increase at the downstream location, while a negative difference represents a decrease downstream.

The difference between upstream and downstream water quality is shown in terms of the absolute differences in medians (units), and as a percentage of the upstream (%). Testing the significance of the difference in the upstream and downstream sample results used a paired equivalency test using NIWA's Time Trends software, with a significance level of 0.05, an upper bound of +10% and a lower bound of -10%. The paired equivalency test investigates any difference between upstream and downstream samples taken on the same day.

Table 8. Water quality differences in the Makaretu River directly upstream and downstream of the discharge point

Parameter[1]	Upstream 50 m		Downstream 50m		Change	Evidence*
	Median	Range	Median	Range		
cBOD$_5$ [2] (mg/L)	<1	0-3	1	0-3	None	Strong
COD [2]	8	0-18	8	0-8	None	Strong
NH_4-N (mg/L)	0.01	0.01-0.07	0.01	0.01-0.06	**Increase**	**Trivial**
Nitrate-N (mg/L)	0.17	0.01-2.24	0.18	0.01-1.46	None	Strong
DIN [2] (mg/L)	0.07	0.01-0.35	0.12	0.01-0.38	**Increase**	**Trivial**
Total-N [2] (mg/L)	0.16	0.03-0.39	0.20	0.05-0.45	**Increase**	**Trivial**
Total-P [2] (mg/L)	0.034	0.016-0.050	0.038	0.018-0.070	**Increase**	**Trivial**
DRP (mg/L)	0.017	0.003-0.050	0.020	0.003-0.060	**Increase**	**Trivial**
TSS (mg/L)	<3	0-3060	<3	0-3570	Increase	Inconclusive
FC (CFU/100ml)	120	0-3700	140	0-3100	Increase	Inconclusive
E. coli [2] (CFU/100ml)	140	0-300	100	0-400	Increase	Inconclusive
pH	7.7	7.3-8.6	7.6	0.1-8.8	**Decrease**	**Trivial**
Temp	12.0	6.6-22.1	12.3	0.1-21.9	**Increase**	**Trivial**
DO (ppm)	10.61	0.05-12.62	10.50	0.05-13.14	**Decrease**	**Trivial**
Cond (µS/cm)	9.4	0.1-13.3	9.5	0.1-13.1	None	Strong

Note: Orange highlight indicates the ANZECC physical and chemical stressor trigger[3], HBRC RRMP PC6[4] or MAC Grade C[5] criteria are exceeded, red highlight indicates the ANZECC toxicity trigger[6], MAC Grade D[5] or the NPS:FM national bottom line guidelines[7] are exceeded. **Bold text** indicates a statistically significant increase or decrease between upstream and downstream

* Strong – Strong evidence for the conclusion
Trivial – Some evidence for an increase / decrease, but this is trivial when compared to equivalence limits (10%)
Inconclusive – Not enough data

[1] Data is from CHBDC dataset (July 2014-June 2020) unless otherwise stated.

[2] Data is from CHBDC dataset (July 2019-June 2020).

[3] ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated

[4] Hawke's Bay Regional Resource Management Plan (2015) – Plan Change 6

[5] MfE Microbiological Assessment Category for Freshwater Grade C and D

[6] National Policy Statement for Freshwater Management (NPS-FM) – Attribute State B, 95% species protection level (annual median/maximum)

All parameters sampled showed a large variation in the range of concentrations recorded both upstream and downstream. It is likely that the fluctuation in concentrations recorded are related to seasonal variation in flow.

From Table 8, the following conclusions are made:

- Concentrations of TP and DRP exhibit an increase downstream of the discharge and are elevated above their respective water quality criteria. It is important to note that phosphorus concentrations are already elevated above the criteria upstream of the discharge.
- The datasets of NH_4-N, DIN, TN concentrations, and temperature show an increase downstream of the discharge. The median concentrations of these parameters do not exceed their relevant water quality criteria.
- pH and DO indicate a trivial decrease between upstream and downstream monitoring locations.
- Bacterial indicators (FC and *E. coli*) and TSS also display a quantifiable increase downstream of the discharge point, however this conclusion is considered inconclusive (not enough data). The median concentrations of FC and *E. coli* are below the relevant criteria; however, their ranges indicate that exceedances would occasionally occur.

Based on the statistical analysis there is no strong evidence for a statistically significant change in any parameters between the upstream and downstream sites. Where increases are observed, Time Trends determines the evidence for a significant difference to be 'trivial'.

Based on the analysis carried out above, a number of parameters show an increase between the 50 m upstream and 50 m downstream monitoring locations, whereas pH and dissolved oxygen show a decrease between the upstream and downstream monitoring locations. For additional comparisons, summary statistics of the parameters that increased downstream of the treated wastewater discharge point are presented below along with box plots comparing the sites at 50 m upstream, 50 m downstream and 400 m downstream.

Visual comparisons of the box plots below indicate that the median and 95th percentile values at the 50 m downstream monitoring location are elevated above the 400 m downstream location for DIN, TN, TP, DRP, TSS, FC and *E. coli*. This suggests that the oxidation pond discharge influences a localised increase in contaminant concentrations directly downstream of the discharge, which is then attenuated at the 400 m downstream monitoring location.

(a) Total Ammoniacal Nitrogen

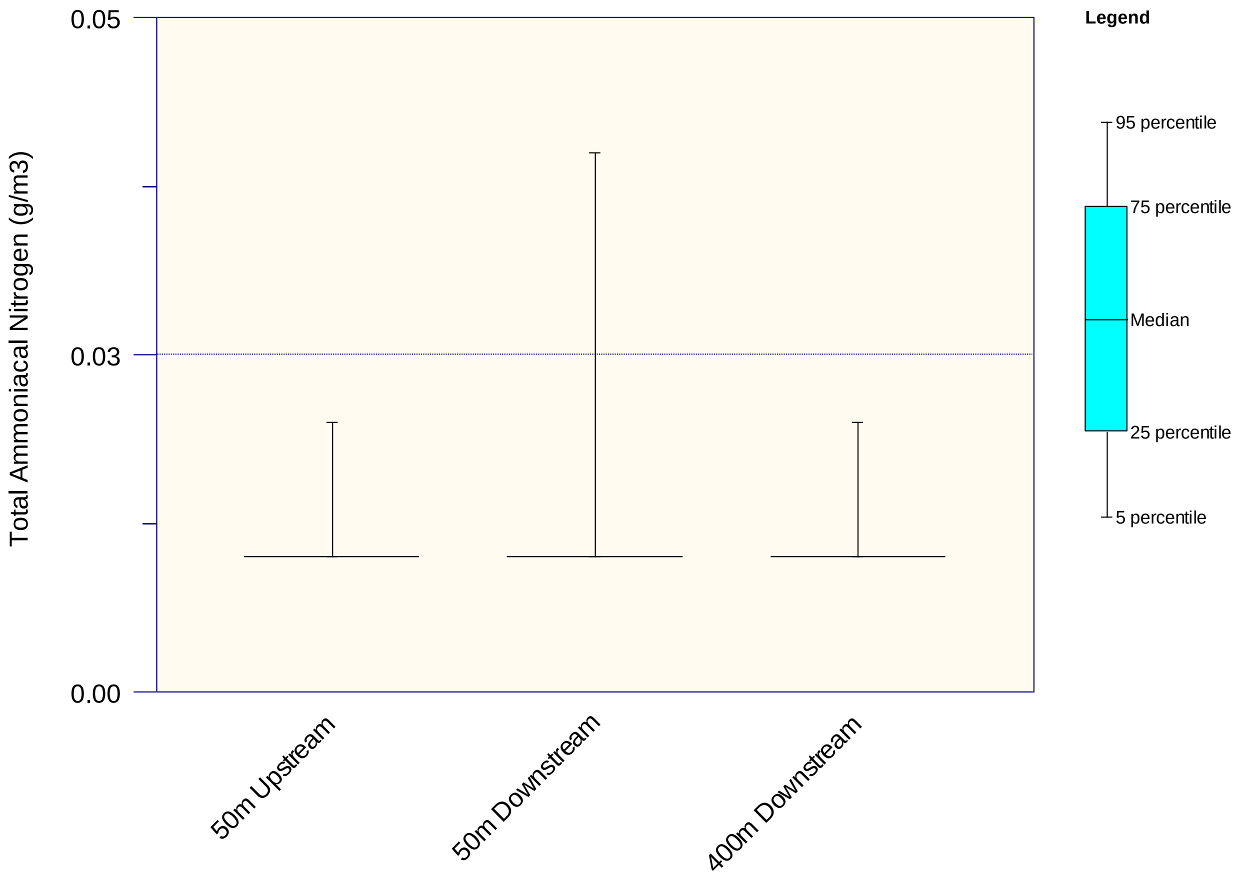

Figure 7. CHBDC Total Ammoniacal Nitrogen Monitoring Data Boxplot

Table 9. CHBDC Total Ammoniacal Nitrogen Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	0.01	0.01	0.01	0.07	0.02	0.01
50 m Downstream	0.01	0.01	0.01	0.06	0.04	0.01
400 m Downstream	0.01	0.01	0.01	0.03	0.02	0.01

Note laboratory detection limits are 0.01

(b) Dissolved Inorganic Nitrogen

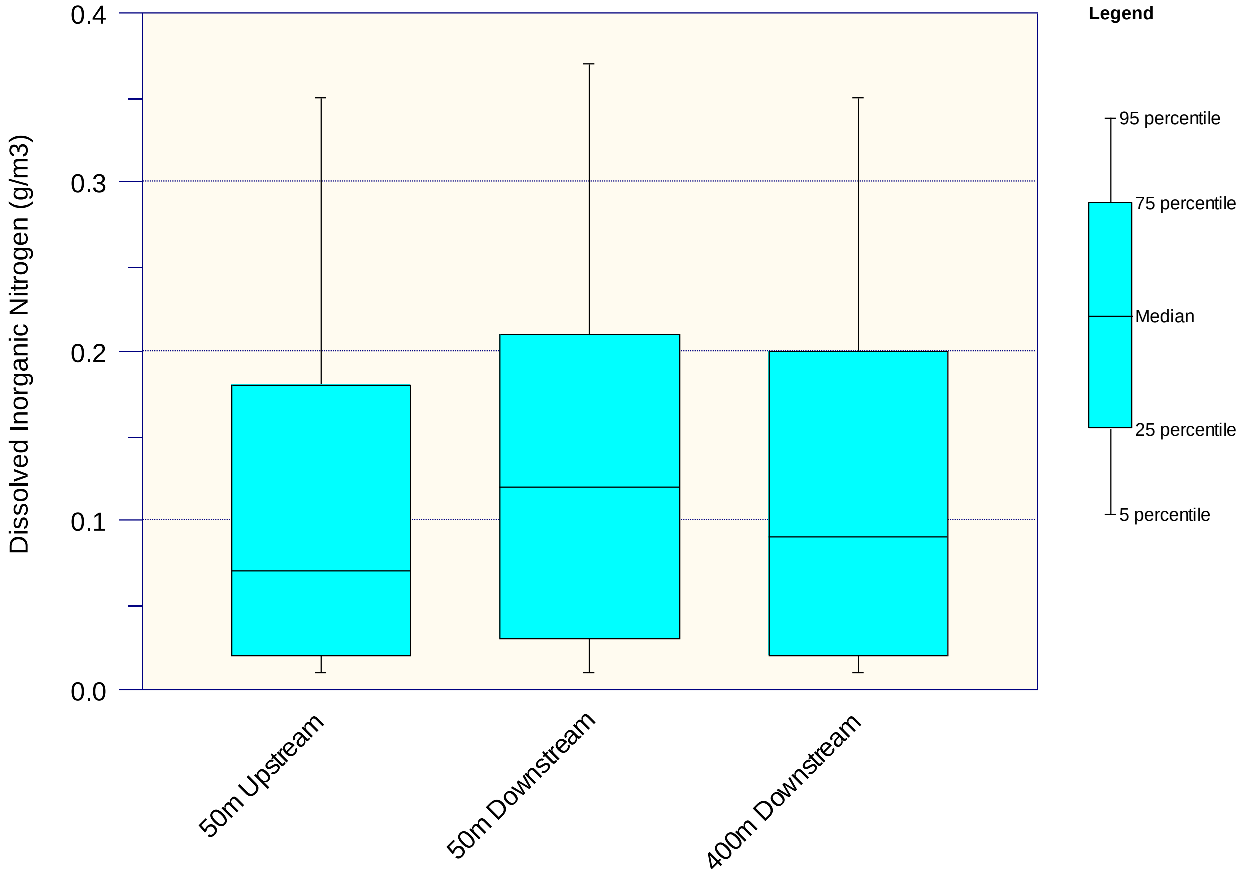

Figure 8. CHBDC Dissolved Inorganic Nitrogen Monitoring Data Boxplot

Table 10. CHBDC Dissolved Inorganic Nitrogen Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	<0.01	<0.01	0.07	0.32	0.35	0.12
50 m Downstream	<0.01	<0.01	0.12	0.36	0.38	0.14
400 m Downstream	<0.01	<0.01	0.09	0.35	0.36	0.13

Note laboratory detection limits are 0.01

(c) Total Nitrogen

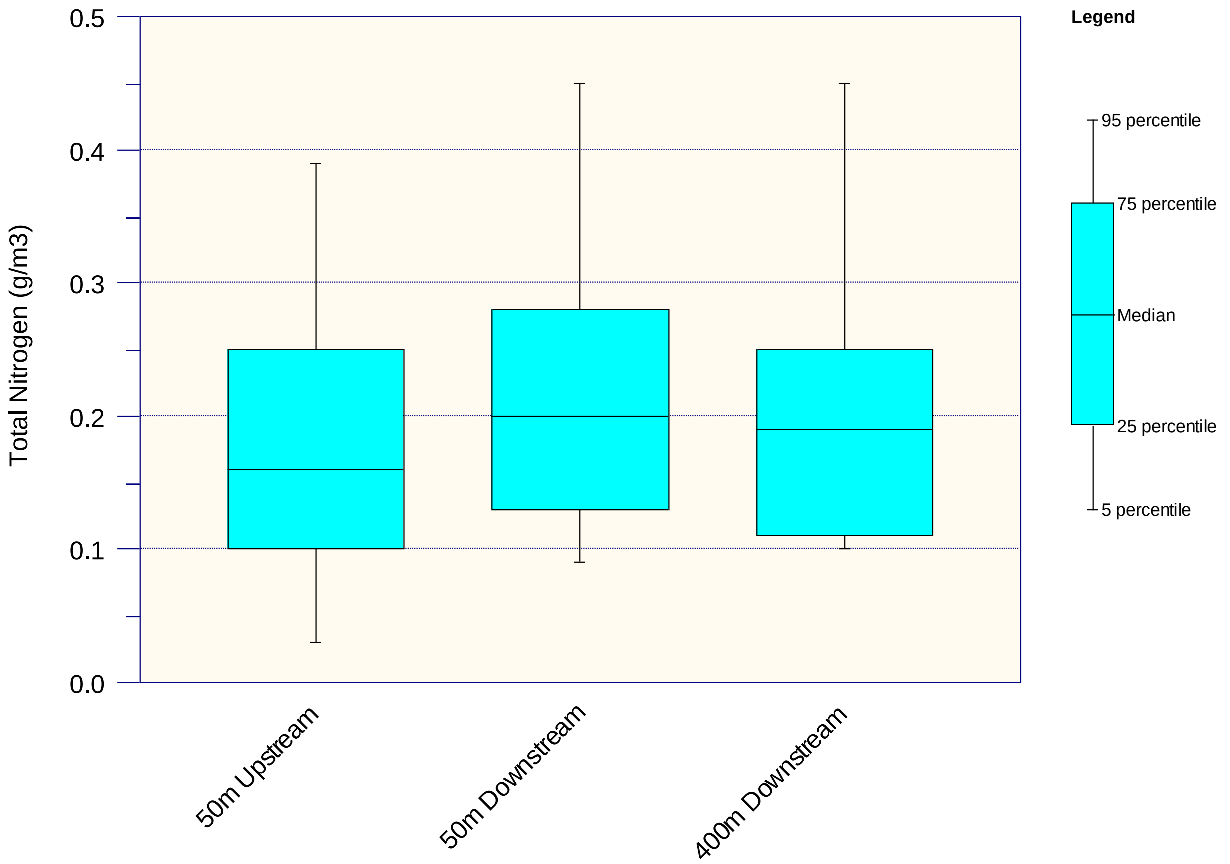

Figure 9. CHBDC Total Nitrogen Monitoring Data Boxplot

Table 11. CHBDC Total Nitrogen Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	0.03	0.04	0.16	0.39	0.39	0.18
50 m Downstream	0.09	0.11	0.20	0.43	0.45	0.22
400 m Downstream	0.10	0.11	0.19	0.42	0.45	0.21

(d) Total Phosphorus

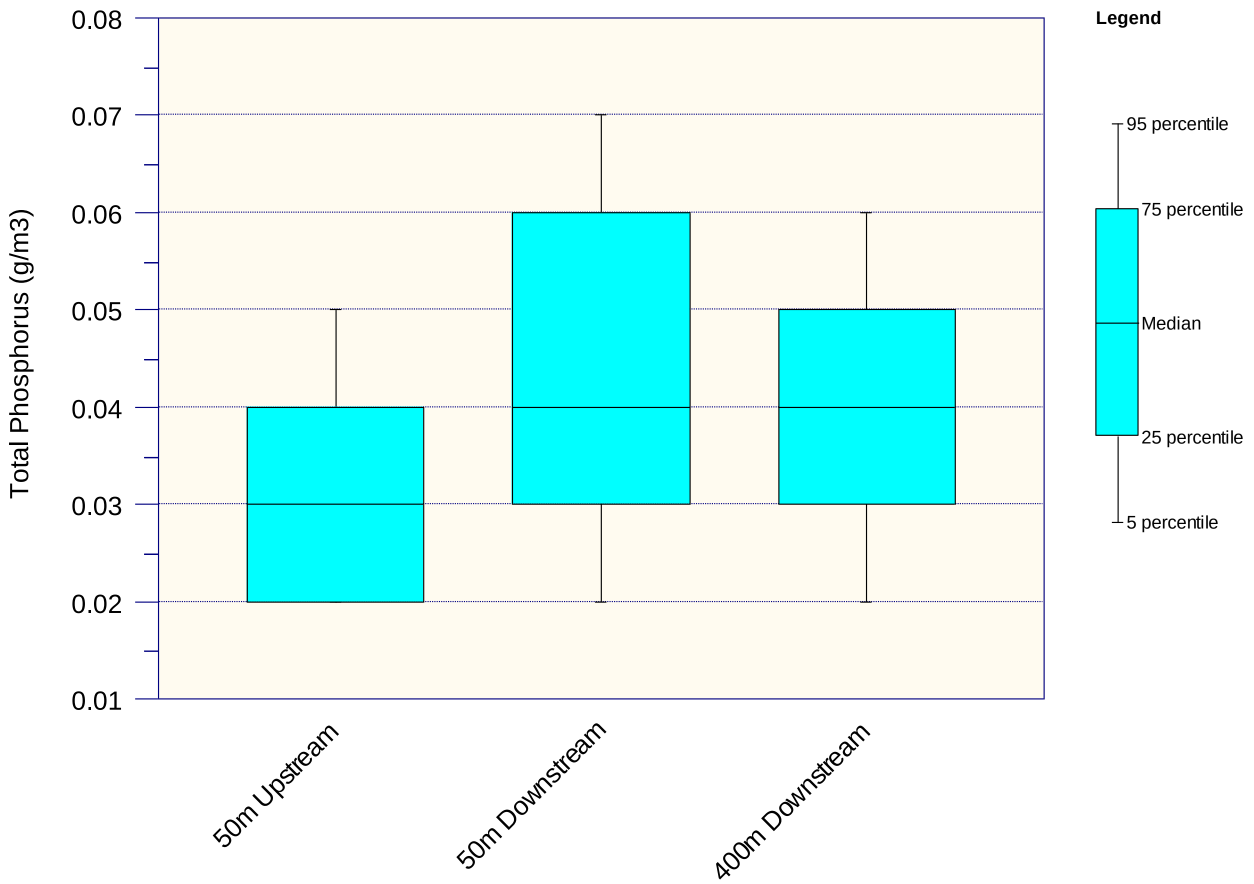

Figure 10. CHBDC Total Phosphorus Monitoring Data Boxplot

Table 12. CHBDC Total Phosphorus Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	0.016	0.016	0.034	0.044	0.047	0.030
50 m Downstream	0.018	0.019	0.038	0.069	0.070	0.041
400 m Downstream	0.017	0.019	0.039	0.062	0.063	0.040

