UPGRADING OF THE MOTUEKA WWTP POND SYSTEM BY TERTIARY PROCESSES INCLUDING ULTRAFILTRATION MEMBRANE

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ABSTRACT

Beca was engaged by Tasman District Council (TDC) to review options for upgrading the pond-based Motueka Wastewater Treatment Plant (WWTP) and the treated effluent discharge. An Issues and Options report was prepared by Beca in June 2014, which included a review of earlier reports relating to the Motueka WWTP. Much of the earlier work was focused on land application for wastewater disposal. However, this option had been found to be not viable due to unsuitable land conditions in the local area and predicted sea level rise. TDC and its stakeholders now consider that moving the WWTP to an inland site to allow for future land application could be required, perhaps in a 30 year timeframe.

For the immediate future, continued discharge to coastal water would be required. The Beca 2014 Report considered the treatment required to achieve the treated effluent quality limits that could comply with the required nearshore receiving water criteria, primarily based on the Ministry for Environment/Ministry of Health (2003) shellfish gathering and contact recreation guidelines.

The report recommended a combination of treatment upgrades as follows:

- Removal of sludge from the main oxidation pond;
- Pond partitioning to reduce short circuiting and formation of two polishing ponds to reduce algae solids concentration;
- Increased mechanical aeration and mixing in both the inlet aeration basin and main oxidation pond;
- Recirculation of final pond effluent over the upper portion of two rock bunds using high volume, low pressure sprays, to reduce ammonia and total nitrogen by nitrification and denitrification;
- Membrane (ultrafiltration) polishing treatment for algae solids removal and disinfection;
- Construction of a new outfall pipe with a submerged diffuser in an isolated branch of the Motueka River, directly adjacent to Tasman Bay; and
- Rehabilitation of the former effluent infiltration basins into stormwater habitat wetlands.

Consents were granted in October 2015 with a 20 year term. The project was delivered through a number of contracts and completed in September 2016 within the $8 million budget. The paper describes the above upgrading methods and presents a summary of effluent quality during the first nine months of operation.

KEYWORDS

Pond upgrading, ultrafiltration membranes, tertiary treatment, pond aeration, total nitrogen and ammoniacal nitrogen removal

1 INTRODUCTION

1.1 BACKGROUND

The Motueka WWTP is located north-east of the Motueka Township with the Motueka River to the north, Tasman Bay coast to the east and estuary area to the south, as shown in Figure 1. The WWTP treats flows from Motueka, Kaiteriteri and Riwaka.

Beca was engaged by Tasman District Council (TDC) to review options for upgrading the Motueka Wastewater Treatment Plant (WWTP) and the treated effluent discharge to coastal water. An Issues and Options report was prepared by Beca in June 2014, which included a review of earlier reports relating to the Motueka WWTP. Much of this earlier work was focused on land application for wastewater disposal. However, this option was found to be not viable, due to unsuitable land conditions in the local area and predicted sea level rise. TDC and its stakeholders, consider that moving the WWTP to an inland site is likely to be required in the future, perhaps in a 30 year timeframe.

For the immediate future, continued discharge to coastal water would be required. The Beca 2014 report included a review of previous studies carried out on the receiving environment and considered the treatment required to achieve the treated effluent quality that could comply with receiving water criteria, primarily the Ministry for Environment/Ministry of Health (2003) shellfish gathering and contact recreation guidelines.

The Beca report also recommended a programme of work to identify a preferred solution and to take forward for design and consenting. The report concluded that the previously considered option of floating treatment wetlands (FTW) and UV disinfection, was unlikely to meet the effluent quality required. The report recommended progressing with multiple treatment upgrades as follows:

- Removal of sludge from the main oxidation pond;
- Pond partitioning to reduce short-circuiting and formation of two polishing ponds to reduce algae solids concentration;
- Increased mechanical aeration and mixing in both the inlet aeration basin and main oxidation pond;
- Recirculation of final pond effluent over the upper portion of two rock bunds using high volume, low pressure sprays, to reduce ammonia and total nitrogen by nitrification and denitrification;
- Membrane (ultrafiltration) treatment for algae solids removal and disinfection;
- Construction of a new outfall pipe with a submerged diffuser in an isolated branch of the Motueka River, directly adjacent to Tasman Bay; and
- Rehabilitation of the former effluent infiltration basins into stormwater habitat wetlands.

