ECONOMICAL WASTEWATER TREATMENT DESIGN FOR HIGHLY VARIABLE LOADS

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ABSTRACT

There are many municipal wastewater treatment plants (WWTP's) in New Zealand that are treating large industrial wastewater loads. Treating these large industrial loads can be challenging due to the characteristics and variability of the wastewater. Often these WWTP's are located in rural towns where financial constraints have a large influence on the plant design. The Te Kuiti WWTP is one of these plants and underwent a significant upgrade in 2012/13.

The Te Kuiti WWTP is owned and operated by the Waitomo District Council (WDC). The plant receives domestic wastewater from the town of Te Kuiti and also receives wastewater from two meatworks that, when in full production, contribute up to 80% of the total BOD load entering the WWTP. Prior to the recent upgrade, the WWTP regularly breached its resource consent particularly with respect to ammonia. Problems included: the reactor was too shallow; aerators were unreliable and inefficient; the anoxic zone was too small; inadequate instrumentation; the hydraulic loading rate on the clarifier was too high (large inflow and infiltration during rainfall events); low ultraviolet transmissivity (UVT) in the final effluent during high load periods, poor disinfection (no specific disinfection).

With low cost solutions in mind and attention to the highly variable load, an innovative activated sludge (AS) reactor design was installed that utilised existing infrastructure wherever possible. To minimise the cost, the reactor was constructed with a circular earth bund and a central anaerobic zone utilising a curtain structure. An oxidation ditch type AS process was created within the reactor annulus. That eliminated the need for expensive internal pipe-&-pump recycles and also provided flexibility to increase/decrease the reactor aerobic/anoxic fractions as the wastewater loads increased/decreased. The reactor was also designed to allow the reactor depth/volume to be adjusted according to the load. A mix of submerged aspirator and floating aerators were used in the aerobic zone and both directional and non-directional mixers were used in the anoxic and anaerobic zones. Further upgrades installed included: a pre-clarifier chemical dosing system for use when required; tertiary filtration and UV disinfection; storm flow by-pass; sludge stabilisation; sludge dredge and dewatering system.

The upgraded plant is performing very well. The final effluent results for the high load period January – March 2014 inclusive were as follows (Table 1):

Table 1: Te Kuiti WWTP Final Effluent Results Analysis for the High Influent Load Period – January to March (inclusive) 2014.

Contaminant	Average	90^{th}%-ile
Total nitrogen (g/m^3 TN)	5	9
Total ammoniacal nitrogen (g/m^3 TAN)	0.4	0.5
Total phosphorous (g/m^3 TP)*	2	3
$cBOD_5$ (g/m^3 $cBOD_5$)	2	3
Total Suspended Solids (g/m^3 TSS)	9	14

* From a typical raw influent TP concentration of between 40-60g TP/ m^3.

KEYWORDS

Economical Wastewater Treatment, Industrial Wastewater, Meatworks, Biological Nutrient Removal, Variable Loads.

1 INTRODUCTION AND BACKGROUND

The Te Kuiti wastewater treatment plant (WWTP) is located approximately 2km north of the Te Kuiti township and is owned and operated by the Waitomo District Council (WDC). The WWTP receives domestic wastewater from the town of Te Kuiti that has a population of approximately 5000.

1.1 INDUSTRIAL WASTEWATER

The WWTP also receives wastewater from two meatworks that, when in full production, contribute up to 80% of the total BOD load entering the treatment plant.

The meatworks operation is seasonal. Peak production is usually during summer, tapering off in autumn, with winter and spring being the low production periods. There are times when the meatworks shutdown and at that time the wastewater load received by the WWTP is limited to domestic wastewater from the Te Kuiti township plus some commercial and small industry loads.

Table 2 below shows the low, average and high influent load estimates for the Te Kuiti WWTP activated sludge system. These loads are sustained loads that the activated sludge system must treat. As shown in Table 2 there is a significant $cBOD_5$ load variability between the low and high loads. The high $cBOD_5$ load is 5.6 times greater than the low load. The low load is the base load (no meatworks load) and assumes a population of 5000 and a commercial and light industry contribution equating to 25% of the domestic load. The average and high load estimates are based on plant influent data collected between the period 1st April 2009 and the 31st March 2010. For design, these figures were adjusted for an anticipated 25% $cBOD_5$ load reduction from the two meatworks and similarly 10% TN load reduction due to reduction measures agreed with the two meatworks.