(e) Dissolved Reactive Phosphorus

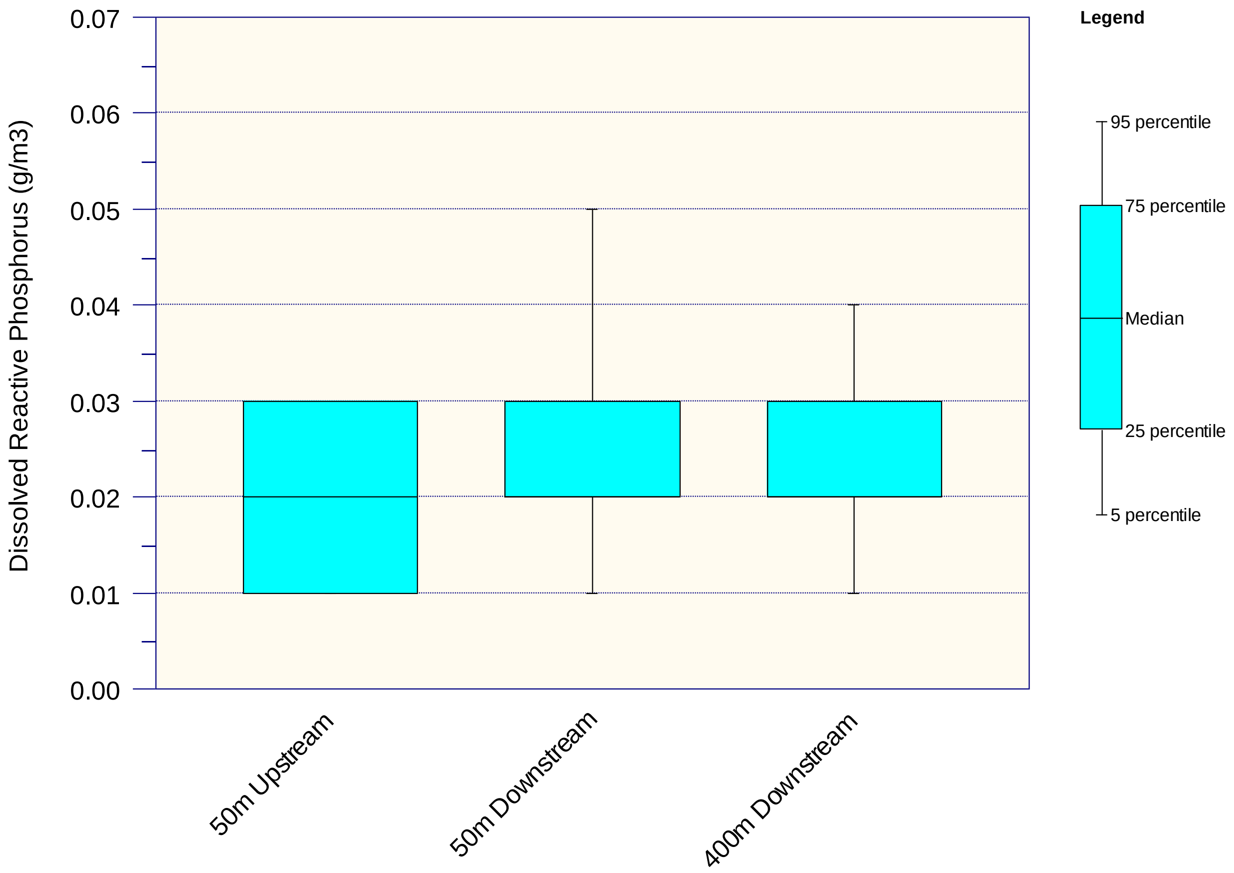

Figure 11. CHBDC Dissolved Reactive Phosphorus Monitoring Data Boxplot

Table 13. CHBDC Dissolved Reactive Phosphorus Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	<0.005	0.007	0.017	0.034	0.039	0.019
50 m Downstream	<0.005	0.006	0.020	0.051	0.060	0.023
400 m Downstream	<0.005	0.008	0.019	0.044	0.057	0.022

Note laboratory detection limits are 0.005

(f) pH

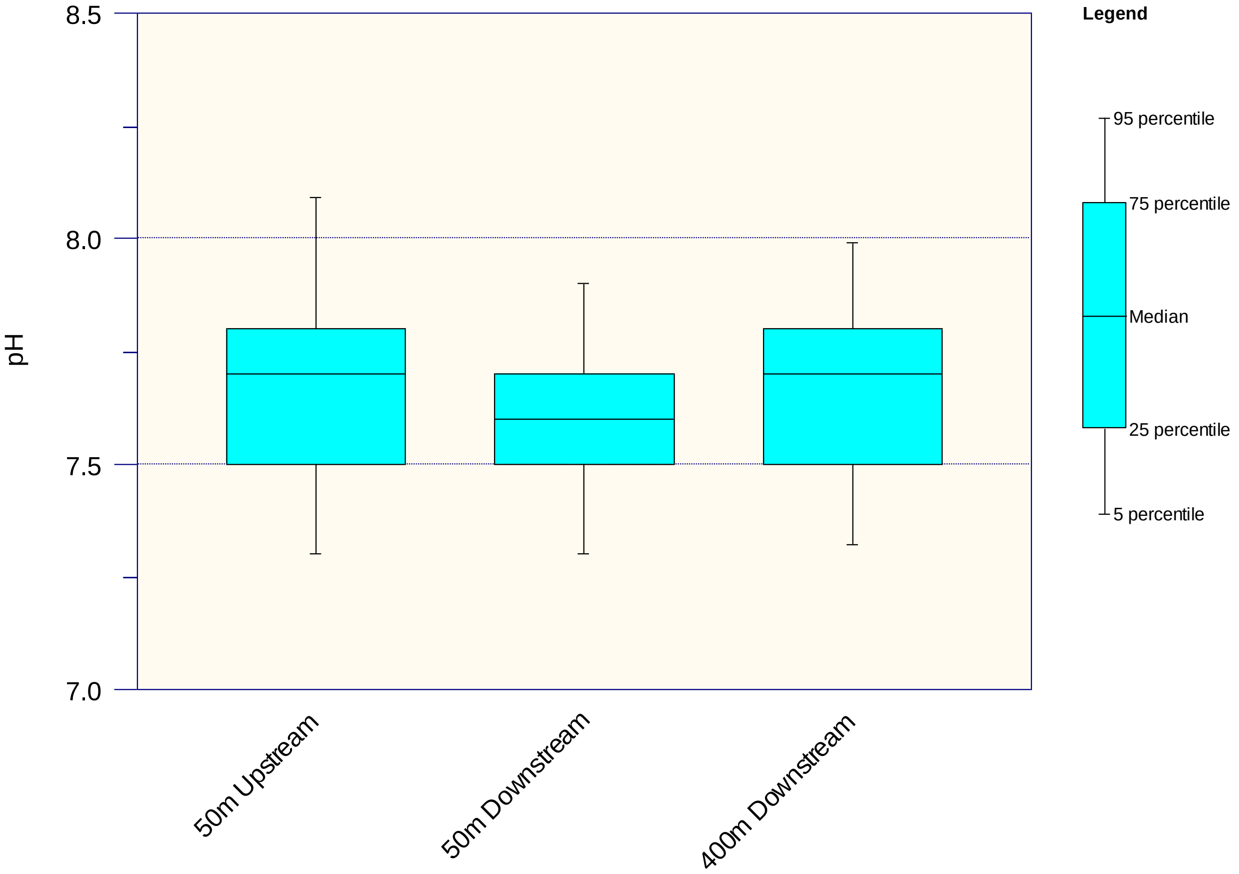

Figure 12. CHBDC pH Monitoring Data Boxplot

Table 14. CHBDC pH Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	6.9	7.3	7.7	8.0	8.6	7.7
50 m Downstream	7.0	7.3	7.6	7.9	8.8	7.6
400 m Downstream	7.2	7.4	7.6	7.9	8.5	7.7

(g) Temperature

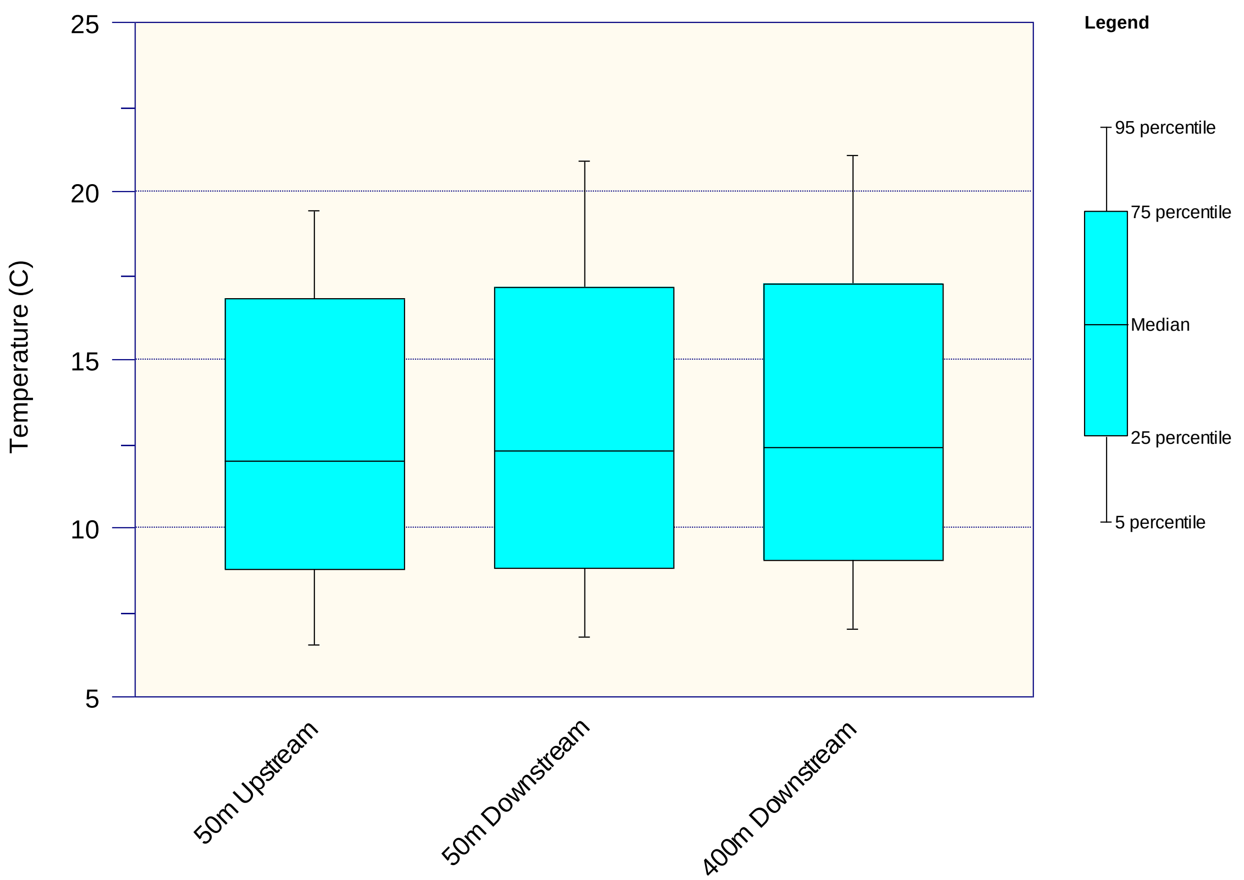

Figure 13. CHBDC Temperature Monitoring Data Boxplot

Table 15. CHBDC Temperature Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	6.1	6.6	12.0	19.4	22.1	12.8
50 m Downstream	6.2	7.0	12.3	20.8	21.9	13.0
400 m Downstream	6.2	7.1	12.4	20.5	23.4	13.3

(h) Dissolved Oxygen

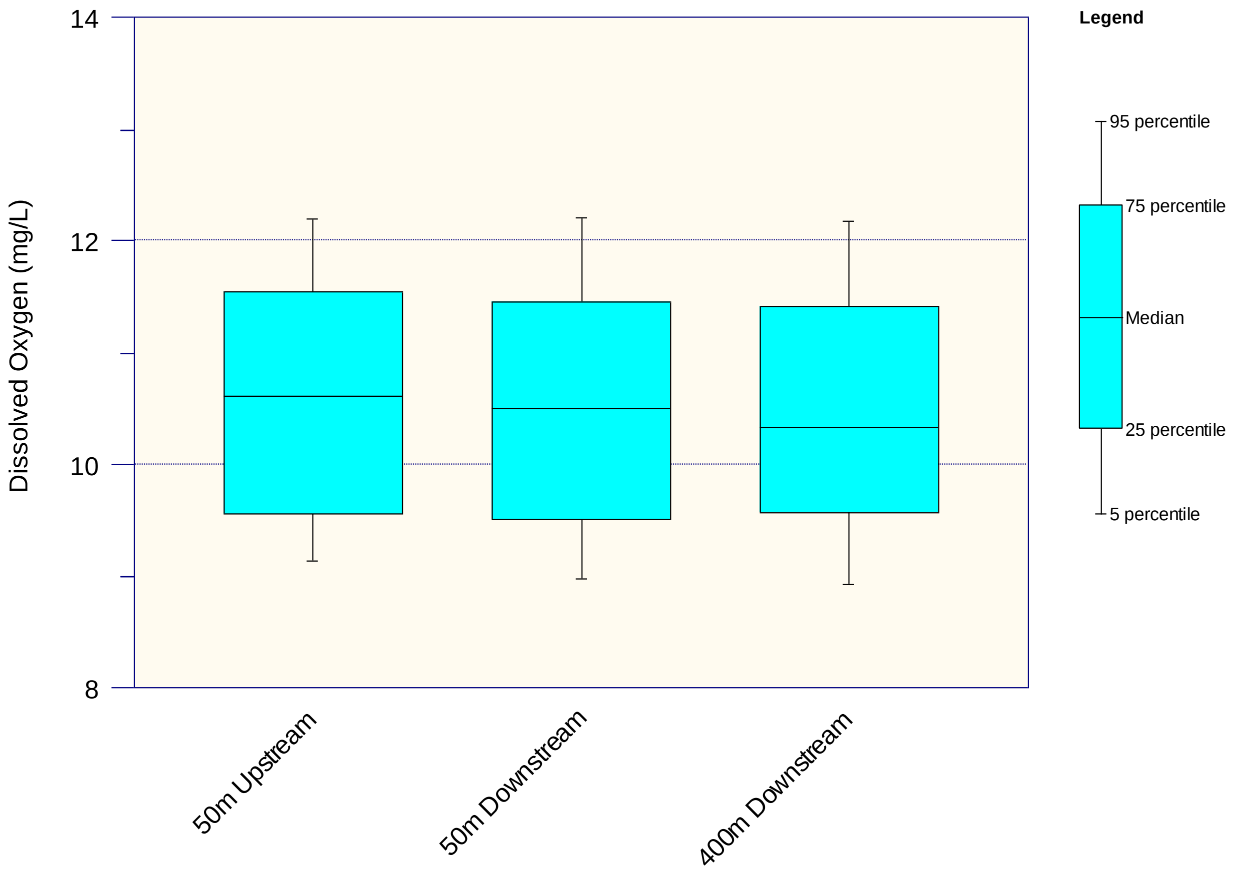

Figure 14. CHBDC Dissolved Oxygen Monitoring Data Boxplot

Table 16. CHBDC Dissolved Oxygen Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	8.6	9.1	10.6	12.1	12.6	10.6
50 m Downstream	8.3	9.0	10.5	12.2	13.1	10.5
400 m Downstream	3.8	9.0	10.3	12.1	12.5	10.4

(i) Total Suspended Solids

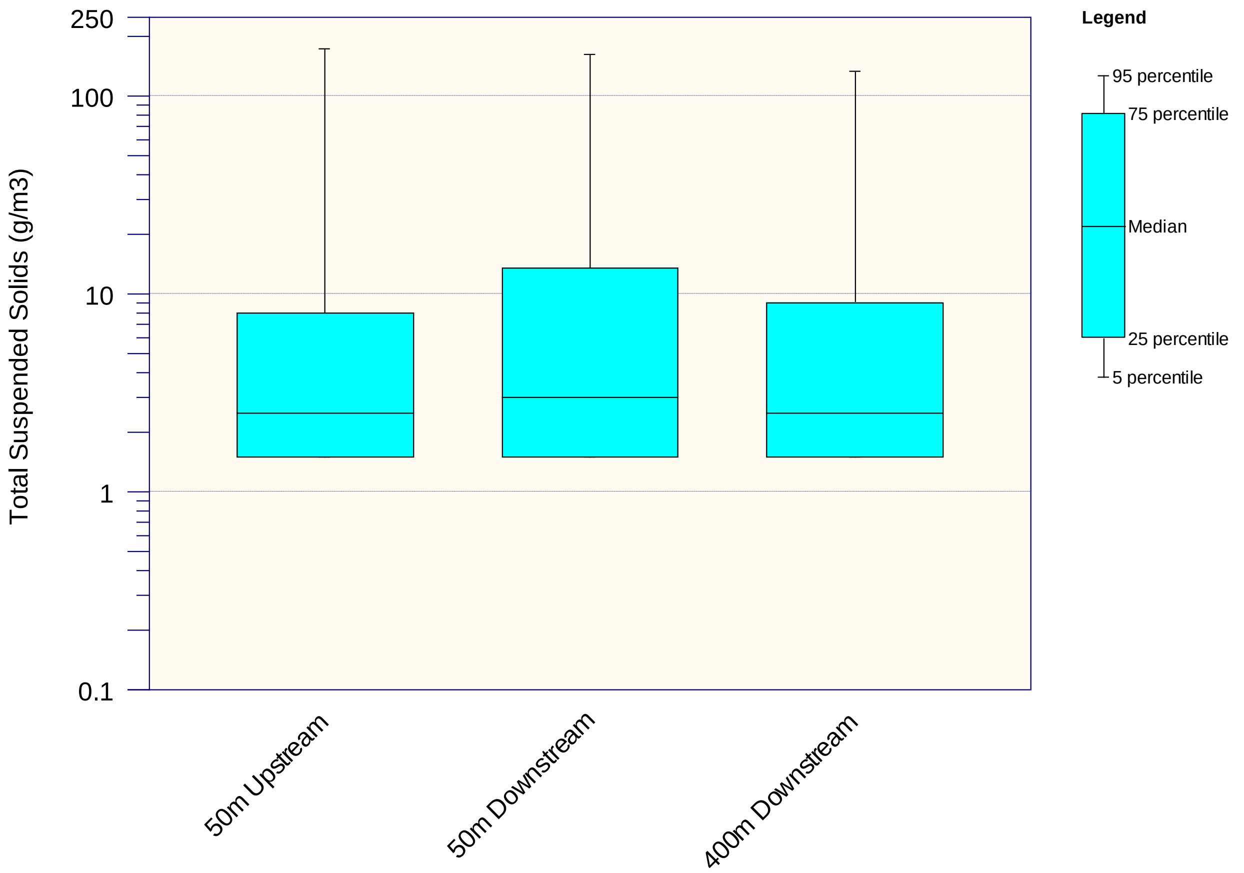

Figure 15. CHBDC Total Suspended Solids Monitoring Data Boxplot

Table 17. CHBDC Total Suspended Solids Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	<3	<3	<3	151	3,060	63
50 m Downstream	<3	<3	<3	131	3,570	71
400 m Downstream	<3	<3	<3	130	3,120	63

Note laboratory detection limits are 3

(j) Faecal Coliforms

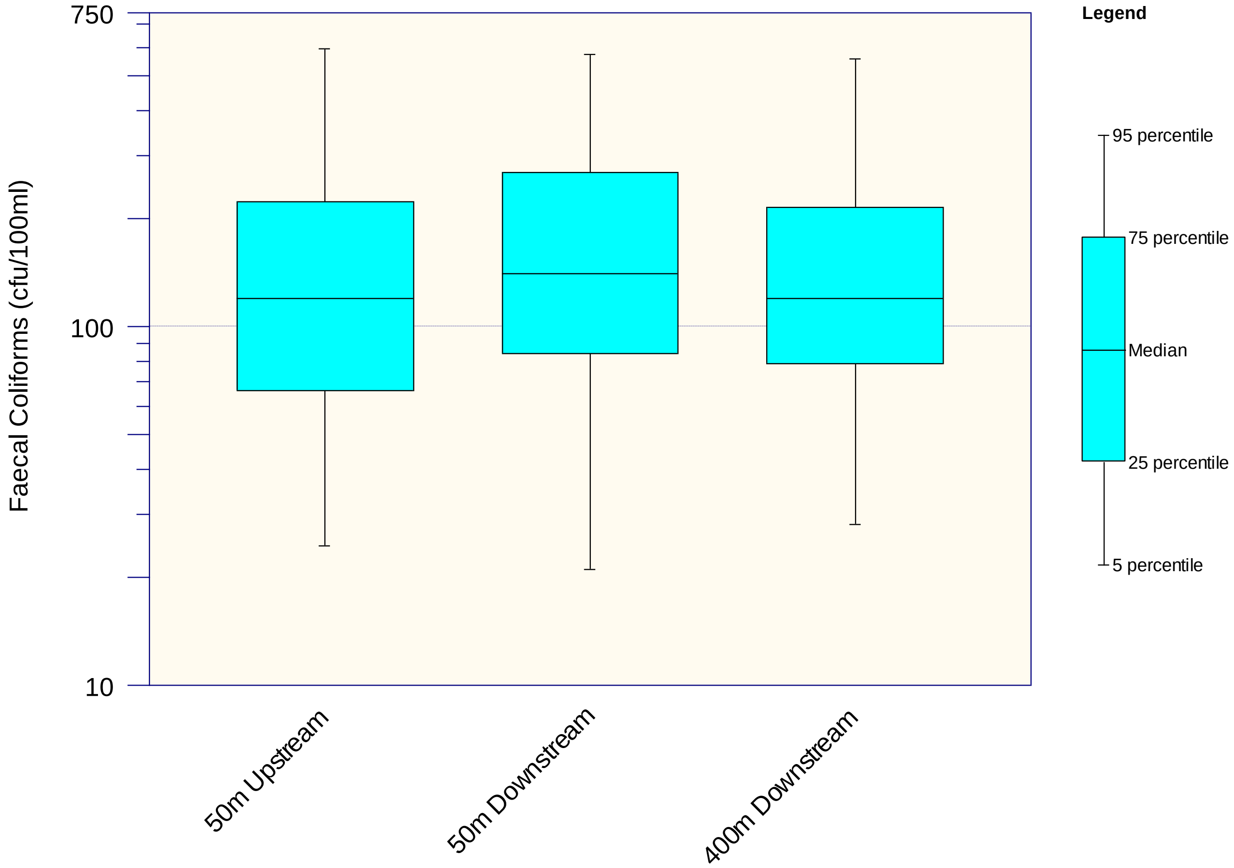

Figure 16. CHBDC Faecal Coliforms Monitoring Data Boxplot

Table 18. CHBDC Faecal Coliforms Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	16	26	120	588	3,700	224
50 m Downstream	16	24	140	562	3,100	251
400 m Downstream	20	28	120	554	2,600	213