The report also recommended undertaking further characterisation of the receiving environment, to facilitate the consenting process.

Following consideration of these recommendations, the 8 July 2014 meeting of the TDC Motueka WWTP Upgrading Working Party agreed to support the option of membrane filtration at the Motueka WWTP with discharge to the sea, where the South Branch of the Motueka River meets the Tasman Bay.

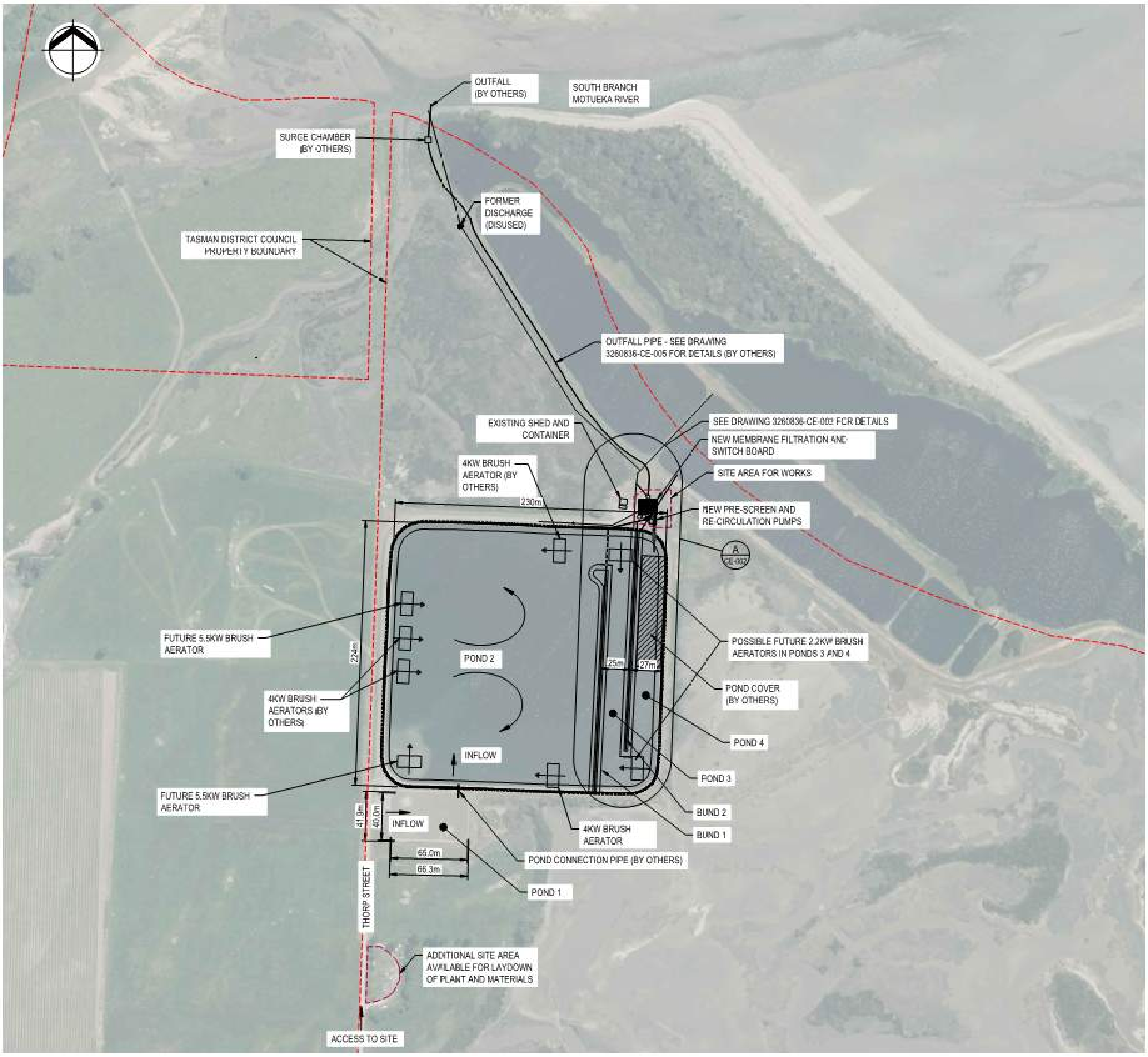

Figure 1: Locality Plan

1.2 CONSENT PROCUREMENT

The previous consent for discharge of the Motueka WWTP was due to expire in December 2018. TDC was required to lodge a new consent application, under a consent variation, for the long-term treatment and disposal of the treated wastewater by 19 December 2014.

The following technical reports were prepared in support of this consenting process:

- DHI carried out modelling on the new outfall site that was included in the AEE (Assessment of Environmental Effects).

- Cawthron Institute carried out a baseline study and prepared an assessment of the effects of the proposed discharge on the receiving water quality, which was included in the AEE.
- NIWA produced a QMRA (Quantitative Microbial Risk Assessment), which is a quantitative way of estimating the health risk to people who are swimming in the area and consuming raw shellfish harvested from waters impacted by microbial contaminants from the discharge.

Beca prepared the AEE and TDC managed the consultation with stakeholders. The new consent was granted on 16 October 2015 and will expire 20 years from expiry of the existing consent. TDC was able to get overall approval for the proposal (including with key Iwi groups) and a formal hearing was not required.

2 DESIGN BASIS

2.1 FLOWS AND LOADS

The flows and loads to the WWTP from the resident population and the peak summer population, are shown in Table 1.