Table 2: Secondary Influent Flow and Load Data Used for Plant Design

Contaminant	Base Load	Average	High (95%-ile)	High/Base Load Ratio
Flow (m^3/d)	1250	2895	4115	3.3
$cBOD_5$ Load (kg/d)	500	1571	2814	5.6

The industrial wastewater load contains a soluble/colloidal fraction that is difficult to treat biologically. This material reduces the ultra-violet transmissivity (UVT) of the secondary clarified effluent and therefore reduces the performance of the ultra-violet (UV) disinfection process. Jar tests were performed prior to the upgrade and it was found that dosing with coagulant and flocculent could easily improve the UVT from an initial UVT of 30% to a UVT of greater than 60%.

1.2 CONSENTING ISSUES

Prior to the expiry of the Te Kuiti WWTP discharge consent, WDC submitted a consent application to renew the consent. Terms of the consent have yet to be agreed and in the meantime the plant has been operating under the previous consent conditions, known as the "Operative Consent Conditions".

The Assessment of Environmental Effects (AEE) produced for the consent application identified that the adverse effects of the WWTP discharge on the receiving environment (the Mangaokewa Stream) were more than minor. The main effluent quality parameters requiring improvement were:

- Ammoniacal nitrogen
- Total nitrogen
- $cBOD_5$

- Total suspended solids (TSS)
- Pathogens

Treatment plant improvements were therefore required.

Prior to the upgrade the plant had been breaching a number of its Operative Consent Conditions, particularly with respect to ammonia.

1.3 TARGET EFFLUENT CONDITIONS

The initial target for the upgrade was to meet the Operative Consent Conditions. The numerical final effluent quality parameters for the Operative consent are shown in Table 3 below.

The upgrade also needed to be designed to meet the numerical parameters proposed for the new consent as given in the AEE. These proposed conditions are also provided in Table 3.

Table 3: Numerical Consent Conditions for both the Operative and Proposed New Consent Conditions

Consent Conditions	**TSS (g/m^3)**	**$cBOD_5$ (g/m^3)**	**TP (g/m^3)**	**TN (g/m^3)**	**TAN (g/m^3)**	***E.coli* (MPN/100mL)**
Operative	Only 1/10 > 30	Only 1/10 > 30	Only 1/10 > 10	Only 1/10 > 21	Only 1/10 > 6	Median < 1000
	Maximum < 40	Maximum < 40	Maximum < 13	Maximum < 28	Maximum < 10	Maximum < 10,000
AEE Proposed	90^{th} %-ile < 20	90^{th} %-ile < 20	90^{th} %-ile < 12	Nov-Mar(incl): Mean < 43kg/d*	90^{th} %-ile < 12	90^{th} %-ile < 200
				Apr-Oct(incl): Mean < 73kg/d*		

* For average plant flow ($2895m^3/d$), the final effluent TN concentration needs to be less than 14.9 g/m^3 to comply with the AEE proposed load limit of 43kg/d TN and 25.2g/m^3 TN to comply with the load limit of 73kg/d.

1.4 PRE-UPGRADE WWTP

Some of the pre-upgrade plant processes were in fairly poor condition and the plant design imposed serious limitations on the effluent quality. The most significant factors were as follows:

- The activated sludge reactor was too shallow at a depth of between 1.0-1.5m and therefore the aeration system was very inefficient.
- The aerators were old, unreliable, inefficient and received noise complaints.
- The anoxic zone was too small for effective denitrification.
- There was limited instrumentation and process control capabilities at the plant.
- The flow through the reactor regularly exceeded the hydraulic loading rate design limit of the secondary clarifier.
- The WWTP did not have an effective disinfection process. Disinfection was limited to that achieved through the pond system.
- The plant could not respond quickly enough to reliably treat the variable wastewater loads coming from the meatworks.
- The ponds were filling with sludge and there was no long term sludge management plan or infrastructure to manage that sludge.