(k) Escherichia coli

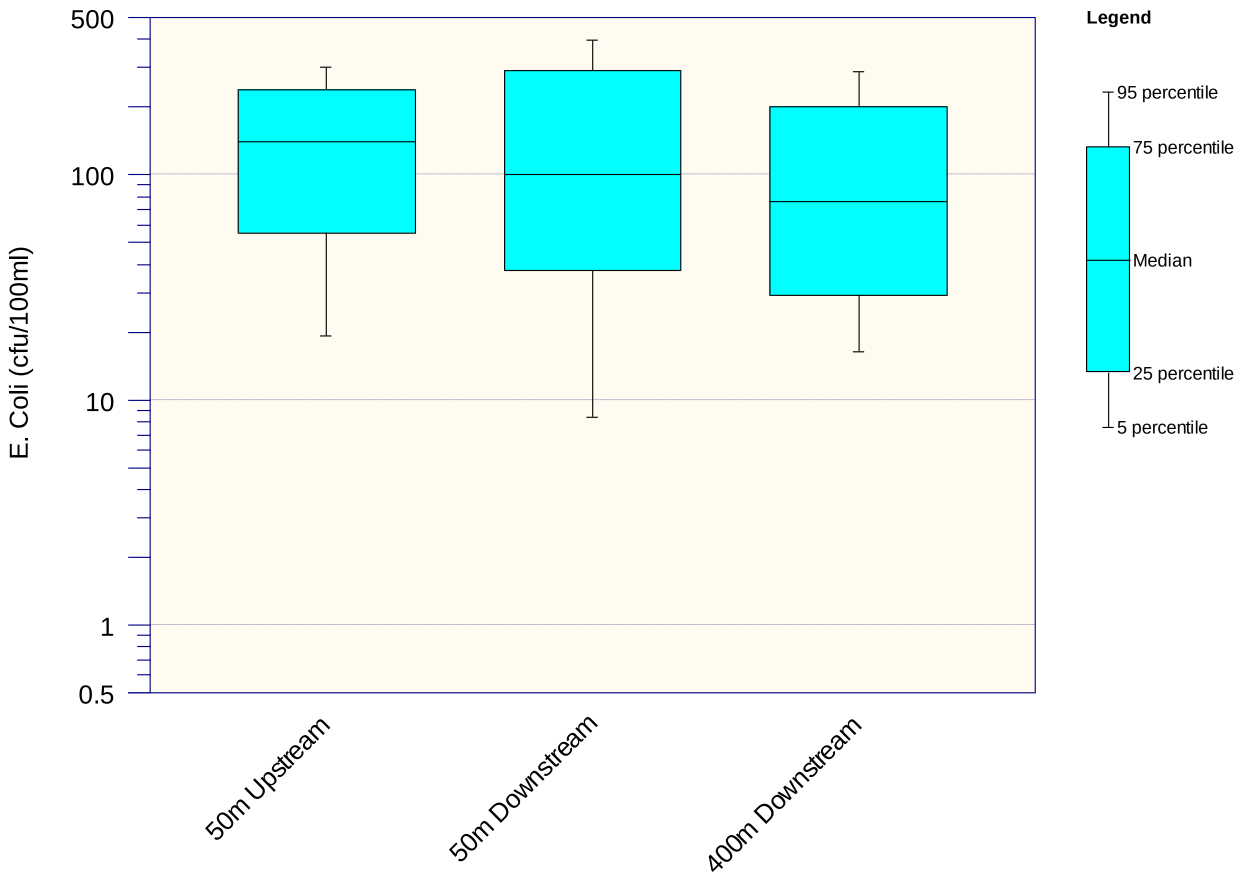

Figure 17. CHBDC E. coli Monitoring Data Boxplot

Table 19. CHBDC E. coli Monitoring Data Summary

Location	Min	5%	Median	95%	Max	Mean
50 m Upstream	19	22	140	300	300	148
50 m Downstream	8	12	100	370	400	152
400 m Downstream	16	20	76	260	290	113

4.3.2 Water Quality Outside Reasonable Mixing Zone

While there are no specific consent conditions relating to reasonable mixing, it is worth assessing the stream quality at the 400 m downstream location (outside the 200 m reasonable mixing zone) to evaluate the stream quality in the context of the HBRC RRMP. A summary of recent water quality results for the Makaretu River 400 m downstream of the treated wastewater discharge is presented in Table 20.

Table 20. CHBDC Water quality monitoring results from 400 m downstream of Takapau WWTP. Approx. 70 samples taken monthly between 2014 and 2020 (June).

Parameter	5%	Median	95%	Criteria[1]	Trigger[2]
$cBOD_5$ (mg/L) *	<1	<1	3		
Chemical Oxygen Demand*	<15	<15	<15		
Total Ammoniacal Nitrogen (mg/L)	<0.01	<0.01	0.02	0.03[5] / 0.05[5] / 0.24[3]	
Nitrate (mg/L)	<0.01	0.18	1.114	$3.8_{(a)}$ / $5.6_{(b)}$	
Dissolved Inorganic Nitrogen (mg/L) *	0.01	0.085	0.345	0.8	
Total Nitrogen (mg/L) *	0.11	0.19	0.42	0.281[2]	
Total Phosphorus (mg/L) *	0.019	0.039	0.062	0.023[2]	
Dissolved Reactive Phosphorus (mg/L)	0.008	**0.019**	**0.044**	0.010	
Total Suspended Solids (mg/L)	<3	<3	130.4	4.6	
Faecal Coliforms (CFU/100ml)	28	120	**554**	200[4]	
E. coli (CFU/100ml) *	20	76	**260**	261-550	>550[1]
Horizontal Visibility (Water clarity)	3.8	3.8	3.8	>3.0	
pH	7.4	7.6	7.94	7.27 – 7.8[2]	
Temperature	7.1	12.4	20.5		
Dissolved Oxygen (ppm)	8.98	10.33	12.13	>80%	82-100%
Conductivity (µS/cm)	6.72	9.5	12.24	86[2]	

Note: Orange highlight indicates the ANZECC physical and chemicalstressor[2] trigger are exceeded, red highlight indicates the NPS:FM national bottom lines[5], consent conditions[6], or relevant toxicity triggers are exceeded, and **bold text** indicates the HBRC RRMP[1] target or regional river guidelines are exceeded[6].

* Sampling of these analytes began in August 2019 (11 monthly samples)

[1] All parameters are Hawkes Bay Regional Resource Management Plan Change 6 (2014) Surface water quality limits, targets and indicators for the Tukituki catchment (Tables 5.9.1B and C) – Zone 3, Mainstem, except where otherwise stated.

[2] All parameters are ANZECC (REC) default guideline values (DGVs) for physical and chemical (PC) stressor values for Warm Dry Low-elevation classification, except where otherwise stated

[3] National Policy Statement for Freshwater Management (NPS-FM) – Attribute States B, 95% species protection level (annual median / maximum)

[4] Hawke's Bay Regional Resource Management Plan (RRMP) (republished as at 1 October 2015). Note that the faecal coliform surface water guideline value represents the concentration of contaminant in the water body that should not be exceeded after reasonable mixing.

[5] NPS-FM – Attribute State A, 99% species protection level (annual median / maximum)

This water quality summary at the 400 m downstream location is very similar to the summary provided in Section 2.2.2 for the 50 m upstream location. The median values of TP and DRP at the 400 m upstream site are slightly above their respective trigger values, while the 95th percentile values of TN, TSS, FC, E. coli and pH exceed their respective trigger values.

4.3.3 Summary

In general, NH_4-N, DIN, TN, TP, DRP and Temperature show an increase downstream of the discharge point. According to the Time Trends software, there is statistical evidence for these increases, however the increase is considered trivial when compared to equivalence limits. TP and DRP are the only parameters whose downstream medians are above their respective water quality criteria. However, the upstream concentrations of TP and DRP are already above their respective water quality criteria. Suspended solids and microbiological contaminants (*E. coli* and FC) also show an increase downstream of the discharge point, however the significance of this increase is inconclusive and median concentrations are well below the water quality criteria.

Overall, the analysis of the monitoring data reveals that a number of minor increases in contaminant concentrations were measured downstream of the discharge. Additionally, visual comparison of box plots suggests that nutrient and microbiological contaminants 50 m downstream of the discharge are higher than at the 400 m downstream monitoring location. Despite these two lines of evidence, the majority of the parameters are well below their respective water quality criteria, with the exception of TP and DRP, which are above their respective criteria upstream and downstream of the oxidation pond discharge.

4.4 Predicted Water Quality Downstream of Discharge on the Makaretu River

Mixing water quality effects were assessed using a standard mass-balance approach as described in Section 4.2.3. This approach utilises measured data and existing flow records to inform the potential concentrations of water quality parameters following full mixing. The mass-balance method was carried out for two scenarios. The first scenario is normal (median) flow conditions that would be expected most of the time. The second assessment simulates a 'worst-case', low-flow scenario by calculating the seven-day mean annual low flow (MALF) of the Makaretu River while still assuming a median flow input of treated wastewater from the WWTP. The mass-load contribution of TN and TP to the catchment by the Takapau WWTP is also presented in Section 4.4.3, calculated by the methodology described in Section 4.2.4.

4.4.1 Mass Balance under Median River Flow Conditions

Assessment of predicted changes in key contaminant concentrations in the Makaretu River downstream of the wastewater discharge under annual median stream flow conditions are summarised in Table 21 below.

The predicted effects of the wastewater discharge are based on a number of assumptions including:

- River flow of 2,246 L/s (2.25 m^3/s) for the Makaretu River was calculated based on correlated flow gauges and HBRC flow data (Tukituki River at Tapairu Road correlated to Makaretu River at Speedy Road Bridge spot gauging measurements at a ratio of 0.98[15]);
- The wastewater discharge flow was the median daily discharge volume of 114 m^3/day (0.001 m^3/s) based on existing CHBDC records (2015-2019);
- The wastewater contaminant concentrations are medians calculated from the monitoring data collected from the outlet between July 2014 and June 2019, with the exception of the toxicants, total ammoniacal nitrogen (NH_4-N) and nitrate-N (NO_3-N), which used the 95th percentile; and
- Makaretu River contaminant concentrations are medians calculated from monitoring data collected by CHBDC monitoring site 50 m upstream of the Takapau WWTP discharge collected between July 2014 and June 2019.

[15] Correlation factor provided by Hawke's Bay Regional Council

Dilution is estimated to be 1700-fold under median River flow conditions[16].

Table 21. Predicted downstream contaminant concentrations - Median flow dilution (1700 x) within Makaretu River

Parameter	Unit	Discharge	Upstream	Downstream	Change
$cBOD_5$	mg/L	26	<3	<3	5%
TSS	mg/L	79	3	3	2%
NH_4-N	g/m³	0.33	0.01	0.01	3%
NO_3-N	g/m³	0.29	0.17	0.17	0%
DIN	g/m³	5.800	0.070	0.075	8%
TN	g/m³	14.10	0.16	0.17	8%
TP	g/m³	3.820	0.034	0.038	11%
DRP	cfu/100ml	2.670	**0.017**	0.020	15%
E. coli	cfu/100ml	18,000	140	157	12%
FC	cfu/100ml	27,000	120	145	21%

Note: Orange highlight indicates the ANZECC physical and chemical stressor trigger or MAC Grade D is exceeded, red highlight indicates the ANZECC toxicity trigger is exceeded, red text indicates the national bottom line guidelines are exceeded and **bold text** indicates the regional river guidelines are exceeded (See Table 8).

The assessment indicates that, under normal stream flow conditions:

- The oxidation pond discharge is predicted to cause a moderate increase (>10%) in the concentration of TP, DRP, E. Coli and FC in the Makaretu River downstream of the discharge. TP and DRP concentrations are already above the ANZECC and HBRC criteria upstream of the WWTP. All other concentrations are still predicted to be below the HBRC RRMP PC6 criteria.
- $cBOD_5$, DIN and TN are predicted have a minor increase (5-10%) downstream of the oxidation pond discharge. All concentrations are predicted to remain below the relevant water quality guidelines despite the predicted increase.
- Very minor or no change (<5%) is predicted for TSS, NH_4-N and NO_3-N. None of which exceed the set water quality criteria.

Based on these predictions, it appears that the Takapau WWTP discharge would be expected to cause a moderate to minor increase in nutrient concentrations in the Makaretu River water quality during median (normal) flow conditions.

4.4.2 Mass Balance under Low Stream Flow Conditions

The realistic worst case effects for WWTP discharges typically occur in summer, when a combination of higher stream water temperature and low stream flow results in lower contaminant dilutions and greater stress on aquatic life. These effects can be noticeable in rural, upper-catchment waterways such as the Makaretu River.

The Makaretu River low stream flow rate is based on the estimated seven-day MALF value of 178 L/s (0.18 m³/s) at Speedy Road Bridge (correlated) (July 2014-June 2019) provided by HBRC. Other assumptions (contaminant concentrations and wastewater median daily discharge volume) remain the same as in Section 4.4.1. The results of the predicted changes in water quality during low stream flow conditions are provided in Table 22. Dilution is estimated to be 136-fold under MALF conditions[17].

[16] Median Dilution factor - (River flow / Wastewater flow) + 1 - (2.246 / 0.00132) + 1 = 1706 $m^3_{river}/m^3_{discharge}$

[17] MALF Dilution factor - (River flow / Wastewater flow) + 1 - (0.178 / 0.00132) + 1 = 136.1 $m^3_{river}/m^3_{discharge}$

Table 22. Predicted downstream contaminant concentrations - Low flow dilution (136x) within the Makaretu River

Parameter	Unit	Discharge	Upstream	Downstream	Change
$cBOD_5$	mg/L	26	<3	<3	37%
TSS	mg/L	79	3	4	19%
NH_4-N	g/m^3	0.33	0.01	0.01	24%
NO_3-N	g/m^3	0.29	0.17	0.17	1%
DIN	g/m^3	5.800	0.070	0.112	60%
TN	g/m^3	14.10	0.16	0.26	64%
TP	g/m^3	3.820	0.034	0.062	82%
DRP	cfu/100ml	2.670	**0.017**	**0.036**	115%
E. coli	cfu/100 mL	18,000	140	**271**	94%
FC	cfu/100ml	27,000	120	**317**	165%

Note: Orange highlight indicates the ANZECC physical and chemical stressor trigger or MAC Grade D is exceeded, red highlight indicates the ANZECC toxicity trigger is exceeded, red text indicates the national bottom line guidelines are exceeded and **bold text** indicates the regional river guidelines are exceeded (See Table 8).

The assessment indicates that, under low (MALF) stream flow conditions:

- The oxidation pond discharge is predicted to cause a major increase (>100%) in the concentration of DRP and FC in the Makaretu River downstream of the discharge with concentrations predicted to be elevated above HBRC RRMP PC6 water quality criteria. DRP is already elevated above HBRC RRMP PC6 criteria upstream of the discharge.
- The discharge is predicted to cause a substantial increase (51-100%) in the concentration of DIN, TN, TP and *E. coli* in the Makaretu River downstream of the discharge with concentrations of TP and *E. coli* predicted to be elevated above HBRC RRMP PC6 river guidelines. TP is already elevated above ANZECC PC stressor guidelines upstream of the discharge.
- A moderate increase in the concentrations of $cBOD_5$, TSS and NH_4-N is predicted downstream of the discharge point. All parameters are below the water quality criteria upstream at both locations.
- Very minor or no change is predicted for NO_3-N

Based on these predictions, it appears that the Takapau WWTP discharge would be expected to cause a moderate increase in nutrient and microbiological contaminant concentrations in the Makaretu River water quality during low-flow conditions. In particular, *E. coli* and FC are predicted to exceed the HBRC RRMP PC6 river guidelines. While the increase is likely to be moderate during very low flows, it would not occur for an extended period of time. The above assessment indicates that elevated nutrients and microbiological contaminants could occur in low flow scenarios, however recent ecological investigations report periphyton biomass well below HBRC RRMP PC6 targets and biotic indices that were indicative of fair to good water quality. Furthermore, despite the assessed concentration increases, even under the worse-case low-flow conditions, concentrations of NH_4-N and NO_3-N are predicted to be well below their respective toxicity thresholds.

4.4.3 Mass Loads to Tukituki Catchment Zone 3

This assessment provides a baseline for comparison to the future staged discharge scenario described in Section 5. The baseline mass-loading accounts for the WWTP discharge to the Makaretu River based on average discharge flow rates and measured contaminant concentrations. The relative contribution of the WWTP is compared to the downstream nutrient loads at the HBRC monitoring location at Tapairu Road. This can be considered representative of the MZ3 catchment. The prediction of the annual MZ3 mass-loads has been calculated in accordance with the following parameters:

- An average annual river flow of 449,540,634 m^3/yr, taken from HBRC 2015-2020 data;
- Average annual Total Nitrogen concentration of 1.6 g/m^3, taken from HBRC 2015-2020 data; and
- Average annual Total Phosphorus concentration of 0.04 g/m^3, taken from HBRC 2015-2020 data.

The prediction of the annual mass-loading to the river by the WWTP discharge has been calculated in accordance with the following parameters:

- An average annual flow from the WWTP of 56,765 m^3/yr, , taken from 2015-2020 data;
- Average annual Total Nitrogen concentration of 15.1 g/m^3, taken from 2015-2020 data; and
- Average annual Total Phosphorus concentration of 3.89 g/m^3, taken from 2015-2020 data.

The mass loading of the Takapau WWTP relative to the wider MZ3 catchment (Tapairu Road) is presented in Table 23 below:

Table 23. Existing WWTP discharge nutrient mass loading

Contaminant	Unit	Loss to River	% of Tukituki at Tapairu Rd (MZ3)
Total Nitrogen Load	kg/day	2.35	0.12% (747.77 T/yr)
	T/yr	0.86	
Total Phosphorus Load	kg/day	0.60	1.27% (17.38 T/yr)
	T/yr	0.22	

4.5 Summary of Effects of the Current Discharge

In summary, the assessment of the effects of the current discharge on the Makaretu River was undertaken based on approaches by measurement and prediction. The assessment results indicate that:

- The water quality of the Makaretu River is slightly nutrient enriched with respect to phosphorus, as shown by the elevated TP and DRP concentrations upstream of the discharge point. Upstream nutrient concentrations of TP and DRP are already elevated above the HBRC RRMP PC6 and ANZECC physical and chemical stressor guidelines prior to the point of discharge.
- The treated wastewater discharge is currently causing a minor increase in nutrient and microbiological contaminant concentrations in the Makaretu River downstream of the discharge during both median and low stream flow conditions. In particular, the increase in faecal coliforms and *E. coli* are predicted to exceed relevant guideline values during low flow scenarios.
- Previous ecological investigations indicate that the discharge does not appear to result in the formation of excessive plant, algae and slime growths in the Makaretu River relative to upstream.
- The predictions based on mass balance calculations suggest that the wastewater discharge would be expected to cause a moderate increase in nutrient (phosphorus) and microbiological (*E. coli* and FC) concentrations in the Makaretu River water quality during low flow conditions and a less than minor increase during median flow conditions.
- The Takapau WWTP contributes a mass-load of 857 kg/yr of Total Nitrogen and 221 kg/yr of Total Phosphorus to the Makaretu River. This amounts to 0.1% and 1.3%, respectively, of the total Tukituki Catchment MZ3 loads as measured by HBRC at the Tapairu Road monitoring location.

Overall, the analysis of the monitoring data reveals that multiple increases in contaminant concentrations were measured downstream of the discharge. The evidence of these increases, while statistically significant, is considered trivial, rather than strong, when compared to the 10% equivalence limits of the datasets according to Time Trends software. The monitored results from the last five years indicate that median concentrations of TP and DRP are the only contaminants elevated above ANZECC and PC6 targets downstream of the discharge. Notably, TP and DRP concentrations are already elevated above the guidelines upstream of the oxidation pond discharge in both median and low-flow scenarios.

Similarly, mass-balance contaminant mixing calculations for median and low-flow river scenarios indicate that TP and DRP are the only contaminants elevated above ANZECC and PC6 targets downstream of the discharge at median flow regimes. Meanwhile at low flows, predicted phosphorus (total and dissolved) and microbiological contaminants (faecal coliforms and *E. coli*) exhibit strong increases downstream of the oxidation pond discharge to exceed the ANZECC and regional river guidelines.

5 Assessment of Effects of the Future Discharge of Treated Wastewater

From the assessment above, the contaminant concentration contribution of the Takapau WWTP discharge on the Makaretu River are measurable albeit minor. Phosphorus concentrations are elevated in the river upstream of the discharge (total and dissolved) and appear to be exacerbated slightly downstream of the treated wastewater discharge with more noticeable effects predicted during the lowest flows in the river.

Parameters of note include *E. coli*, faecal coliforms and phosphorus (Total and Dissolved). *E. coli* and faecal coliforms are modelled to exceed HBRC RRMP PC6 trigger values during low flows. Total phosphorus and dissolved reactive phosphorus, while already elevated above PC6 criteria upstream of the discharge, exhibit a small, yet measurable, increase downstream.

The mass load analysis of the current discharge in Section 4.4.3 accounts for the contribution from the WWTP discharge only. The proposed future development of the Takapau WWTP will divert a significant portion of the current river discharge and irrigate to the adjacent farm instead. In order to adequately assess the effects of the future discharge options, an existing discharge baseline has been established which includes the WWTP river discharge as well as the loss of nutrients from the farmland in its current state. Overseer nutrient modelling of farm losses for the baseline (Scenario 1) and the future treated wastewater irrigation scenario (Scenario 2) was undertaken by LEI (Table 24):

Table 24. Overseer nutrient losses undertaken by LEI

Name	Unit	Total Nitrogen Loss	Total Phosphorus Loss
Scenario 1 (baseline)	kg/yr	2,097	10
Scenario 2 (including WWTP irrigation)	kg/yr	2,530	20

The farm nutrient losses modelled by Overseer are assumed to be entering the subsoil rooting zone and groundwater bearing layers. It is considered likely that nutrient attenuation in the subsurface will occur, particularly in relation to phosphorus. Further investigation would be required to quantify the attenuation potential of the soils and groundwater and therefore, a conservative assumption of no nutrient (nitrogen and phosphorus) attenuation by soils or groundwater has been assumed. The groundwater assessment in **Appendix A** provides commentary on the indicative flow directions and sensitive receptors, whereby discharge to surface waters is likely to be several kilometres downstream of the WWTP, but still within the MZ3 catchment. As such, the mass-load contribution of the WWTP to the surface waters is assessed relative to the nutrient loading in the river at the most downstream monitoring point within the MZ3 catchment (Tukituki at Tapairu Road).