The flow and biochemical oxygen demand (BOD) of the wastewater inflow to the Motueka WWTP were estimated using values for typical NZ WWTP. Proportional tradewaste (commercial) flows were estimated based on the resident population.

The ammonia and total nitrogen loads are based on the Motueka WWTP inflow data between January and July 2014. They are significantly higher than per person data gathered from elsewhere in NZ and are therefore conservative.

Table 1: Motueka WWTP Design Flows and Loads 2034/35

Parameter		Resident 2034/35	Summer Peak 2034/35
Population	persons	10,212	12,641
Average Flow	m^3/d	3,860	4,700
BOD Load	kg/d	1,020	1,201
Ammonia Load	kg/d	150	230
Total Nitrogen Load	kg/d	180	270

2.2 PROCESS IMPROVEMENTS

The process improvements are summarised below and shown in Figure 2.

- Replacement of the existing aerators in Pond 1 (aeration basin) to provide more aeration and mixing to reduce BOD;
- Installation of rock bunds in Pond 2 (the oxidation pond) to reduce short circuiting and create two small ponds (Ponds 3 and 4) prior to the outlet;
- Aeration mixing added to Pond 2 to increase BOD removal capacity and create multiple circulation currents which improve utilisation of the pond area and minimise short-circuiting;
- Effluent sprays on the rock bunds to increase the nitrifying biofilm and contact with oxygen, resulting in increased ammonia reduction;
- Provision for future aeration added to Ponds 3 and 4 to reduce blue-green algal growth, if required;

- Possible addition of a covered area to Pond 4 to reduce suspended solids (algae) growth and total nitrogen (not implemented); and
- Membrane Filtration (MF) treatment of pond effluent for disinfection to remove microorganisms such as bacteria and viruses. MF also reduces most of the algae and other solids resulting in a clear effluent.