The combined mass-load baseline contribution of nutrients by the WWTP (Section 4.4.3) and the adjacent farm (Table 24 - Scenario 1) to MZ3 surface waters is set out in Table 25 below:

Table 25. Baseline (Farm Loss + WWTP Discharge) nutrient mass loading

Contaminant	Unit	Loss to River	% of Tukituki at Tapairu Rd (MZ3)
Total Nitrogen Load	kg/day	8.09	0.39% (747.77 T/yr)
	T/yr	2.95	
Total Phosphorus Load	kg/day	0.63	1.33% (17.38 T/yr)
	T/yr	0.23	

With the above considerations in mind, a staged development approach has been adopted to progressively reduce the discharge through the existing wetland to the Makaretu River, eventually discharging all but exceptional flows to farmland at a rate which provides irrigation benefit, some fertiliser inputs and avoids excessive drainage.

The timeframe for implementation of each of the stages is subject to funding approvals through the Long Term Plan (LTP) process, however it is expected that the final stage of the new land discharge system will be operational within five years (2026), and wastewater storage to be completed at this time also.

There are three future stages that support this transition. The Baseline scenario (stage zero) represents the current situation and is described and assessed in Section 4 above. Baseline conditions of discharge are set to continue for the initial period of the consent duration (up to three years). This section assesses the discharge of the two future stages (One and Two) in the context of mass balance and mass load methodologies introduced in Sections 4.2.3 and 4.2.4 respectively. A description of each of the stages is also presented. An assessment of each of the development stages in the context of water quality effects compared to the Baseline scenario presented above is then presented in Section 5.3

5.1 Stage One Water Quality Assessment

The stage one development involves the initial WWTP treatment improvements, and development of the initial storage and irrigation facilities. The predicted effects of the stage one farm and wastewater discharge against the baseline are based on the following description:

- Establishment of pumping, UV and filtration facilities for the irrigation system;
- Modifications to the wastewater treatment pond, including changes to allow for an initial 2,000 m^3 of active storage to manage the timing of discharge;
- Re-engineering or replacement of the wetland discharge to ensure sufficient retention time and ground contact is achieved for renovation of the discharge before it enters the Makaretu River. This discharge is now referred to as a High Rate Land Passage (HRLP) discharge;
- Development of a minimum of 5 ha of irrigation (for rotational cropping and low-intensity grazing), allowing for irrigation of approximately 60% of the current average annual wastewater discharge volume to irrigation and 40% to the HRLP when river flows exceed half median flow (see modelled HRLP discharge in Table 26);
- The Stage One Overseer modelled estimates (Table 24 - Scenario 2) include a nitrogen loss of 2,530 kg/yr and phosphorus loss of 20 kg/yr from the irrigated farmland, this is an increase of 433 kg/yr and 10 kg/yr, respectively, in comparison to the baseline scenario.

The proposed transition to predominantly farm irrigation results in reduced flow volumes through the HRLP discharge and reduction of mass-load nutrient contributions from the WWTP directly to the Makaretu River relative to the baseline.

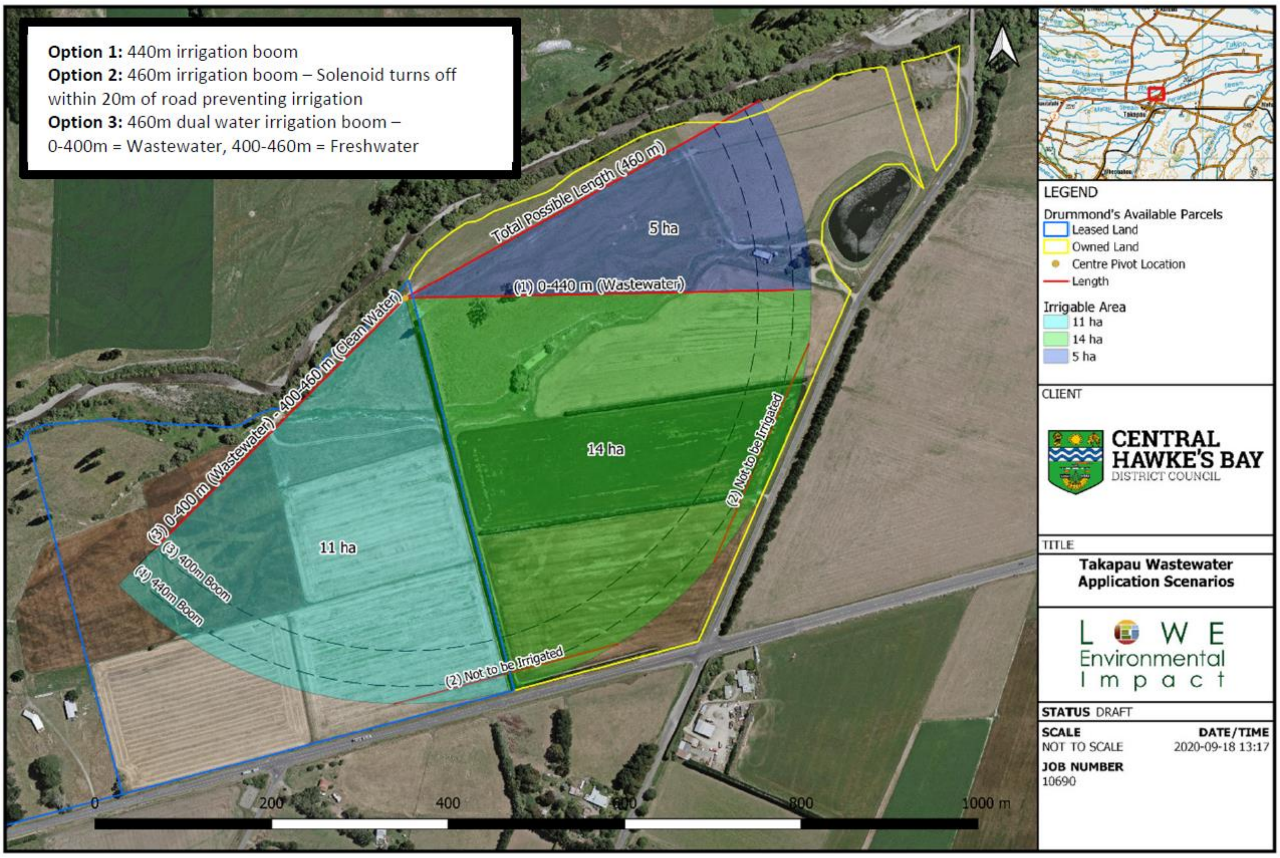

Figure 18. Proposed Irrigation Layout

LEI have provided a modelled discharge volume to the HRLP based on the historic years of climate fluctuations (2015 to 2019) modelled years – this can be taken as an approximation of the likely future discharge scenarios. Table 26 shows that during stage 1 the annual volume discharged to the HRLP would vary greatly between approximately 7,000 m^3/year (a typical dry year) and 29,000 m^3/year (a typical wet year). Table 27 also shows that the main discharge period when the HRLP is anticipated to operate is between the months of June-September (i.e. winter and early spring).

Table 26. HRLP Modelled Discharge Stage One

Monthly HRLP discharge (m^3)	2015	2016	2017	2018	2019
January	0	0	0	0	0
February	0	0	600	0	0
March	0	0	0	790	0
April	264	0	2200	0	0
May	0	0	0	0	0
June	3663	2299	7717	8310	2456
July	6860	3012	9089	9058	2106
August	7112	4482	7017	8749	2361
September	1200	0	0	1600	0
October	0	0	200	0	0
November	0	0	0	400	0
December	0	0	0	0	
Total	**19097**	**9793**	**26823**	**28907**	**6923**

5.1.1 Stage One Mass Balance

Although the main discharge at stage one will be to land, an assessment of the periodic HRLP discharge has been undertaken and is presented below. The predicted mixing water quality effects of the periodic HRLP wastewater discharge are based on a number of assumptions including:

- Half median River flow of 691 L/s (0.69 m^3/s) for the Makaretu River was calculated based on correlated flow gauges and HBRC flow data (Tukituki River at Tapairu Road correlated to Makaretu River at Speedy Road Bridge spot gauging measurements at a ratio of 0.98[18]);
- The treated wastewater discharge flow was taken from Table 26 as an average, over 2015-2019, of the month with the highest predicted outflow. An average monthly discharge volume of 6,025 m^3/month (0.002 m^3/s) for July represents a realistic worst-case event scenario;
- The treated wastewater contaminant concentrations are medians calculated from the monitoring data collected from the outlet between July 2014 and June 2019, with the exception of the toxicants, total ammoniacal nitrogen (NH_4-N) and nitrate-N (NO_3-N), which used the 95th percentile, and *E. Coli* which has been modelled based on the instalment of UV treatment at Stage One; and
- Makaretu River contaminant concentrations are medians calculated from monitoring data collected by CHBDC monitoring site 50 m upstream of the Takapau WWTP discharge collected between July 2014 and June 2019.

Assessment of predicted changes in key contaminant concentrations in the Makaretu River downstream of the wastewater discharge, as a result of discharge through the HRLP, under the Stage One scenario are summarised in Table 27 below. Dilution is estimated to be 302-fold based on a high WWTP discharge (July) and half-median river flow scenario[19].

Table 27. Predicted downstream contaminant concentrations – Half median flow dilution (302x) within the Makaretu River

Parameter	Unit	Discharge	Upstream	Downstream	Change
$cBOD_5$	mg/L	26	<1	<1	17%
TSS	mg/L	79	3	3	8%
NH_4-N	g/m^3	0.33	0.01	0.01	11%
NO_3-N	g/m^3	0.29	0.17	0.17	0%
DIN	g/m^3	5.800	0.070	0.089	27%
TN	g/m^3	14.10	0.16	0.21	29%
TP	g/m^3	3.820	0.034	0.047	37%
DRP	cfu/100ml	2.670	**0.017**	**0.026**	52%
E. coli	cfu/100 mL	5,000	140	156	11%

Note: Orange highlight indicates the ANZECC physical and chemical stressor trigger or MAC Grade D is exceeded, red highlight indicates the ANZECC toxicity trigger is exceeded, red text indicates the national bottom line guidelines are exceeded and **bold text** indicates the regional river guidelines (PC6) are exceeded (See Table 8).

The assessment indicates that, under the Stage One scenario:

- The HRLP treated wastewater discharge is predicted to cause a moderate increase (>10%) in the concentration of $cBOD_5$, NH_4-N, DIN, TN, TP, DRP and E. Coli in the Makaretu River downstream of the discharge. TP and DRP concentrations are already above the relevant criteria upstream of the WWTP. $cBOD_5$, NH_4-N, DIN, TN and *E. coli* concentrations are predicted to remain below the relevant water quality criteria despite the predicted increase.

[18] Correlation factor provided by Hawke's Bay Regional Council

[19] Median Dilution factor - (River flow / Wastewater flow) + 1 - (2.246 / 0.00132) + 1 = 1706 $m^3_{river}/m^3_{discharge}$

- TSS is predicted to have a minor increase (5-10%) downstream of the oxidation pond discharge. None of which are predicted to exceed the set water quality criteria.
- Very minor or no change (<5%) is predicted for NO_3-N and it is not predicted to exceed the set water quality criteria.

The mass-balance assessment above is for HRLP discharge to the Makaretu River at half median flow. It is important to note that the discharge is not expected to be continuous throughout the year. Based on modelling presented in Table 26, the discharge regime is expected to occur for the wettest time of the year between June and September. This is also when dominant river flow volumes are likely to increase due to higher rainfall rates. As such, this assessment is considered to reflect realistic worst-case conditions for the stage one scenario.

Downstream percentage increases for the Stage One mass-balance scenario across all contaminants range from 0% to 57%. This indicates an improvement to the current discharge worst-case presented in Section 4.4.2, in which downstream percentage increases range from 1% to 115%.

Based on these predictions, it appears that, when the HRLP discharge is occurring, the Takapau WWTP discharge would be expected to cause, at most, a minor to moderate increase in nutrient concentrations in the Makaretu River water quality during half median flow conditions. Phosphorus (Total and Dissolved) and *E. Coli* show the largest increases, however phosphorus is already elevated above the relevant criteria upstream of the discharge.

5.1.2 Stage One Mass Loading

A prediction of the annual mass-loading to the river by the WWTP discharge and the irrigated farm has been calculated for the Stage One development scenario. The combined mass-load contribution of the WWTP and the farm represent the future scenario in stage one whereby irrigation to the farm is the predominant method of discharge with periodic, reduced HRLP discharge. This can be compared to the baseline established in Table 23 to assess the future stage scenarios. The Stage One mass-loads have been calculated in accordance with the following parameters:

- Annual TN loss, by the farm, of 2,530 kg/yr, from LEI Overseer model Scenario 2;
- Annual TP loss, by the farm, of 20 kg/yr, from LEI Overseer model Scenario 2;
- An average annual flow from the WWTP of 18,308 m^3/yr, taken from Table 26;
- Average annual TN concentration of 15.1 g/m^3, taken from 2015-2020 data; and
- Average annual TP concentration of 3.89 g/m^3, taken from 2015-2020 data.

Total Nitrogen and Total Phosphorus mass-loads for the Stage One scenario, compared to the MZ3 catchment (Tapairu Rd), is presented in Table 28 below:

Table 28. Stage One nutrient mass loading

Contaminant	Unit	Loss to River	Change to Baseline	% of Tukituki at Tapairu Rd (MZ3)
Total Nitrogen Load	kg/day	7.69	- 5%	0.37% (747.77 T/yr)
	T/yr	2.81		
Total Phosphorus Load	kg/day	0.25	- 60%	0.52% (17.38 T/yr)
	T/yr	0.09		

5.2 Stage Two Water Quality Assessment

The stage two development involves the development of additional storage and irrigation area. The predicted effects of the stage two farm and wastewater discharge against the baseline are based on the following description:

- Involves the development of an additional 15-25 ha of irrigation allowing for irrigation of approximately 90% of the forecasted future average annual wastewater discharge volume to farm irrigation and 10% to the HRLP when river flows exceed median flow (see modelled HRLP discharge in Table 29);.
- Construction of 18,000 m^3 additional storage of treated wastewater to enable wastewater to be stored during wet soil conditions instead of behind discharged to the HRLP;
- The Stage Two Overseer modelled estimates (Table 24 – Scenario 2) include a nitrogen loss of 2,530 kg/yr and phosphorus loss of 20 kg/yr from the irrigated farm.

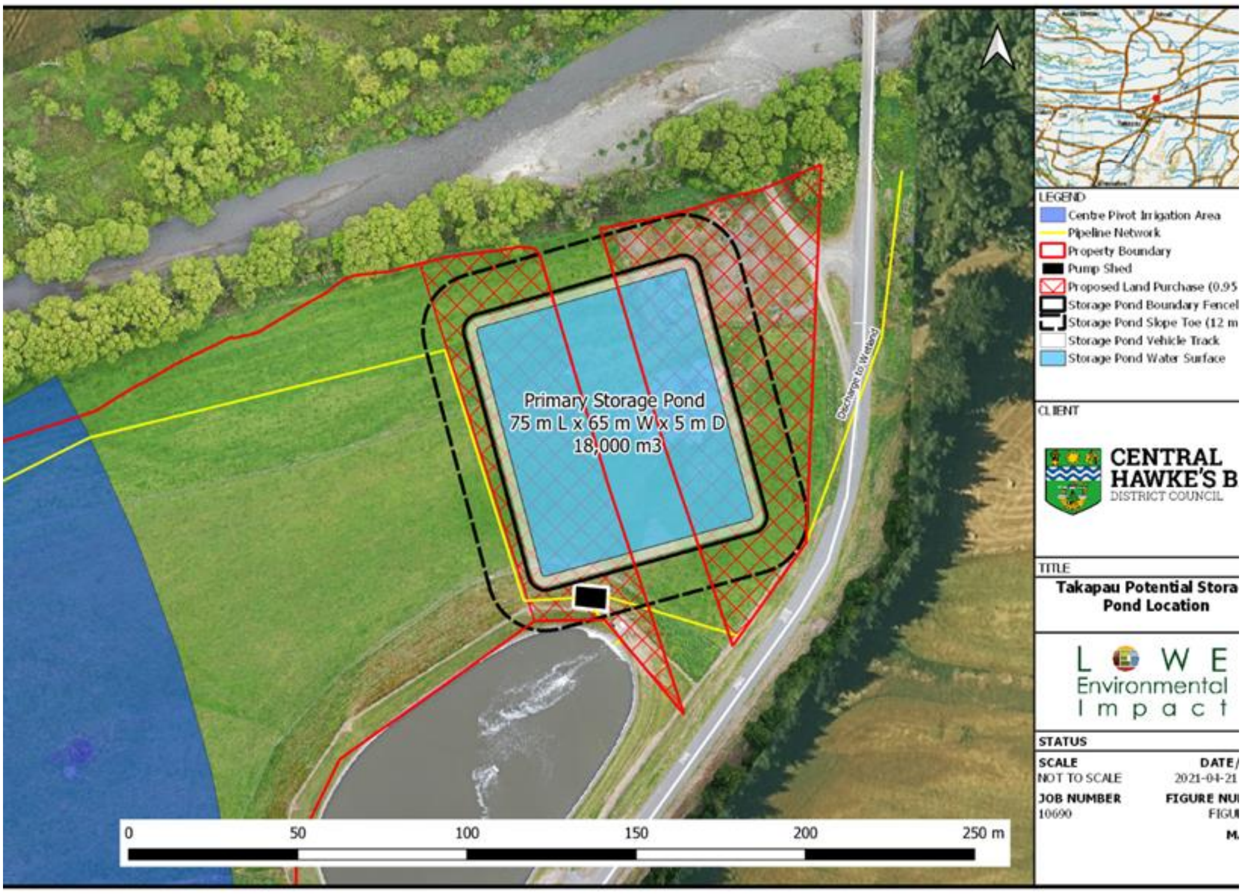

Figure 19. Proposed Pond Layout

The stage two modelled discharge volume to the HRLP based on the historic years of climate fluctuations (2015 to 2019) modelled years is presented in Table 29. The predicted discharge rates show that after Stage Two is implemented, the annual volume discharged to the HRLP would vary between approximately 0 m^3/year (a typical dry year) and 16,600 m^3/year (a typical wet year). Table 29 also shows that the main discharge period when the HRLP is anticipated to operate is between the months of June-August (i.e. winter).

Table 29. HRLP Modelled Discharge Stage Two

Monthly HRLP discharge (m^3)	2015	2016	2017	2018	2019
January	0	0	0	0	0
February	0	0	0	0	0
March	0	0	0	0	0
April	0	0	0	0	0
May	0	0	0	0	0
June	0	0	5600	3000	0
July	3528	0	5600	3929	0
August	2792	156	5400	3105	0
September	0	0	0	0	0
October	0	0	0	0	0
November	0	0	0	0	0
December	0	0	0	0	
Total	6320	156	16600	10034	0

5.2.1 Stage Two Mass Balance

Although the main discharge at Stage Two will be to land, an assessment of the periodic HRLP discharge has been undertaken and is presented below.

The predicted mixing water quality effects of the periodic HRLP wastewater discharge are based on a number of assumptions including:

- Median River flow of 1,381 L/s (1.38 m^3/s) for the Makaretu River was calculated based on correlated flow gauges and HBRC flow data (Tukituki River at Tapairu Road correlated to Makaretu River at Speedy Road Bridge spot gauging measurements at a ratio of 0.98[20]);
- The HRLP treated wastewater discharge flow was taken from Table 29 as an average, over 2015-2019, of the month with the highest predicted outflow. An average monthly discharge volume of 2,611 m^3/month (0.001 m^3/s) for July represents a realistic worst-case event scenario;
- The treated wastewater contaminant concentrations are medians calculated from the monitoring data collected from the outlet between July 2014 and June 2019, with the exception of the toxicants, total ammoniacal nitrogen (NH_4-N) and nitrate-N (NO_3-N), which used the 95th percentile, and *E. Coli,* which has been modelled based on the instalment of UV treatment at Stage One; and
- Makaretu River contaminant concentrations are medians calculated from monitoring data collected by CHBDC monitoring site 50 m upstream of the Takapau WWTP discharge collected between July 2014 and June 2019.

Assessment of predicted changes in key contaminant concentrations in the Makaretu River downstream of the wastewater discharge under the Stage Two scenario are summarised in Table 30 below. Dilution is estimated to be 2,261-fold based on a high WWTP discharge (July) and median river flow scenario[21].

[20] Correlation factor provided by Hawke's Bay Regional Council

[21] Median Dilution factor - (River flow / Wastewater flow) + 1 - (2.246 / 0.00132) + 1 = 1706 $m^3_{river}/m^3_{discharge}$

Table 30. Predicted downstream contaminant concentrations - Low flow dilution (2,261x) within the Makaretu River

Parameter	Unit	Discharge	Upstream	Downstream	Change
cBOD5	mg/L	26	<3	<3	4%
TSS	mg/L	79	3	3	2%
NH4-N	g/m3	0.33	0.01	0.01	2%
NO3-N	g/m3	0.29	0.17	0.17	0%
DIN	g/m3	5.800	0.070	0.074	6%
TN	g/m3	14.10	0.16	0.17	6%
TP	g/m3	3.820	0.034	0.037	8%
DRP	cfu/100ml	2.670	**0.017**	**0.019**	11%
E. coli	cfu/100 mL	5,000	140	143	2%

Note: Orange highlight indicates the ANZECC physical and chemical stressor trigger or MAC Grade D is exceeded, red highlight indicates the ANZECC toxicity trigger is exceeded, red text indicates the national bottom line guidelines are exceeded and **bold text** indicates the regional river guidelines (PC6) are exceeded (See Table 8).

The assessment indicates that, under the Stage Two scenario:

- The HRLP treated wastewater discharge is predicted to cause a moderate increase in the concentration of DRP. DRP concentrations are already above the PC6 criteria upstream of the WWTP.
- A minor increase in the concentration of DIN, TN, and TP is expected. TP concentrations are already above the ANZECC and HBRC criteria upstream of the WWTP.
- Very minor or no change is predicted for all other contaminants. None of which are predicted to exceed the set water quality criteria.

The mass-balance assessment above is for HRLP discharge to the Makaretu River at median flow. It is important to note that the discharge is not expected to be continuous throughout the year. Based on modelling presented in Table 29, the discharge regime is expected to occur in winter between June and August, with zero flows for most of the year. This is also when dominant river flow volumes are likely to increase due to higher rainfall rates. As such, this assessment is considered to reflect realistic worst-case conditions for the stage two scenario.

Downstream percentage increases for the Stage Two mass-balance scenario across all contaminants range from 0% to 11%. This indicates an improvement compared to the current discharge worst-case presented in Section 4.4.2, in which downstream percentage increases range from 1% to 115%.

Based on these predictions, it appears that, when the HRLP discharge is occurring, the Takapau WWTP discharge would be expected to cause, at most, a minor increase in nutrient concentrations in the Makaretu River water quality during median (normal) flow conditions.

Given the HRLP discharge will be periodic and limited to river flows about median flow, overall adverse effects of the proposed discharge on the water quality of the Makaretu River are predicted to be negligible.

5.2.2 Stage Two Mass Loading

A prediction of the annual mass-loading to the river by the WWTP discharge and the irrigated farm has been calculated for the Stage Two Scenario. The combined mass-load contribution of the WWTP and the farm represent the future scenario in Stage Two whereby there is increased irrigation to the farm as the predominant method of discharge and periodic, reduced HRLP discharge. This can be compared to the baseline established in Table 23 to assess the future stage scenarios. The Stage Two mass-loads have been calculated in accordance with the following parameters:

- Annual Total Nitrogen loss, by the farm, of 2,530 kg/yr, from LEI Overseer model Scenario 2;
- Annual Total Phosphorus loss, by the farm, of 20 kg/yr, from LEI Overseer model Scenario 2;

- An average annual flow from the WWTP of 6,622 m^3/yr, taken from Table 29;
- Average annual Total Nitrogen concentration of 15.1 g/m^3, taken from 2015-2020 data; and

Average annual Total Phosphorus concentration of 3.89 g/m^3, taken from 2015-2020 data.

Total Nitrogen and Total Phosphorus mass-loads contribution to MZ3 surface waters for the Stage Two scenario is presented in Table 31 below:

Table 31. Stage Two nutrient mass loading

Contaminant	Unit	Loss to River	Change to Baseline	% of Tukituki at Tapairu Rd (MZ3)
Total Nitrogen Load	kg/day	7.21	- 11%	0.35%
	T/yr	2.63		(747.77 T/yr)
Total Phosphorus Load	kg/day	0.13	- 80%	0.26%
	T/yr	0.05		(17.38 T/yr)

5.3 Summary of Staged Future Discharge Effects

5.3.1 Mass Balance

A summary of the percentage increase in downstream dilution concentrations, for each development stage, is presented in Table 32 and Figure 20. The results are presented as a function of the downstream percentage increase compared to the upstream concentration. All concentrations indicate an increase of less than 12% in the Stage Two scenario.

Table 32. Comparison of mass balance mixing analysis for each development stage

		Downstream Concentration			Downstream Percentage Increase from Upstream		
Parameter		Baseline MALF	Stage 1	Stage 2	Stage 0 MALF	Stage 1	Stage 2
$cBOD_5$	mg/L	<1	<1	<1	37%	17%	4%
TSS	mg/L	3	3	3	19%	8%	2%
NH_4-N	g/m3	0.01	0.01	0.01	24%	11%	2%
NO_3-N	g/m3	0.17	0.17	0.17	1%	0%	0%
DIN	g/m3	0.112	0.089	0.074	60%	27%	6%
TN	g/m3	0.26	0.21	0.17	64%	29%	6%
TP	g/m3	0.062	0.047	0.037	82%	37%	8%
DRP	cfu/100ml	**0.036**	**0.026**	**0.019**	115%	52%	11%
E. coli	cfu/100 mL	**271**	156	143	94%	11%	9%

Note: Orange highlight indicates the ANZECC physical and chemical stressor trigger or MAC Grade D is exceeded, red highlight indicates the ANZECC toxicity trigger is exceeded, red text indicates the national bottom line guidelines are exceeded and **bold text** indicates the regional river guidelines (PC6) are exceeded (See Table 8).

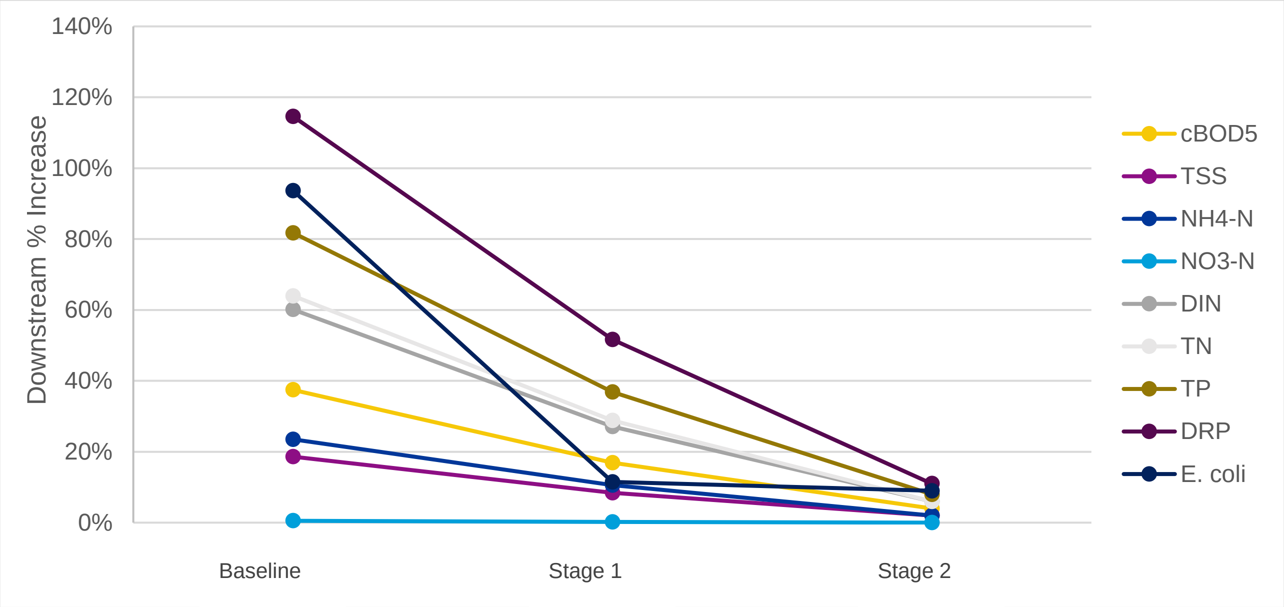

Figure 20. Downstream contaminant mass balance percentage increases for each development stage (assuming the HRLP discharge is occurring)

The reduction in mass-balance concentrations are a function of a reduced discharge via the HRLP, as well as the inclusion of conditional discharges only when the Makaretu River is at half median (Stage One) or median (Stage Two). The marked improvements in *E. Coli* between the Baseline and Stage One are also due to the installation of a UV treatment device. It is important to note that the conditional stream discharges assessed above represent the worst-case scenario for each of the stages as the discharge will occur at **or above** the set conditions. Further, it is likely that a high rate discharge will occur due to significant weather events, which will coincide with periods of high flow, thus increasing the dilution potential of the Makaretu River.

With respect to PC6 water quality limits set for Tukituki Catchment MZ3, this assessment indicates there will be no additional exceedances of parameters referenced in PC6 Tables 5.9.1A and 5.9.1B as a function of the future WWTP development stages. UV treatment and higher dilution rates contribute to the expectation that downstream *E. Coli* concentrations will meet PC6 targets year-round, even in the realistic worst-case scenarios. This is an improvement to the current discharge effects, in which *E. Coli* concentrations are predicted to be elevated above HBRC RRMP PC6 river guidelines in the current realistic worst-case (MALF) scenario.

5.3.2 Mass Loads

A summary of the change in mass loads for each development stage is presented in Table 33 and Figure 20. The relative percentage contribution of each stage to the mass loads at two HBRC monitoring locations is also provided. Tukituki at Tapairu can be considered as representative of PC6 Tukituki Catchment Management Zone 3, while Tukituki at Red Bridge represents the entire Tukituki Catchment.

The relative mass load contribution of the Takapau WWTP, under the baseline scenario, to Tukituki Catchment Management Zone 3 is calculated as 0.39% and 1.33% for nitrogen and phosphorus respectively. This is considered a minor contribution to the wider catchment totals which is progressively improved to 0.35% and 0.26%, respectively, by Stage Two.

Table 33. Total Nitrogen and Total Phosphorus mass load calculations for each development stage with comparisons to Tukituki at Tapairu and Tukituki at Red Bridge HBRC monitoring locations.

Discharge Scenario	Total Nitrogen	% of Tapairu	% of Red Bridge	Total Phosphorous	% of Tapairu	% of Red Bridge
Baseline	2.95 T/yr	0.39	0.29	0.23 T/yr	1.33	0.61
Stage One	2.81 T/yr	0.37	0.28	0.09 T/yr	0.52	0.24
Stage Two	2.63 T/yr	0.35	0.26	0.05 T/yr	0.26	0.12

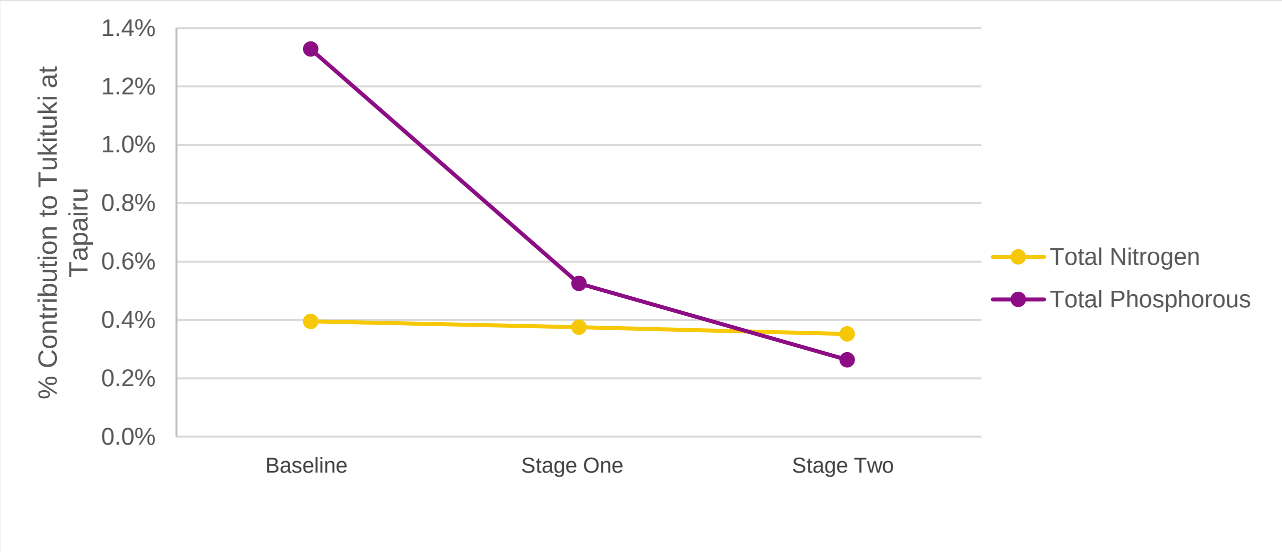

Figure 21. Downstream contaminant mass load percentage contribution to Tapairu Bridge HBRC Monitoring Location for each development stage

Nitrogen and phosphorus loads show significant modelled reductions at each development stage. In particular, total phosphorus loads more than half at each stage of the development. This is largely due to the planned reduction in direct river discharge through the wetland and subsequent HRLP. Phosphorus is readily taken up by allophanic soils that are characteristic of the area and it is therefore expected that the land irrigation scheme will intercept a significant portion of the phosphorus load that is currently discharging to the Makaretu River. This is a significant outcome as phosphorus, more than nitrogen, has been identified in this body of work as a catchment specific contaminant of concern.

The relative percentage contribution of Total Nitrogen to the catchment mass-loads only reduces by <0.5%. While this appears to be a minor reduction in overall nitrogen catchment loads, the mass-load contribution reduction is estimated to be over 0.3 T/yr. This is a measurable improvement for the Takapau WWTP despite other significant nitrogen sources within the catchment

5.3.3 Future Discharge Effects on Macroinvertebrates and Periphyton

The future discharges scenarios assessed in this report and to be adopted by CHBDC indicate improvements in water quality for the Makaretu River and wider Tukituki Catchment Management Zone 3 compared to the current scenario which has been assessed as having a trivial impact on the Makaretu River in the first place. While not directly assessed, additional consideration should be given to macroinvertebrate and periphyton indicators in regard to the future discharge scenarios. It is noted in this report that macroinvertebrate communities were similar upstream and downstream of the WWTP and MCI scores were generally above 100, indicative of good water quality habitats. Furthermore, periphyton biomass was well below the HBRC RRMP Plan Change 6 (2014) limit of 120 mg/m^2 at all three sites.

With these considerations in mind, and with regard to the wholesale improvement in the future discharge at both stages One and Two, it is likely that the reduced nitrogen and phosphorus loads discharged to the River will positively contribute towards reduced level of periphyton downstream and improved habitat and water quality for macroinvertebrate communities.

5.3.4 Tukituki River Catchment Outcomes

The Makaretu River water quality has been assessed throughout this report against the HBRC RRMP Plan Change 6 limits and targets set out in PC6 Tables 5.9.1A and 5.9.1B for MZ3 – Ruataniwha South. The relevant overarching listed objectives for PC6 include:

OBJ TT1 - To sustainably manage the use and development of land, the discharge of contaminant including nutrients, and the taking, using, damming, or diverting of fresh water in the Tukituki Catchment so that:

- Groundwater levels, river flows, lake and wetlands levels and water quality maintain or enhance the habitat and health of aquatic ecosystems, macroinvertebrates, native fish and trout;
- Water quality enables safe contact recreation and food gathering;
- Water quality and quantity enables safe and reliable human drinking water supplies;
- The frequency and duration of excessive periphyton growths that adversely affect recreational and cultural uses and amenity are reduced; and
- The mauri of surface water bodies and groundwater is recognised and adverse effects on aspects of water quality and quantity that contribute to healthy mauri are avoided, remedied or mitigated;

OBJ TT2 - Where the quality of fresh water has been degraded by human activities to such an extent that OBJ TT1 is not being achieved, water quality shall not be allowed to degrade further and it shall be improved progressively over time so that OBJ TT1 is achieved by 2030.

This assessment has shown that the proposed development of the Takapau WWTP will contribute towards achieving OBJ TT2 through the steady diversion of treated wastewater discharge from the river to adjacent farmland. The addition of UV treatment and likely attenuation of treated wastewater through soils will lead to significant water quality improvements for the Makaretu River, thus, addressing the points listed in OBJ TT1.

6 Conclusions

The existing Takapau WWTP treated wastewater discharge has been shown to marginally increase concentrations of nutrients and microbiological contaminants, in the Makaretu River downstream of the discharge point, under the existing discharge. Increased downstream concentrations are relatively minor downstream of the oxidation pond discharge during median flow levels, but effects are likely to be moderate in low-flow scenarios.

Median concentrations of total phosphorus and dissolved reactive phosphorus were found to be elevated above relevant guidelines upstream of the oxidation pond discharge. The most notable predicted effects of the oxidation pond discharge are an increase in *E. coli* and faecal coliforms at low flows, which exceed relevant water quality guidelines downstream of the oxidation pond discharge in the existing discharge mass balance analysis in this report.

The Takapau WWTP contributes a mass-load of 2.95 and 0.23 T/yr of Total Nitrogen and Total Phosphorus respectively. This amounts to 0.39% and 1.33% of the total Tukituki Catchment Management Zone 3 loads as measured by HBRC at the Tapairu Road monitoring location. Phosphorus (total and dissolved) is identified as a contaminant of concern in the Makaretu River upstream of the discharge. Measured and modelled concentrations of phosphorus exhibit minor increases downstream of the discharge under normal flow conditions.

Future development stages were assessed using the mass balance and mass load methodologies as a comparison to the existing discharge effects. Overall, the diversion of treated wastewater to land as irrigation and the inclusion of minimum stream flow discharge conditions (half-median for stage one and median for stage two) are predicted to result in significant reductions in the discharge effects to the Makaretu River.

With respect to the predicted downstream concentrations, downstream contaminant concentration increases are limited to 11%, with most contaminants expected to exhibit an increase of less than 5%. These increases are considered to be periodic only when HRLP discharge is required, which will likely coincide with times of higher river flow volumes (winter months).

Overall, given the HRLP discharge will be periodic and limited to river flows above median flow, adverse effects of the proposed discharge on the water quality of the Makaretu River are predicted to be negligible. The mass load of total nitrogen and total phosphorus is also predicted to reduce at each development stage. Nitrogen loads reduce from the baseline 2.95 T/yr to 2.81 T/yr in Stage One and 2.63 T/yr in Stage Two. Phosphorus load contributions in particular reduce from 0.23 T/yr (baseline) to 0.09 T/yr in Stage One to 0.05 T/yr in Stage Two. This is a notable improvement in a catchment where high phosphorus concentrations have been noted in this report and historically.

In summary, the proposed development is considered to be consistent with Tukituki Catchment Management Plan objectives. By removing a significant amount of nutrients from the catchment, the development will contribute towards improving the downstream water quality and ecology of the Makaretu River and Tukituki catchment.

A

Appendix A - Takapau WWTP - Hydrogeological Assessment

Beca

Takapau Wastewater Treatment Plant – Hydrogeological Assessment

Report No. T:B.14

Prepared for Central Hawke's Bay District Council
Prepared by Beca Limited

23 April 2021

Creative people together transforming our world

Revision History

Revision Nº	Prepared By	Description	Date
1	Vitor Vieira Centeno	For issue	23/04/2021

Document Acceptance

Action	Name	Signed	Date
Prepared by	Vitor Vieira Centeno		23/04/2021
Reviewed by	Keg Alexander and Sian France		23/04/2021
Approved by	Anna Lewis		23/04/2021
on behalf of	Beca Limited		

Contents

Appendices

Executive Summary

As part of the consent renewal for wastewater discharge at the Takapau Wastewater Treatment Plant (WWTP), a revised system comprised of spray irrigation of treated wastewater at the surface is proposed. A hydrogeological assessment was conducted to describe the groundwater system at and around the site, and to assess the potential movement of treated wastewater once it has infiltrated into the groundwater system.

A conceptual model showing the interpreted water table elevation around the WWTP has been developed. The model indicates that groundwater flow around the Takapau WWTP is from west to east generally parallel to the Makaretu River.

Near the WWTP, the Makaretu River is interpreted to be a losing stream, i.e. subsurface flow is from the river to groundwater, based on regional and local groundwater levels.

The two most significant potential receptors, identified as being the Makaretu River and the Source Protection Zone (SPZ) around the Takapau public supply bore, are both upgradient of the site, suggesting that infiltrated wastewater from the WWTP site will not travel towards these locations.

There are 27 existing groundwater bores known to be located within 2 km of the WWTP but none are considered to be directly downgradient and most are located upgradient, or on the other side of significant surface water bodies, hence infiltrated wastewater is not expected to travel towards these receptors.

1 Introduction

As part of the consent renewal for wastewater discharge at the Takapau Wastewater Treatment Plant (WWTP), a hydrogeological assessment was conducted to describe the groundwater characteristics at and around the site, and to assess the potential movement of treated wastewater once it has infiltrated into the groundwater system.

The scope of this report is as per Deliverable Scoping Document T:B.14, dated 26/03/2021.

The scope of this report does not include design of the proposed disposal system (drainage calculations etc), which has been undertaken by others.

2 Site Description

2.1 WWTP Location and Operation

The Takapau Wastewater Treatment Plant (WWTP) is located on Burnside Road adjacent to the Makaretu River Bridge in Central Hawke's Bay, approximately 2 km northeast of the town of Takapau (Figure 1).

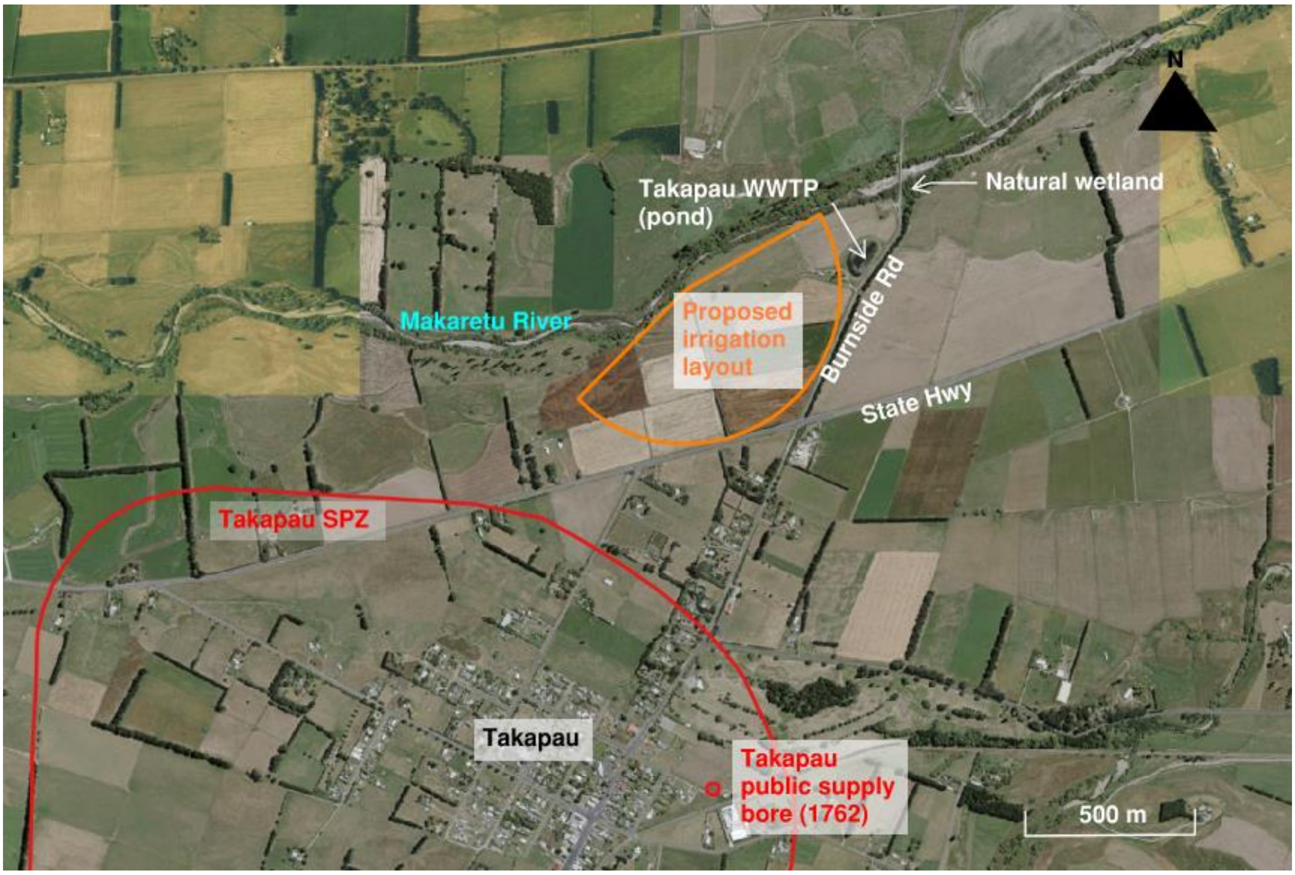

Figure 1: Location of Takapau WWTP. Proposed irrigation plan layout provided by LEI (2021a).