Key features of the upgrading strategy are:

- Continued use of the existing pond structures which were in good condition and had significant freeboard which allowed peak flow buffering and new rock bund volume;
- Enhancement of oxidation pond operation by installing four brush aerators to create desirable circulation patterns to utilise the full pond area, and encouragement of oxygen supply by algal photosynthesis using sunlight energy;
- Use of ultrafiltration membranes with 3 log removal of norovirus, and complete removal of algae; and
- Ammonia and total nitrogen reduction using biofilm on 'rock trickling filters'.

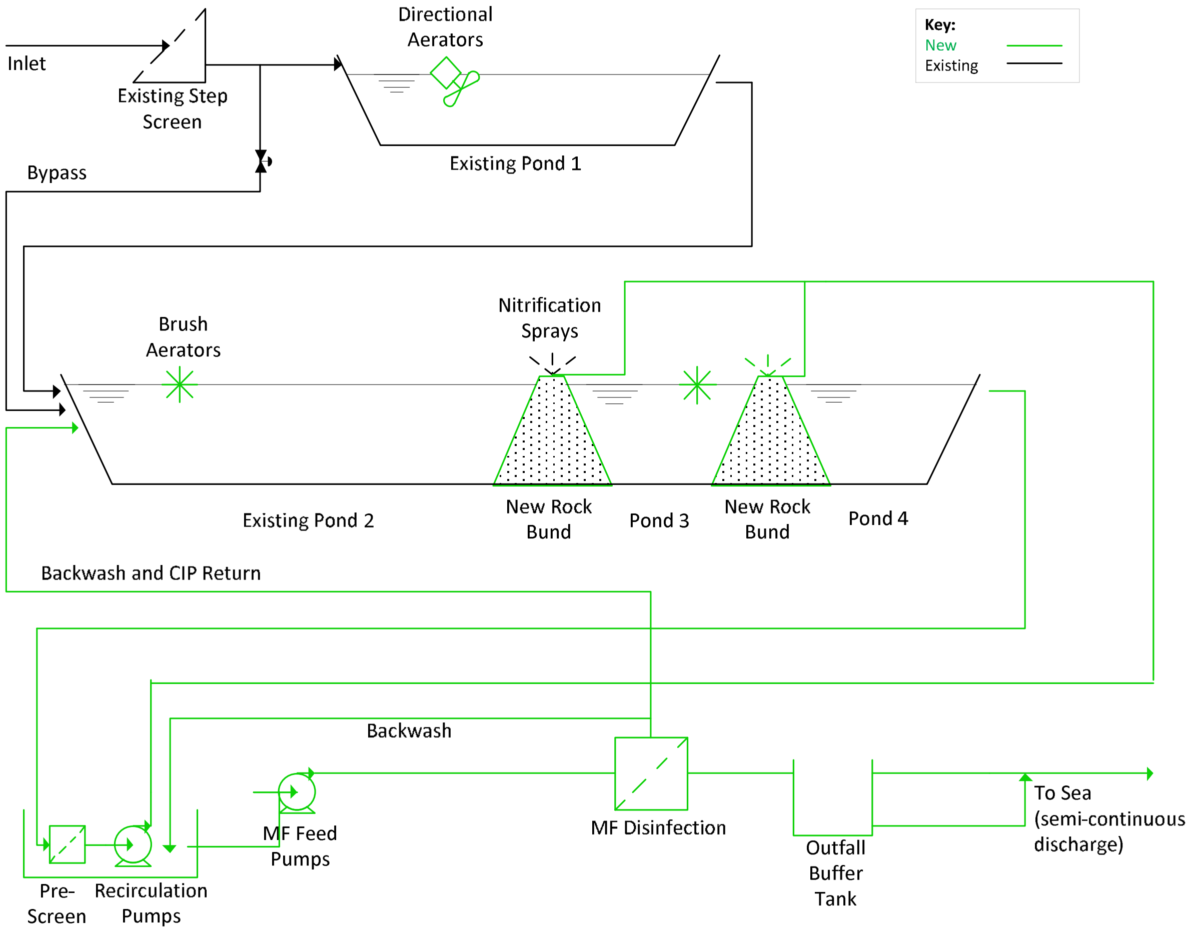

Figure 2: Schematic overview of treatment process improvements

2.3 FLOW BUFFERING

A maximum design flow of 5,500m^3/day was used for the MF design which assumes that Ponds 1, 2, 3, and 4 are used for buffering peak flows. This was determined from modelling carried out using historical flowrate and rainfall data for the period 2007-2014 using Infoworks CS 12.5. In summary, peak inflow rate to the WWTP can exceed 8,000m^3/d. By using the significant freeboard in Ponds 2, 3 and 4, to store some inflow plus the direct rainfall on the ponds, pond outflow to the MF plant can be reduced to 5,500m^3/d which resulted in a significant saving in the MF purchase cost.

2.4 POND UPGRADING FOR TSS AND NITROGEN REDUCTION

The new pond configuration (within the original footprint) resulted in the pond areas and retention times shown in Table 2. The short retention time of Ponds 3 and 4 and more sheltered water, allow some algae to settle and not regrow before membrane treatment.

Table 2: Upgraded pond configuration details

	Depth (m)	Area (ha) Surface	Volume (m^3)	Retention Time in 2034/35 (days)	
				Resident Population	Summer Peak Population
Pond 1	2.5	0.26	5,236	1.4	1.1
Pond 2	1.65	3.76	58,952	15	13
Pond 3	1.65	0.52	8,184	2.1	1.7
Pond 4	1.65	0.47	7,331	1.9	1.6
Totals		5.00	79,704	21	17