Wastewater from the small rural community is currently pumped to the Takapau WWTP, which consists of one clay-lined stabilisation pond of approximately 0.6 ha. Treated effluent is discharged to a drainage system in a natural wetland located approximately 120 m to the northeast adjacent to the southern bank of the Makaretu River.

The current discharge consent expires on 31 October 2021. For the consent renewal, it has been proposed to avoid discharging from the pond to the wetland, except during low river flow conditions, and to discharge directly to nearby farmland (Drummond Farm) as irrigation.

For this proposed discharge scheme, two key potential receptors are identified as follows:

- The Makaretu River, located 150 m north of the WWTP
- The Takapau Source Protection Zone (SPZ) around the public supply bore 1762. The edge of the SPZ is located approximately 1.1 km southwest of the WWTP.

A search of the Hawke's Bay Regional Council bores database was undertaken, and whilst there are 27 existing bores known to be located within a 2 km radius, there are none considered to be directly down-gradient of the WWTP.

2.2 Geology

The area is situated in the southern Ruataniwha Plains, in the area between Ruahine and Raukawa Ranges. The WWTP is situated between 220 and 222 m above mean sea level (MSL), in the alluvial terrace of the Makaretu River.

The general physical geography of the area is characterised by plains of alluvial origins. Intermediate river terraces composed of Pleistocene-aged alluvium (Q2a) are present across the wider Ruataniwha Plains, while the low terraces are composed of Holocene-aged alluvium (Q1a) generally follow the course of the Makaretu River (Lee et al, 2011). Figure 2 presents the distribution of the stratigraphic units around the WWTP and Table 1 provides the summary of these units.

According to Lee et al (2011), there are three major active faults close to the site, all with reverse movement: Ruataniwha, Oruawharo, and Takapau Faults, located respectively 2.9 km west, 3.0 km east, and 1.5 km southwest of the WWTP. The author also mentions the inactive Waikopiro Fault, situated just 100 m east to the WWTP (Figure 2) although active fault locations are often concealed beneath the alluvium.

Table 1: Stratigraphic formations at Takapau (Lee et al, 2011).

Unit	Typical Lithology	Thickness
Q1a – Holocene river deposits	Poorly consolidated alluvial gravel, sand, and mud	Approximately 40 m
Q2a – Late Pleistocene river deposits	Poorly to moderately sorted gravel with minor sand and silt underlying terraces.	Up to 250 m

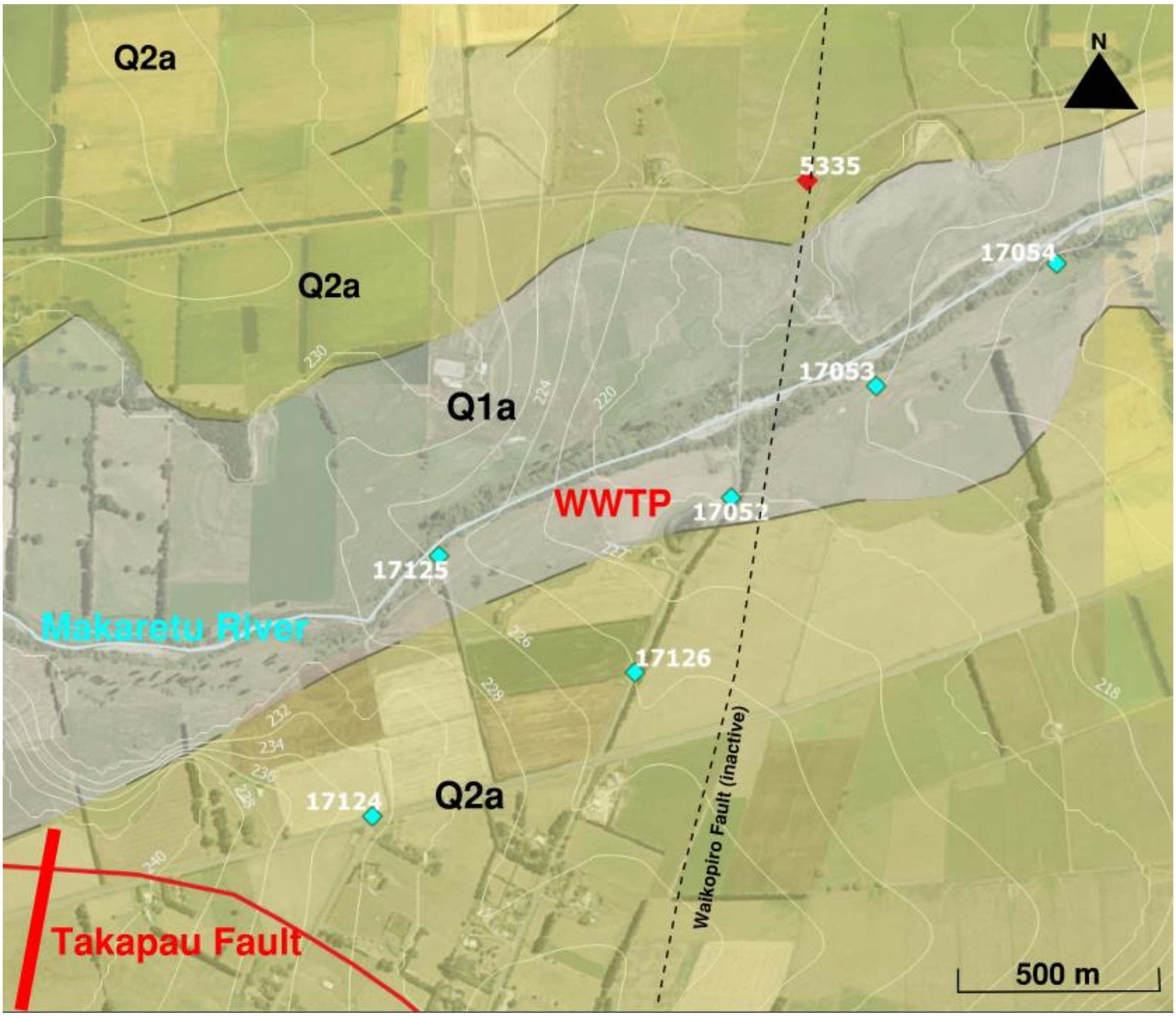

Figure 2: Geology of Takapau area (Lee et al, 2011). Blue point indicate the location of the six piezometers installed in 2020 around the WWTP. Red diamond is a HBRC groundwater level monitoring bore. Contours indicate the ground elevation in m MSL.

2.3 Soil types

A site investigation performed by LEI (2020) identified six different types of soil in the area (Figure 3):

- Lower terrace:
  - Ashburton Silt Loam: silty to sandy loam with gravels, occupying most of the lower terrace
- Upper terrace:
  - Ruataniwha Silt Loam: silty topsoil texture, with some gravels and poorly drained
  - Takapau Silt Loam: silty allophanic soils with no gravels, well drained
  - Tikokino Silt Loam: silty topsoil texture, moderately to well drained
  - Tikokino Shallow and Stony Loam: similar to Tikokino Silt Loam, but with up to 10 cm gravels in the topsoil
- Transition from lower to upper terrace:
  - Oronoko Silt Loam: silty loam with no gravels, moderately well drained, located in the transition from the lower to the upper terrace.

Figure 3: Soils distribution around Takapau WWTP. Source: LEI (2020).

2.4 Hydraulic Conductivity

No site-specific testing of hydraulic conductivity[1] is available; however, some inferences can be made from the soil descriptions and infiltration rates as detailed below.

In 2020, six shallow piezometers (up to 5.8 m deep) were installed around the WWTP to monitor groundwater quality and levels. Their locations are indicated by the blue points in Figure 2 and their details are further presented in Section 3.1. According to LEI (2021b), the soils encountered during installation of piezometers 17124 and 17126, in the Q2a unit, had high clay contents and the piezometers were slow to recharge after purging. A similar behaviour was observed in 17052, located in Q1a but close to the boundary with Q2a. The remaining piezometers, all located in Q1a, had fast recoveries after purging. This is discussed in Section 3.4.

LEI (2020) also performed infiltration tests in four different sites across the WWTP, as shown in Figure 3. These infiltration tests provide a measure of the rate of downward movement of water through the upper meter or so of soil. The results are summarised in Table 2 and indicate that, in general, the soil in the lower terrace Q1a (Site 1) appears to have a higher infiltration rate than the soils in the upper terrace Q2a (Sites 2, 3, 4). This is consistent with the observations of recovery times in the site-specific piezometers described above.

Table 2: Infiltration test results at Takapau WWTP. Source: LEI (2020)

Location	Unsaturated soil infiltration rate (mm/h)
Site 1	119 ± 55
Site 2	65 ± 48
Site 3	26 ± 29
Site 4	50 ± 33

Based on the bore log descriptions and the response of the piezometers to purging, the estimated saturated hydraulic conductivity values of the shallow aquifer in the lower terrace are likely higher than the shallow aquifer in the upper terrace, which has a higher content of fine material (clay and silt).

The estimated upper bound saturated hydraulic conductivity for the shallow alluvial sand and gravel aquifer in the lower terrace could be as high as $4x10^{-4}$ to $4x10^{-3}$ m/s (Geotechdata.info, 2013); the estimated range of saturated hydraulic conductivity values for the shallow aquifer in the upper terrace could be 1-2 orders of magnitude lower depending on fines content.

2.5 Hydrogeology

According to Bay Geological Services Ltd (2019), most aquifers in the southern Ruataniwha Plains are typically thick intermittent gravel lenses of variable permeability. These materials are grouped into two main Quaternary geological units. The older one, the Salisbury Gravels (Q2a - Lower Quaternary), can be up to 250 m thick. This unit is overlain by Young Gravels (Q1a - Upper Quaternary), which is approximately 40 m thick and comprise mostly unconfined aquifers composed of gravels with sandy, clayey, or silty matrix.

Recharge of the aquifer system occurs mainly by precipitation in the Ruahine Range to the west, especially during winter, and from losing rivers across the plains.

Hawke's Bay Regional Council (HBRC) has an extensive groundwater monitoring network. Table 3 provides a summary of the bores that are shallower than 30 m that are within 15 km of the WWTP.

[1] A measure of how easily groundwater water can pass through saturated soil or rock.

Table 3: HBRC monitoring bores within 15 km of the WWTP

Bore ID	NZTM Coordinates (m)	Elevation (m MSL)[1]	Distance from WWTP (km)	Screened Interval[1]	Total depth[1]	Maximum water level	Minimum water level	Average water level
5335	E: 1886887 N: 5566276	221.06	0.8	28.8 – 29.8 m BGL 192.3 – 191.3 m MSL	29.8 m BGL 191.3 m MSL	3.52 m BGL 217.54 m MSL	5.24 m BGL 215.82 m MSL	4.00 m BGL 217.05 m MSL
16507	E: 1892932 N: 5563970	180	6.5	27.6 – 28.8 m BGL 152.4 – 151.2 m MSL	28.8 m BGL 151.2 m MSL	9.62 m BGL 170.38 m MSL	9.95 m BGL 170.05 m MSL	9.71 m BGL 170.29 m MSL
16095	E: 1886853 N: 5569343	222.68	3.8	25.1 – 26.1 m BGL 197.6 – 196.6 m MSL	26.1 m BGL 201.6 m MSL	3.77 m BGL 218.91 m MSL	7.01 m BGL 215.67 m MSL	5.21 m BGL 217.47 m MSL
1376	E: 1896318 N: 5568312	154.96	10.1	20.1 – 25.2 m BGL 134.9 – 129.8 m MSL	24.2 m BGL 130.8 m MSL	0.52 m BGL 154.44 m MSL	0.93 m BGL 154.03 m MSL	0.72 m BGL 154.24 m MSL
16252	E: 1884059 N: 5569026	251.65	4.3	22.3 – 23.5 m BGL 229.4 – 228.2 m MSL	23.5 m BGL 228.2 m MSL	10.70 m BGL 240.95 m MSL	10.97 m BGL 240.68 m MSL	10.84 m BGL 240.81 m MSL
16247	E: 1890384 N: 5571135	194.75	6.7	12.5 – 14.0 m BGL 182.3 – 180.8 m MSL	14.0 m BGL 180.8 m MSL	1.84 m BGL 192.91 m MSL	4.84 m BGL 189.90 m MSL	2.87 m BGL 191.88 m MSL
16479	E: 1883704 N: 5566042	254.28	3.0	10.7 – 11.5 m BGL 243.6 – 242.8 m MSL	12.0 m BGL 242.3 m MSL	3.63 m BGL 250.65 m MSL	4.32 m BGL 249.96 m MSL	3.94 m BGL 250.34 m MSL
16503	E: 1890973 N: 5563088	192.66	5.0	10.3 – 11.5 m BGL 182.4 – 181.2 m MSL	11.5 m BGL 181.2 m MSL	1.70 m BGL 190.96 m MSL	2.23 m BGL 190.44 m MSL	1.94 m BGL 190.72 m MSL
16500	E: 1897758 N: 5570301	149.11	12.1	10.3 – 11.4 m BGL 138.8 – 137.7 m MSL	11.4 m BGL 137.7 m MSL	1.29 m BGL 147.82 m MSL	1.60 m BGL 147.51 m MSL	1.51 m BGL 147.60 m MSL
16491	E: 1894469 N: 5567402	163.3	8.1	4.4 – 5.6 m BGL 158.9 – 157.7 m MSL	5.6 m BGL 157.7 m MSL	2.34 m BGL 160.96 m MSL	3.34 m BGL 159.96 m MSL	2.75 m BGL 160.55 m MSL

[1]Elevations in m MSL estimated from an 8-m resolution Digital Elevation Model downloaded from Land Information New Zealand (LINZ).

Table 3 also presents the maximum, minimum, and average water levels recorded between July 2020 and February 2021.

As further discussed in Section 3, these bores indicate a general groundwater flow from west to east, approximately parallel to the Makaretu River.

Of the ten HBRC monitoring bores used in our assessment, five are shallower than 15 m BGL, while the remaining five are deeper than 20 m BGL. There are no nested piezometers, or pairs of piezometers (at the same location but screened at different depths) with which to assess vertical gradients.

Seasonal ranges (the difference between maximum winter and minimum summer levels) at individual bores vary from as little as 0.27 m (bore 16252) to 3.24 m (in bore 16095, Table 3). There is no clear correlation between seasonal range and depth, and the maximum and minimum water levels at individual bores can occur at different periods in the year (i.e. the summer low level across all bores does not occur consistently in the same month). The lack of clear depth, spatial or temporal correlation suggests that the seasonal ranges may reflect localised conditions, variability in screened unit etc.

2.6 Hydrology

The site is located in the Makaretu River sub-catchment, which is contained within the wider Tukituki catchment. The Makaretu River sub-catchment is approximately 80 km^2 and is located in the south-western, inland area of the Hawke's Bay Region (Figure 4). The sub-catchment is a linear feature draining from the southwest in the foothills of the Ruahine Ranges (at approximately 400 m MSL) onto the Ruataniwha Plains (Forbes et al, 2011).

The Makaretu River sub-catchment is bordered to the north and south by similarly defined, linear subcatchments – Tukipo and Porangahau respectively – all of which are contained within the wider Tukituki catchment management zone.

The Makaretu River, along with the Tukipo River and Porangahau Stream (via the Maharakeke River), converge with the Tukituki River approximately 5 km upstream of Waipukurau.

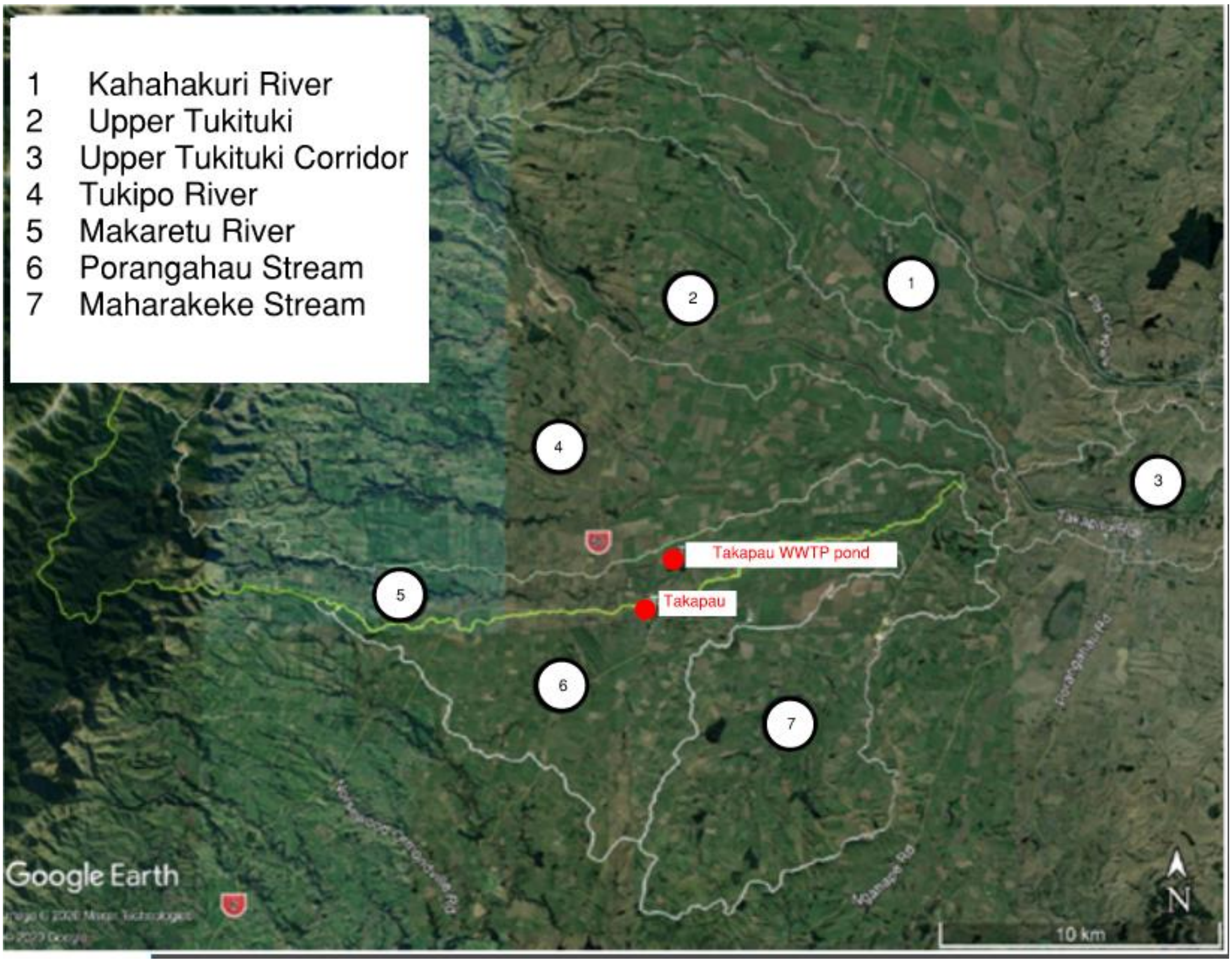

Figure 4: Southern sub-catchments of the Tukituki River catchment.

The relationship between these rivers and groundwater is discussed in Johnson (2011, as cited in Wilding & Waldron, 2012). According to this study, the rivers originating in the Ruahine Ranges tend to be conservative upstream (neither gaining nor losing water to groundwater), and then become losing streams in their middle reaches as the river water infiltrates the permeable alluvium material. Downstream, these rivers tend to gain flow from groundwater, as they intercept spring-fed tributaries at lower elevation areas, where the groundwater tends to be shallower.

Figure 5 shows the stream reaches in the Tukituki catchment and their classification as gaining, losing, or conservative reaches (Johnson, 2011). A further discussion based on our hydrogeological conceptual model is provided in Section 3.3.

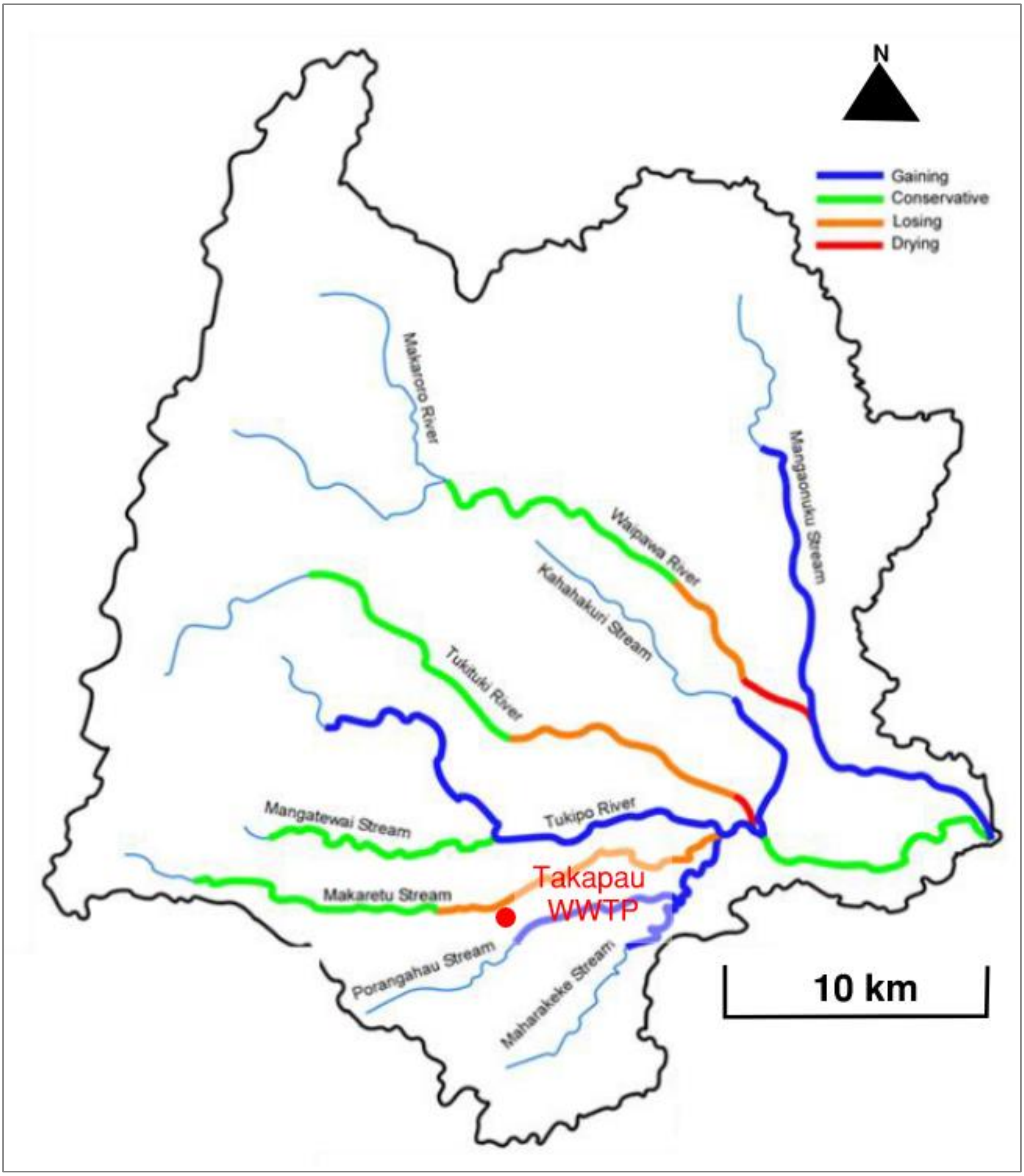

Figure 5: Conservative, losing and gaining stream reaches in the Tukituki Catchment. Source: Johnson (2011, as cited in Wilding & Waldron, 2012).

3 Conceptual hydrogeological model

3.1 Model set-up

A conceptual hydrogeological model was created using Golden Software Inc's Surfer 11 software using the following inputs:

- Groundwater level measurements obtained on 18 February 2021 from 6 shallow piezometers (no deeper than 5.8 m BGL) installed around the WWTP. Information about these piezometers was provided by LEI (2021b).
- Groundwater level measurements obtained on 23 February 2021 from 10 bores located within 15 km of the WWTP that are part of the groundwater monitoring network of HBRC. These data were obtained from HBRC Maps and GIS database.
- Approximately 850 elevation points located along Tukipo River, Makaretu River, Porangahau Stream and Maharakeke Stream. The groundwater elevation at these points was assumed to be equal to the surface water at these locations. Elevation data were estimated using an 8-m resolution Digital Elevation Model (DEM) obtained from LiDAR data downloaded from Land Information New Zealand (LINZ).

The location of the bores used in the model are presented in Figure 6 and their details are summarised in Appendix A.

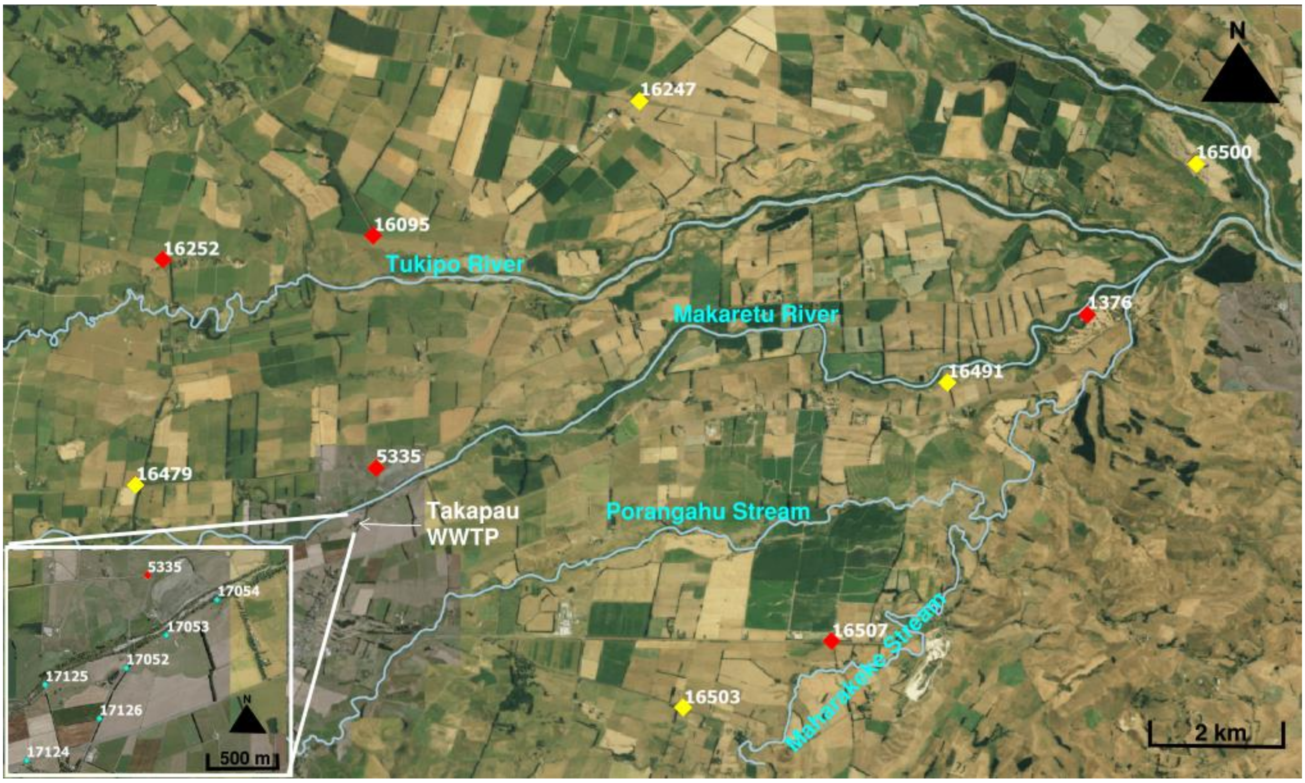

Figure 6: Regional bore locations used for hydrogeological conceptual model. Bores denoted by red dots are screened between 20 and 30 m and bore denoted by yellow dots are screened between 4 and 14 m. Blue dots indicate the location of the six piezometers around the WWTP.

We make the following observations:

- Water levels measured in the regional bores in February 2021 (dry season) were compared with water levels measured in August 2020 during the wet season. No significant seasonal differences in the interpreted groundwater flow direction were observed.

- There is only one set of groundwater level measurements (February 2021) from the 6 piezometers at the WWTP. No assessment of seasonal variation is available for these bores.
- The elevations in m MSL presented in this document are approximately 10 m lower than elevations presented in Table 1 of LEI (2021b). The LEI report notes that elevations are based on LiDAR data collected in 2006, while this report uses LiDAR data obtained in 2012, which we assumed to be more precise and whose levels are matching other sources (e.g. Google Earth). All levels provided by LEI were converted to levels given by the 2012 LiDAR data.
- Of the ten bores from HBRC monitoring network, five are screened below 20 m BGL (red dots in Figure 6), while the other five bores are screened at depths of less than 15 m (yellow dots in Figure 6). Three different conceptual models were developed, one using data from just the shallow bores, another using data from just the deeper bores, and a third using data from all 10 bores. No significant differences were observed between the three models indicating that there does not appear to be a significant hydraulic separation.

3.2 Groundwater Levels and Direction of Flow

The conceptual hydrogeological model shown in Figure 7 presents the water table elevation in m MSL and interpreted shallow groundwater flow direction in the vicinity of the WWTP site on a regional scale, whilst Figure 8 shows this on a local scale.

The groundwater at the site flows from west to east at a gradient of approximately 0.005 (1 m drop over a horizontal distance of 200 m), as can be inferred from Figure 8.

3.3 Connection between groundwater and surface water

The relationship between groundwater and the Tukipo River, Makaretu River, Porangahau Stream and Maharakeke Stream can be seen on the 3D blocks shown in Figure 7 and Figure 8. These figures illustrate that the reaches of these rivers closest to the WWTP are either conservative (neither gaining nor losing water) or losing water to groundwater.

In agreement with Johnson (2011), our conceptual model indicates that immediately adjacent to the Takapau WWTP, the Makaretu River is slightly more elevated than the surrounding water table, suggesting that the river is losing water to groundwater in this area.

Downstream, below the junction with the Tukipo River, the groundwater table becomes higher and the river starts to gain flow (Figure 5).

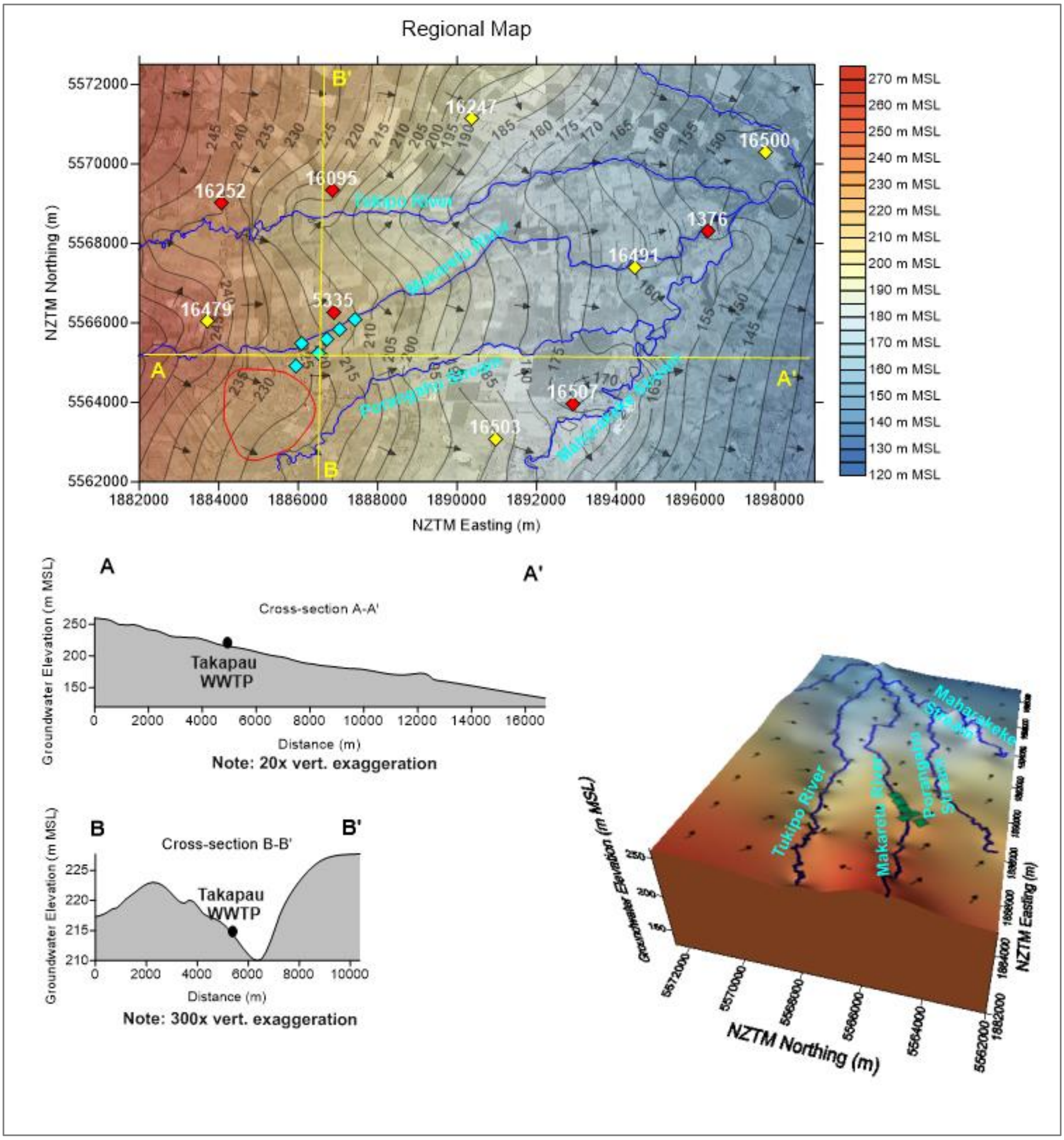

Figure 7: Regional conceptual hydrogeological model. The WWTP is located at the intersection of the cross-section lines. Red circle to SW is the Source Protection Zone for the Takapau water supply bore. Regional bores shown as red and yellow diamonds and local piezometers shown by blue diamonds. Contours indicate the water table elevation in m MSL and arrows indicate the interpreted groundwater flow direction.

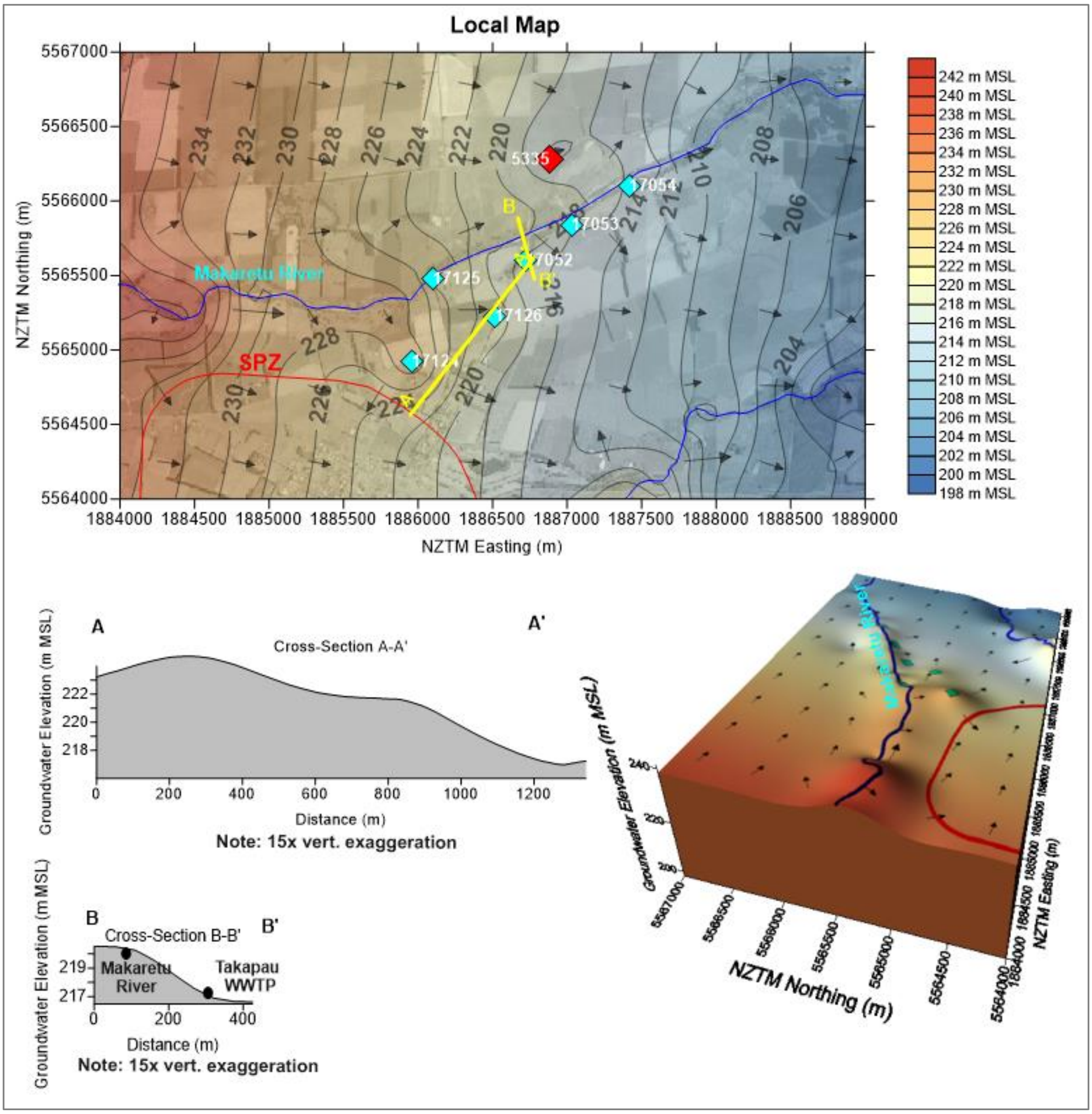

Figure 8: Local conceptual hydrogeological model. Regional bore 5335 shown as red diamond and local piezometers shown by blue diamonds. Contours indicate the water table elevation in m MSL and arrows indicate the interpreted groundwater flow direction.

3.4 Hydraulic gradient and travel time assessment

Figure 7 indicates the regional hydraulic gradient is predominantly from west to east (Cross-section A-A' in that same figure).

Cross-section A-A' in Figure 8 shows the hydraulic gradient over the shortest path between the Takapau SPZ and the WWTP site. Likewise, Cross-section B-B' in Figure 8 shows the hydraulic gradient over the shortest path between the Makaretu River and the WWTP site. Both cross-sections indicate that the potential receptors (the SPZ and the Makaretu River) are ***upgradient*** of the WWTP and thus, shallow groundwater flow and infiltrated wastewater from the WWTP would not be expected to flow towards these potential receptors and so travel time has not been assessed.

There are also private groundwater bores located within 2 km of the WWTP; these are shown in Figure 9 and their details are included in Appendix B. The yellow dots show bores deeper than 30 m, while the blue dots show the bores shallower than 30 m. There is only one bore that is directly downgradient of the WWTP, bore 4838, which is screened below 80 m BGL, and hence is considered unlikely to have any connection with the shallow groundwater.

Bores 1384 and 4254, which are shallower than 30 m BGL and are possibly downgradient of the WWTP, but are located 1.7 km and 1.9 km away, respectively, and on the other side of the Porangahau Stream, and, therefore, are unlikely to be impacted by any infiltrated wastewater from the WWTP.

Bore 1381 is along gradient and all other bores located between the Makaretu River and the Porangahau Stream are considered to be upgradient of the WWTP.

There is the possibility of upgradient bores reversing the hydraulic gradient when pumping, in which case the capture zone of the pumped bore could cause nearby shallow groundwater to flow toward the pumping bore. It is not possible to fully quantify this without details of well operation and performance (pumping rate and durations, drawdown etc) however qualitatively we would note:

- There are only three water take consents within 2 km of the WWTP, all of them relate to bores deeper than 30 m and based on bore 1762 described below, there is likely to be some hydraulic separation between shallow groundwater and the deeper aquifer screened in these bores.
- All other unconsented takes and shallower bores are likely to have lower pumping rates and, therefore, are unlikely to reverse the hydraulic gradient over large distances.
- The water take consent associated with bore 1762 is the Takapau community supply. According to its HBRC log (Appendix C), this bore is screened from 31.0 to 33.5 m BGL and there is approximately 22 m of lower permeability units (comprised of multiple clay layers) above the screened interval. These units are likely to provide some hydraulic separation between the pumped aquifer and the shallow groundwater. Further the SPZ is presumably based on an assessed extent of drawdown and suggests that this does not extent a significant distance downgradient.