Ammoniacal nitrogen (AmN) removal in ponds is approximately proportional to water temperature. A correlation based on temperature was used to estimate ammonia removal in the four ponds (Archer and O'Brien 2004 and 2005). This approximation was derived from actual performance of ponds in New Zealand from Blenheim to Christchurch and reflects the temperature range at Motueka. The authors found that the often-quoted Pano-Middlebrooks formula for AmN removal gives optimistic predictions in South Island temperatures.

Table 3 shows the estimated AmN removal at the minimum, average and maximum pond temperatures of 12°C, 19°C and 23°C respectively, depending on season.

Table 3: Predicted median effluent Ammoniacal Nitrogen concentration (g/m^3)

	Resident Winter Population 2034/35		**Summer Peak Population 2034/35**	
Pond Temperature	**12°C**	**19°C**	**19°C**	**23°C**
Pond 1	50	46	47	44
Pond 2	30	12	16	7
Pond 3	28	10	14	5
Pond 4	26	9	12	4

The addition of recirculation sprays on the two rock bunds between Ponds 2, 3 and 4 increases the removal of AmN by adding to the area of biofilm available for nitrification. A spray system was laid on the top of the rock bunds to recirculate Pond 4 effluent – refer to Photos 1 and 2 and discussion in Section 3.

The design incorporates 55 sprays at 3.3m intervals along each bund. At an estimated flow of 1.05l/s per spray, this gives a maximum recirculation flowrate of 116l/s. This is four times the current average inflow rate of 26l/s, and is within the recommended guidelines for this type of treatment – refer to USEPA (2011).

For the operation of the spray system, two 9kW pumps operating continuously, are required to achieve the 116l/s flow. Typically, one pump is operated to reduce electricity costs.

The sprays are tangential entry with a centre nozzle outlet (20mm diameter) that minimises blockages by wind-blown debris and bird feathers. These sprays are also known as 'pot spreaders' which were used for farm effluent irrigation – see Photos 1 and 2.