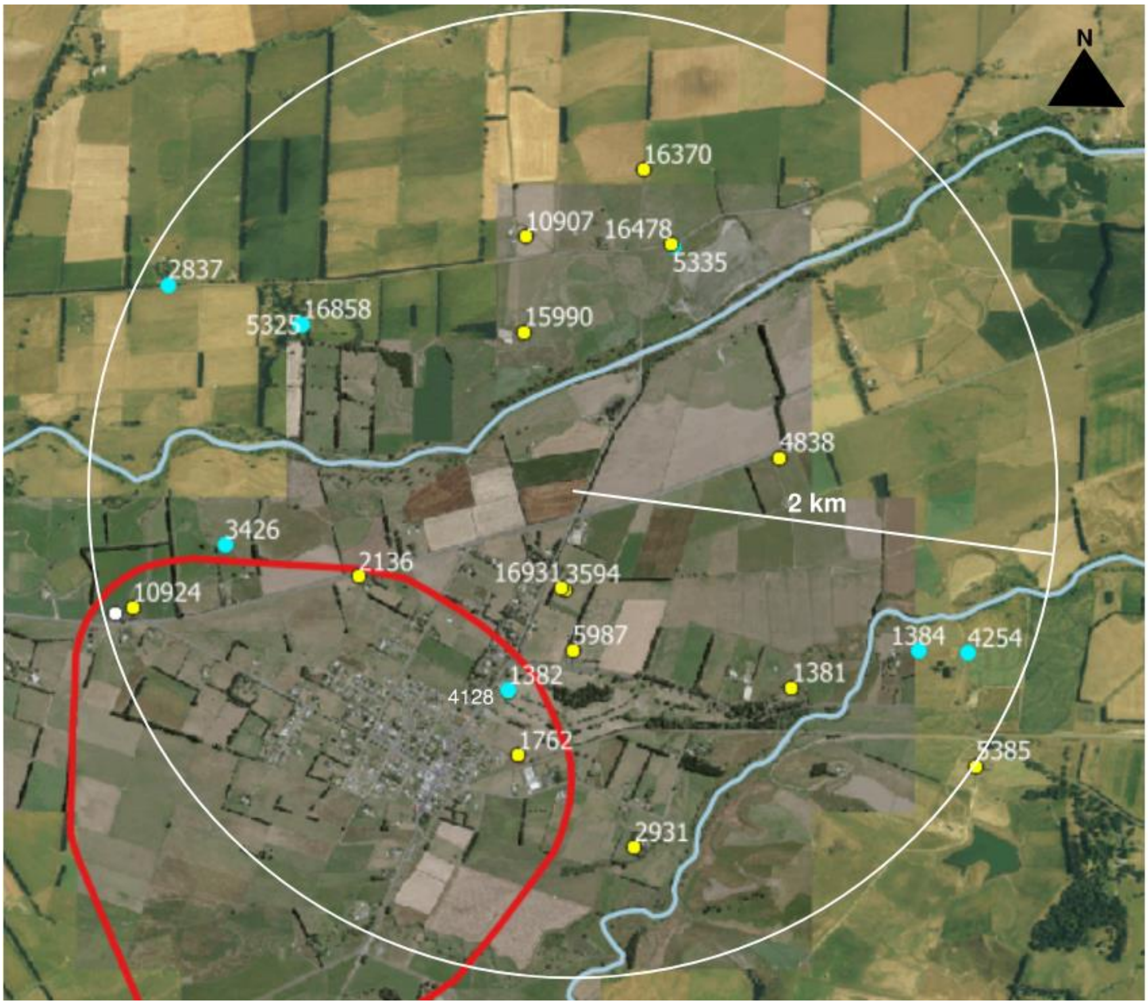

Figure 9: Bores within 2 km of the WWTP. Red line is SPZ surrounding the Takapau water supply bore 1762. The yellow dots show bores deeper than 30 m, while the blue dots show the bores shallower than 30 m.

3.5 Limitations and uncertainties

Table 4 outlines the key limitations to the hydrogeological assessment.

Table 4: Conceptual model and assessment limitations

Element	Comment
Ground elevation	• Limited resolution of LiDAR data and multiple LiDAR data sets • No ground elevation reported on HBRC logs
Water levels	• Limited information about river levels close to Takapau, these have been obtained from LiDAR • No monitoring of Makaretu River level available
Seasonal variations	• Groundwater levels for the six site specific piezometers around the WWTP have only been measured once (in February 2021)
Gradients	• In general, the flow of groundwater is such that there are no directly down-gradient receptors. It is possible that pumping from bores could locally reverse gradients thought the effect of this is likely to be limited to immediately around the bores and would not materially change the assessment presented above.

4 Subsurface nutrient attenuation potential

As described above, the Takapau Source Protection Zone (SPZ) and the Makaretu River are the two most significant potential receptors for this groundwater assessment. Any groundwater interaction between the SPZ and the Makaretu River adjacent to Drummond Farm is likely to be negligible due to the interpreted groundwater flow direction and the indication that the Makaretu River is generally losing water to groundwater along this reach.

There are no receptors (e.g. registered groundwater users, surface water bodies, source protection zones, etc) identified as directly down-gradient but regardless this section assesses the potential for nutrient (nitrogen and phosphorus) transmission through the soil and groundwater should there be unknown receptors down-gradient of the site.

4.1 Nitrogen

As nitrate moves from land to receiving waters there is potential for subsurface denitrification and hence the attenuation of nitrate flux to receiving surface waters. Attenuation potential is dependent on a number of variables including land-use type, soil type, organic carbon content, and permeability (drainage) (Table 5).

Table 5: Nitrogen attenuation factors by soil type (Singh et al, 2019).

Nitrogen attenuation factor		Soil types (soil texture, drainage and carbon classes)*	Rock types (geology)
Low	0.10 – 0.30	Stony sandy loam, and sand & stony gravel; soil carbon class 5; and soil drainage classes 4 and 5, and artificial drainage	e.g. Gravels
Medium	0.35 – 0.65	Sandy and silt loams; soil carbon classes 3 and 4; and soil drainage class 3	e.g. Sandstone, limestone, and siltstone
High	0.70 – 0.95	Heavy silt loam, clay loam and peaty loam; soil carbon classes 1 and 2; and soil drainage classes 1 and 2	e.g. Mudstone and peat

*According to the FSL, soil carbon is classified into 5 classes where soil carbon class 1 is very high soil total carbon content (>20%) and soil carbon class 5 is very low soil total carbon content (2%). Soil drainage classes (1 to 5) where soil drainage class 1 is assigned to very poorly drained soil and soil drainage class 5 to well drained soils.

The Drummond Farm area designated for treated wastewater irrigation is comprised of varying stages of silty loam (Figure 3), underlain by Quaternary river gravels. This is indicative of an environment with a low to medium attenuation factor (AFn) due to the high permeability of the gravels, although the silt and organic carbon content in the near surface soil could contribute to a higher attenuation factor and reduce the total discharge to the sensitive receptors.

Overseer farm nitrogen losses, modelled by LEI, indicate a nitrogen loss of 2,097 kg/yr as a result of the WWTP irrigation combined with existing farm irrigation and fertiliser regimes. Due to the assumed low to medium attenuation factor in the soils, limited attenuation by the soils may occur which would reduce the actual nitrogen loss to groundwater compared with the modelled Overseer value. Once leached from the agricultural soils, nitrogen, in the form of nitrate-nitrogen (NO_3-N), may be further attenuated through a process of denitrification if favourable conditions exist in the groundwater system (Collins et al, 2017).

Based on the interpreted groundwater contours, nitrogen in groundwater would need to travel several km downgradient before it is expected to enter any surface water body (if at all). As such, it is considered that attenuation of nitrogen, initially by soils and subsequently by groundwater, may contribute to reducing the modelled farm-loss mass-load of nitrogen (2,097 kg/yr) to surface water bodies in the Tukituki Catchment.

4.2 Phosphorus

Phosphorus is predominantly lost by erosion and entrainment in the form of overland flow. It binds readily with soil, rather than water, through adsorption with respect to ionic strength, higher clay content and acidic soils (Carpenter et al, 1998). As such, the loss of phosphorus by groundwater leachate is considered to be a minor by-product in the phosphorus cycle. It is considered likely that limited phosphorus would be leached from the site through groundwater.

5 Conclusion and recommendations

The conceptual hydrogeological model indicates the groundwater flow around Takapau WWTP is from west to east generally parallel to the Makaretu River. Near the WWTP, the Makaretu River is interpreted to be a losing stream (subsurface flow is from the river to groundwater) based on regional and local groundwater levels.

The two most significant potential receptors, being the Makaretu River and the Source Protection Zone (SPZ) around the Takapau public supply bore, are both upgradient of the site, suggesting that any infiltrated wastewater from the WWTP site will not travel towards these locations. There are no directly down-gradient receptors identified.

It is recommended that groundwater levels in the six new piezometers near the WWTP should be measured quarterly. The local conceptual hydrogeological model presented in this report should be re-evaluated with additional water level to confirm the assumption here that there is no material change to groundwater flow direction or groundwater-surface water interaction with the Makaretu River seasonally.

6 Applicability Statement

This report has been prepared by Beca on the specific instructions of our Client. It is solely for our Client's use for the purpose for which it is intended in accordance with the agreed scope of work. Any use or reliance by any person contrary to the above, to which Beca has not given its prior written consent, is at that person's own risk.

Should you be in any doubt as to the applicability of this report and/or its recommendations for the proposed development as described herein, and/or encounter materials on site that differ from those described herein, it is essential that you discuss these issues with the authors before proceeding with any work based on this document.

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A

Appendix A – Bores used in the hydrogeological conceptual model

Bore ID	NZTM Coordinates (m)	Ground elevation (m MSL)[1]	Screened Interval[1]	Total depth[1]	Water level - Feb 2021[1]
5335	E: 1886887 N: 5566276	221.1	28.8 – 29.8 m BGL 192.3 – 191.3 m MSL	29.8 m BGL 191.3 m MSL	5.24 m BGL 215.9 m MSL
16507	E: 1892932 N: 5563970	180.0	27.6 – 28.8 m BGL 152.4 – 151.2 m MSL	28.8 m BGL 151.2 m MSL	9.95 m BGL 170.0 m MSL
16095	E: 1886853 N: 5569343	222.7	25.1 – 26.1 m BGL 197.6 – 196.6 m MSL	26.1 m BGL 201.6 m MSL	5.52 m BGL 217.2 m MSL
1376	E: 1896318 N: 5568312	155.0	20.1 – 25.2 m BGL 134.9 – 129.8 m MSL	24.2 m BGL 130.8 m MSL	0.93 m BGL 154.1 m MSL
16252	E: 1884059 N: 5569026	251.7	22.3 – 23.5 m BGL 229.4 – 228.2 m MSL	23.5 m BGL 228.2 m MSL	10.97 m BGL 240.7 m MSL
16247	E: 1890384 N: 5571135	194.8	12.5 – 14.0 m BGL 182.3 – 180.8 m MSL	14.0 m BGL 180.8 m MSL	4.85 m BGL 190.0 m MSL
16479	E: 1883704 N: 5566042	254.3	10.7 – 11.5 m BGL 243.6 – 242.8 m MSL	12.0 m BGL 242.3 m MSL	4.32 m BGL 250.0 m MSL
16503	E: 1890973 N: 5563088	192.7	10.3 – 11.5 m BGL 182.4 – 181.2 m MSL	11.5 m BGL 181.2 m MSL	2.23 m BGL 190.5 m MSL
16500	E: 1897758 N: 5570301	149.1	10.3 – 11.4 m BGL 138.8 – 137.7 m MSL	11.4 m BGL 137.7 m MSL	1.60 m BGL 147.5 m MSL
16491	E: 1894469 N: 5567402	163.3	4.4 – 5.6 m BGL 158.9 – 157.7 m MSL	5.6 m BGL 157.7 m MSL	3.34 m BGL 160.0 m MSL
17125	E: 1886103 N: 5565475	225.6	Unknown	5.8 m BGL 219.8 m MSL	2.00 m BGL 223.6 m MSL

Bore ID	NZTM Coordinates (m)	Ground elevation (m MSL)[1]	Screened Interval[1]	Total depth[1]	Water level - Feb 2021[1]
17053	E: 1887033 N: 5565838	218.2	Unknown	4.5 m BGL 213.7 m MSL	1.78 m BGL 216.4 m MSL
17054	E: 1887420 N: 5566099	215.6	Unknown	4.3 m BGL 211.3 m MSL	0.90 m BGL 214.7 m MSL
17052	E: 1886724 N: 5565599	220.0	Unknown	4.2 m BGL 215.8 m MSL	2.89 m BGL 217.1 m MSL
17124	E: 1885961 N: 5564921	232.6	Unknown	4.2 m BGL 228.4 m MSL	3.38 m BGL 229.2 m MSL
17126	E: 1886519 N: 5565227	224.2	Unknown	4.2 m BGL 220.0m MSL	2.92 m BGL 221.3 m MSL

[1]Elevations in m MSL estimated from an 8-m resolution Digital Elevation Model downloaded from Land Information New Zealand (LINZ).

B

Appendix B – Bores within 2 km of the Takapau WWTP

Bore ID	Easting	Northing	Well Number	Well Depth	Well Diameter	Drill Date	Driller Name	Top Screen	Bottom Screen	Bore No	Open Hole Top	Open Hole Bottom	Aquifer Lithology	Aquifer Condition	Initial Water Level Date	Initial Water Level	Bore Depth	Water Level Access	Location Method	Casing Diameter	Address
1381	1,887,435.25	5,564,251.27	1381	58.36	200	10/02/1982	Hill Well Drillers Ltd	39.36	43	1,381				Confined		-2.2		Unknown	Differential GPS	200	ORUAWHARA RD, TAKAPAU (L/C)
1382	1,886,134.44	5,564,239.07	1382	31.4	150	6/07/1982	N. WEBB	25.45	26.21	1,382				Confined		-5.33		Unknown	Differential GPS	150	CHARLOTTE/RUAWHARA ST, TAKAPAU (L/C)
1384	1,888,013.59	5,564,419.47	1384	19.53	150	1/03/1982	Hill Well Drillers Ltd	16.53	19.53	1,384				Confined				Unknown		150	ORUAWHARA RD, TAKAPAU (L/C)
1717	1,886,232.11	5,566,808.71	1717							1,717			Unknown	Unknown		0		Unknown	Map estimate		
1762	1,886,179.51	5,563,939.89	1762	48.9	150	19/02/1985	N. WEBB	31.08	33.48	1,762				Confined		-4.7		Unknown	Hand-held GPS	150	META ST, TAKAPAU (L/C)
2136	1,885,446.94	5,564,759.29	2136	63.5	200	22/08/1986	Hill Well Drillers Ltd	51.5	63.5	2,136			Gravels	Confined		-15		Yes	Hand-held GPS	200	S.H.2 / TAKAPAU (L/C)
2322	1,884,337.28	5,564,592.01	2322	5.5	1,000.00	3/11/1987	T J DRUMMOND			2,322			Unknown	Unknown		-1.2		Unknown	Differential GPS	1,000.00	S H 2 TAKAPAU
2837	1,884,573.19	5,566,099.99	2837	29.85	100	31/10/1990	Honnor Drilling Limited	17.53	18.96	2,837			Gravels	Confined		-7.31		Unknown	Differential GPS	100	PAGET ROAD, TAKAPAU
2931	1,886,712.91	5,563,518.70	2931	44.2	150	13/06/1991	Honnor Drilling Limited	23.16	40.84	2,931				Confined		-12		Unknown		150	SYDNEY TERRACE, TAKAPAU PH (06) 8558033
3426	1,884,834.53	5,564,906.29	3426	19	100	5/05/1994	Honnor Drilling Limited	15.15	17	3,426			Gravels	Confined		-1.2		Unknown		100	4292 S.H. 2, TAKAPAU
3594	1,886,395.53	5,564,703.40	3594	57.6	150	24/04/1995	Baylis Brothers Limited	51.6	57.6	3,594			Gravels	Confined		-10.5		Unknown	Hand-held GPS	150	4 CHARLOTTE STREET TAKAPAU
4128	1,886,138.44	5,564,233.07	4128	49.6	150	15/06/1998	N. WEBB			4,128			Unknown	Unknown				Unknown	Hand-held GPS	150	CHARLOTTE STREET, TAKAPAU
4254	1,888,240.74	5,564,409.50	4254	22.06	50	12/03/1999	Hill Well Drillers Ltd	14.73	20.45	4,254			Gravels	Confined		-2		Unknown	Differential GPS	50	478 ORUAWHARA ROAD, TAKAPAU
4838	1,887,379.06	5,565,306.94	4838	99.3	200	25/07/2002	Baylis Brothers Limited	80.39	99.3	4,838				Unknown		-17.96		Unknown	Differential GPS	200	SH 2, TAKAPAU
5325	1,885,183.59	5,565,917.97	5325	27.4	100	23/12/2004	Honnor Drilling Limited	25.6	27.4	5,325			Gravels	Flowing confined	12/23/2004, 1:00 PM	4	31	No	Hand-held GPS	100	189 NELSON RD, TAKAPAU
5335	1,886,887.60	5,566,276.47	5335	29.8	150	29/09/2005	Baylis Brothers Limited	28.76	29.76	5,335			Gravels	Confined	9/28/2005, 12:00 PM	-3.1	30.2	Unknown	Differential GPS	150	CNR BURNSIDE & NELSON RDS, TAKAPAU
5385	1,888,279.84	5,563,893.17	5385	117.6	100	15/08/2005	Honnor Drilling Limited	96.85	117.61	5,385			Sand	Confined	8/15/2005, 12:00 PM	-7.11	121	No	Hand-held GPS	100	184 ORUAWHARO RD, RD1, TAKAPAU
5987	1,886,429.60	5,564,423.23	5987	36.4	100	5/01/2009	Honnor Drilling Limited	34.5	36.4	5,987			Gravels	Confined	1/5/2009, 1:00 PM	-16.3	42	Unknown	Hand-held GPS	100	656 ORUAWHARO ROAD, TAKAPAU
10907	1,886,212.17	5,566,320.39	10907	44.1	100	18/02/1998	Honnor Drilling Limited	36.24	38.14	10,907				Unconfined		-3.9		Unknown		100	NELSONS ROAD, TAKAPAU
10923	1,884,511.38	5,564,619.06	10923		200					10,923			Unknown	Unknown				Unknown		200	CNR SH 2 AND SYDNEY ST, TAKAPAU
10924	1,884,411.32	5,564,619.04	10924	34.1	200	23/12/1981	N. WEBB	19.4	34.1	10,924				Unconfined		-5.5		Unknown		200	CNR SH2 & SYDNEY STREET, TAKAPAU
15636	1,888,518.73	5,565,630.32	15636							15,636								Unknown	Map estimate		TAKAPAU
15990	1,886,207.24	5,565,883.12	15990	65.2	150	17/07/2012	Honnor Drilling Limited	63.5	65.2	15,990			Other	Confined	7/17/2012, 12:00 PM	-12.5	81.5	Unknown	Hand-held GPS	150	Cnr Nelson & Burnside Rds, Takapau
16370	1,886,752.46	5,566,627.68	16370	34.75	150	19/05/2015	Honnor Drilling Limited	32.75	34.75	16,370					5/19/2015, 12:00 PM	-5.1	35	Unknown	Hand-held GPS	150	363 Burnside Road, Takapau
16478	1,886,886.60	5,566,285.48	16478	58	100	19/05/2016	Honnor Drilling Limited	56.75	58	16,478					5/19/2016, 12:00 PM	-7.63	96	Unknown	Hand-held GPS	100	Nelson Road, Central Hawke's Bay
16858	1,885,191.60	5,565,917.97	16858	26.2	100	14/03/2019	Honnor Drilling Limited	23.3	26.2	16,858				Flowing confined	3/14/2019, 1:00 PM	2	30	Unknown	Hand-held GPS	100	189 Nelsons Rd, Takapau
16931	1,886,381.52	5,564,710.40	16931	58.4	200	30/08/2019	Baylis Brothers Limited	52.4	58.4	16,931	58.4	59.95			8/30/2019, 12:00 PM	-11.8	59.95	Unknown	Hand-held GPS	200	4 Charlotte Street Takapau

C

Appendix C – HBRC log for Takapau public supply bore

Well 1762

IDENTIFICATION

WQ Site:	
Easting:	1886179.512
Northing:	5563939.889
Method:	Hand-held GPS
Address:	META ST, TAKAPAU (L/C)

WELL INFORMATION

Drill date:	19/02/1985
Driller:	N. WEBB
Casing Diameter (mm):	150
Bore Depth (m)	
Well Depth (m):	48.9
Screen top (m):	31.08
Screen bottom (m):	33.48
Open hole top (m):	
Open hole bottom (m):	
Water level access:	Unknown

Bore Consents

Consent Id	WP140534T
Consent Type	Ground-water consent
Use One	Public Water Supply
Use Two	Potable Supply

Aquifer Information

Inital Water Level	-5
Aquifer Condition	Confined
Aquifer Lithology	

Aquifer Test

Test Reliability	Unreliable
Specific Capacity	
Hydralic Conductivity	
Storativity	
Transmissivity	
Aquifer Thickness	
Number Of Pumping Steps	
Duration	
Maximum Draw Down	
Maximum Pumping Rate	
Report Number	
Bore No	1762

Bore Log (m)

Lithology	TOPSOIL with gravel

From Depth	0
To Depth	1
Lithology	brown CLAY with gravel
From Depth	1
To Depth	13
Lithology	grey CLAY with gravel (basaltic)
From Depth	13
To Depth	16
Lithology	blue CLAY
From Depth	16
To Depth	17
Lithology	grey CLAY with gravel
From Depth	17
To Depth	17
Lithology	blue/grey GRAVEL (basaltic)
From Depth	17
To Depth	18
Lithology	grey CLAY with gravel
From Depth	18
To Depth	19
Lithology	brown/grey GRAVEL (basaltic)
From Depth	19
To Depth	25
Lithology	brown/grey GRAVEL (welded, basaltic)
From Depth	25
To Depth	26
Lithology	brown CLAY with gravel
From Depth	26
To Depth	27
Lithology	blue CLAY
From Depth	27
To Depth	30
Lithology	blue GRAVEL (basaltic)
From Depth	30
To Depth	30
Lithology	blue GRAVEL (cemented, basaltic)
From Depth	30
To Depth	31

Lithology brown GRAVEL (basaltic)
From Depth 31
To Depth 33

Lithology brown GRAVEL (cemented, basaltic)
From Depth 33
To Depth 34

Lithology blue/brown CLAY
From Depth 34
To Depth 35

Lithology brown GRAVEL (basaltic)
From Depth 35
To Depth 35

Lithology fine brown GRAVEL (basaltic)
From Depth 35
To Depth 36

Lithology brown CLAY with gravel
From Depth 36
To Depth 37

Lithology brown GRAVEL (basaltic)
From Depth 37
To Depth 40

Lithology brown CLAY with gravel (basaltic)
From Depth 40
To Depth 43

Lithology GRAVEL with clay (cemented,clayey/claybound, basaltic)
From Depth 43
To Depth 45

Lithology blue/brown GRAVEL (basaltic)
From Depth 45
To Depth 46

Lithology blue CLAY
From Depth 46
To Depth 46

Lithology blue GRAVEL (basaltic)
From Depth 46
To Depth 46

Lithology fine blue GRAVEL (basaltic)
From Depth 46
To Depth 48

Lithology	blue CLAY with gravel
From Depth	48
To Depth	49

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