Photo 1: Rock nitrification sprays at Motueka WWTP

Photo 2: Pot Spreader spray at Motueka WWTP

The recirculation spray system for nitrification described above, takes advantage of the surface area provided by the rocks (above normal water level) in the dividing bunds between Ponds 2, 3 and 4 to mimic the widely used trickling filter process. As with all 'natural' treatment systems, predictions are empirical and are based on experience elsewhere. There are the following risks and mitigation measures:

- Nitrifying bacteria are slow-growing and are sensitive to inhibitory compounds which could be present in the wastewater. The robust upstream processes in Ponds 1 and 2 should remove or modify the inhibitory compounds to reduce the effects on the nitrification process.
- Nitrification performance generally reduces at lower temperatures and use of the sprays in winter would further reduce the temperature in the final ponds. However, Motueka experiences comparatively mild winters, which will be an advantage.
- To counter the slow growth of nitrifiers, it is possible to recycle the normal backwash from MF into the recirculation pump well. This backwash will contain nitrifiers as well as algae and other bacteria. This recycle is the same as used in a conventional nitrifying activated sludge process.
- At higher pond pH values, ammonia can be stripped to atmosphere and the sprays would enhance that effect.

Should the ammonia concentrations not be reduced sufficiently, then the following proprietary treatment units could be installed in Ponds 3 and 4:

- Bio-Shells, as produced by Wastewater Compliance Systems Inc., Utah, USA, which are a series of nested shells placed in a pond to provide additional biofilm surface area. Compressed diffused air is introduced at the base to allow nitrification to proceed. This process has been proven to operate at very low winter temperatures in the mid-west USA.
- Hanging curtains, as supplied by Waterclean as part of their Floating Treatment Media (FTM) systems. The vertical curtains provide biofilm attachment and are spaced 300mm apart with flow between the curtains generated by surface aerators which also provide extra oxygen.
- Aquamats, which are also vertical curtains to provide extra surface area for nitrifying biofilm. Diffused air is introduced through small diameter tubes at the base of the curtains. Ammonia removal performance of this system has been variable at North Island pond sites, which illustrates the inherent difficulty in predicting the performance of such systems – refer to Ratsey (2016).

These three systems would have more substantial capital and operating costs, but would be feasible in comparison with activated sludge type processes for ammoniacal and total N reduction.

2.5 POND AERATION UPGRADING

The Pond 1 aeration upgrade involved replacing all four of the current aerators (each 7.5kW), with four new 15kW aerators, which was required due to the projected increase of oxygen demand in the pond. The chosen brand and model was Fuchs Oxystar OS20, self-aspirating directional aerators. This style of aerator is well-suited for aeration basins as it creates a strong, racetrack circulation with the following attributes:

- Results in good mixing;
- Creates efficient aeration (refer to Table 4); and

- Assists in exposing the raw wastewater to the treatment biomass which grows on the sides and base of the aeration basin.
- Mooring arm is attached to the bank which avoids having to use a boat to retrieve the unit.

Photo 3: New directional aerator on Pond 1

Table 4: Expected oxygen transfer rate in Pond 1 (as advised by Xylem)

Oxygen Transfer Rate	Installed kg O_2/hr		Future Requirement (peak summer 2034 Flows) kg O_2/hr
13kg O_2/hr per aerator	52 (4 aerators in service)	39 (3 aerators in service)	38

The Pond 2 aeration upgrade involved the installation of four new 4 kW floating, brush aerators (S&N Airoflo Series 1600). Provision was made for a further two 5.5kW aerators for peak loads in the future. See photo 4. This aeration/mixing provides:

- Mixing in calm periods to bring green algae to the surface where sunlight will produce oxygen by photosynthesis;
- Oxygen by direct transfer from the agitation of the rotor blades;
- Control the growth of blue-green algae;
- Nitrogen removal by increasing dissolved oxygen (DO) content to allow nitrification; and

- Two circulation cells in Pond 2 which minimises short circuiting and utilises the full pond area.

These aerators are also attached to the bank and can be removed from the pond without using a boat.

Table 5: Expected oxygen transfer rate in Pond 2 (as advised by Sindico)

Oxygen Transfer Rate	Total Expected kg O_2/hr	Future Requirement (peak summer 2034 Flows) kg O_2/hr
7kg O_2/hr per aerator	28 (7 per aerator)	36 (assuming 1.2kgO_2/kgBOD)

Should the growth of blue-green algae in the ponds prove problematic, the mitigating option will be to install further aerators in the two small ponds created by the rock bunds (Ponds 3 and 4). Small (approximately 2.2kW) floating brush aerators would be located at the entry to each pond. It is likely that any algae nuisance will occur in summer months and these small aerators would only need to be operated intermittently.

Photo 4: Pond 2 Brush Aerators

3 PERFORMANCE

The final effluent quality after MF treatment is summarised in Table 6, along with the consent requirements. Because MF provides a barrier, the filtrate contains virtually no bacteria and acceptance testing during commissioning demonstrated that the required 3 log reduction in norovirus was achieved. It is cost-prohibitive to do routine testing for virus reduction.

Table 6: Compliance Requirements and Progress Results

	TSS (g/m³)	$CBOD_5$ (g/m³)	TN (g/m³)	Ammonia-N (g/m³)	E.Coli (CFU/100ml)	FC (CFU/100ml)
Filtrate Annual Rolling Median Compliance Requirements	3.0	5.0	12.0	9.0	5	5
Progress Results (Averaged from Aug-16 to Jun-17)	<3.0	2.6	21.0	12.3	<1	<1

Figure 3 shows the nitrogen forms in the MF filtrate. It is intended that the recirculation sprays on the rock bunds would increase the conversion of ammoniacal N to nitrate, which in turn would be converted to nitrogen gas by denitrification in the anoxic layer at the base of the final ponds. Normally, nitrification is the limiting step with low carbonaceous BOD and ample oxygen conditions being required for adequate nitrifying biofilm activity. Elsewhere, denitrification normally proceeds to completion due to the relatively large anoxic area on the pond base and adequate supply of carbon from breakdown of sludge. Figure 3 shows that nitrite and nitrate nitrogen concentrations are significant at times. When denitrification occurs, alkalinity is restored, which is needed for the nitrification reaction.

Thus, recirculation of effluent from the outlet of Pond 4 should create suitable conditions for the nitrification reaction. However, due to intermittent use of the recirculation pumps, at reduced flow rate to avoid spray drift, the nitrification and denitrification reactions were not consistent during the first 8 months of operation. In mid-May 2017, the spray pumps were fitted with wind speed and direction control so that the pump turns off when spray drift is likely to affect areas where the public may walk. Also, the pump speed was increased to 50Hz which has resulted in greater wetted area on the rock bunds.

Liquid temperature has recently reduced following the normal seasonal pattern in winter and little nitrification can be expected at temperatures below 12^{o}C as predicted in Table 3. This trend can be seen in Figure 3.

It is expected that with more consistent use of the sprays on the rock bunds that more nitrification will be achieved when temperatures increase in Spring 2017. If the denitrification reaction doesn't increase, consideration will be given to diverting a fraction of the raw inflow to Pond 3 to provide more readily degradable BOD for the denitrification reaction (which will reduce nitrate, nitrite and total nitrification).

CONCLUSIONS

By utilising existing pond treatment processes, the project has provided cost–effective upgrading for Tasman District Council that met stakeholder and consenting requirements. It was completed within the $8 million budget allowance. The fully automated ultrafiltration membrane plant is 'state-of-the-art' and achieves virtually complete removal of solids and bacterial contamination, plus 3 log removal of virus. A clear effluent is produced which eliminates the previous 'green plume' in the nearshore coastal water.

Initial results indicate that ammoniacal nitrogen can be fully removed in summer as predicted, when the sprays on the rock bunds are operating at a sufficient flow rate. Fine tuning of the system later in 2017 is expected to achieve an increase in both ammoniacal and total nitrogen removal during summer and autumn.

ACKNOWLEDGEMENTS

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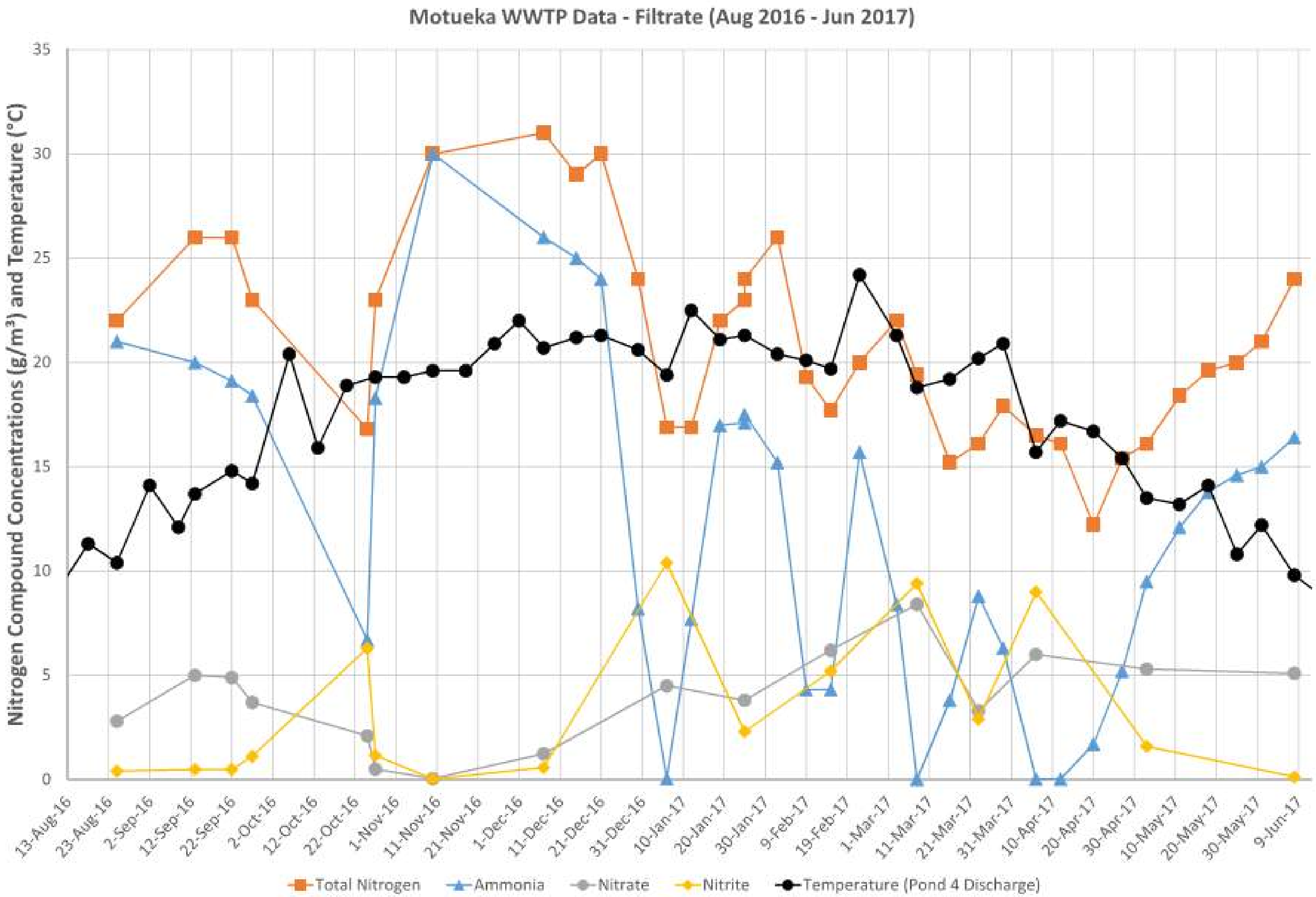

Figure 3: Membrane Filtrate Nitrogen Forms (final effluent)