1.5 UPGRADE AFFORDABILITY

The financial rating of the people living in the town of Te Kuiti is regarded as poor and an overly expensive WWTP upgrade would have placed an untenable financial burden on the community. Te Kuiti was given a high deprivation index rating, based on the Ministry of Health Sanitary Works Subsidy Scheme (SWSS) assessment criteria. WDC subsequently submitted a successful SWSS funding application to the MoH for the upgrade. However, the funding only covered upgrade components that directly improved the human health risks and did not cover upgrade improvements for nutrient removal or plant capacity improvements due to industrial wastewater loads.

The design challenge for the upgrade was therefore to find economical design solutions that the Te Kuiti ratepayers could afford, in terms of capital expenditure, future replacement and operating expenditure.

2 DESIGN SOLUTIONS AND DISCUSSION

This section describes the improvements that were incorporated into the upgrade. Also discussed are how these improvements fulfill the design requirements discussed in the Introduction section.

2.1 PLANT BY-PASS AND OXIDATION POND

The secondary clarifier installed at the Te Kuiti WWTP pre-upgrade had a design limit of approximately 4,000m^3/d. Therefore a by-pass system was installed to restrict the flow rate to the reactor during high rainfall events. An automated penstock was installed at the inlet works to control the flow. The bypass flow is directed to the existing oxidation pond. A pump station in the oxidation pond returns effluent from the oxidation pond to the head of the plant when the plant influent flow is less than 4,000m^3/d. During extreme wet weather events the pond effluent can be pumped directly to the tertiary treatment and disinfection systems.

2.2 SECONDARY TREATMENT PROCESS

The secondary treatment process is a biological nutrient removal (BNR) system. The reactor was constructed with a circular earth bund (refer to Photograph 1) and a central anaerobic zone utilising a curtain structure. An oxidation ditch type activated sludge (AS) process, with aeration and anoxic zones, was created within the reactor annulus. The three zones work together to provide BOD, total nitrogen (TN) and total phosphorous (TP) removal.

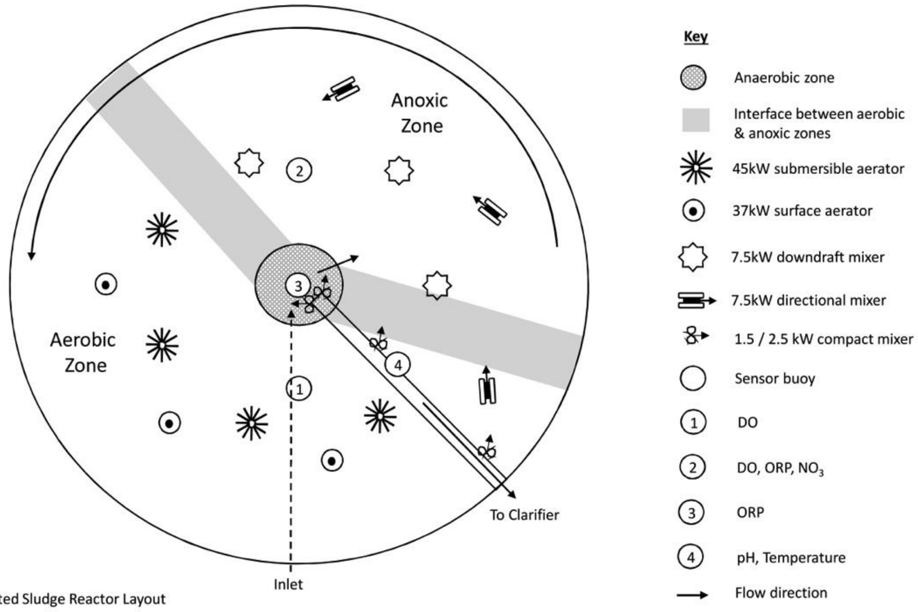
The reactor layout is shown in

Figure 1. Also refer to the process flow diagram (Figure 2) that shows the connectivity between the processes.

The reactor earth bund is the main cost saving feature of the upgraded plant when compared to concrete tank design. The earth bunds were build-up instead of build-down due to concerns about ground conditions, particularly ground water complications. Erosion protection was provided by geoweb (refer to Photograph 2, Photograph 3, Photograph 4).

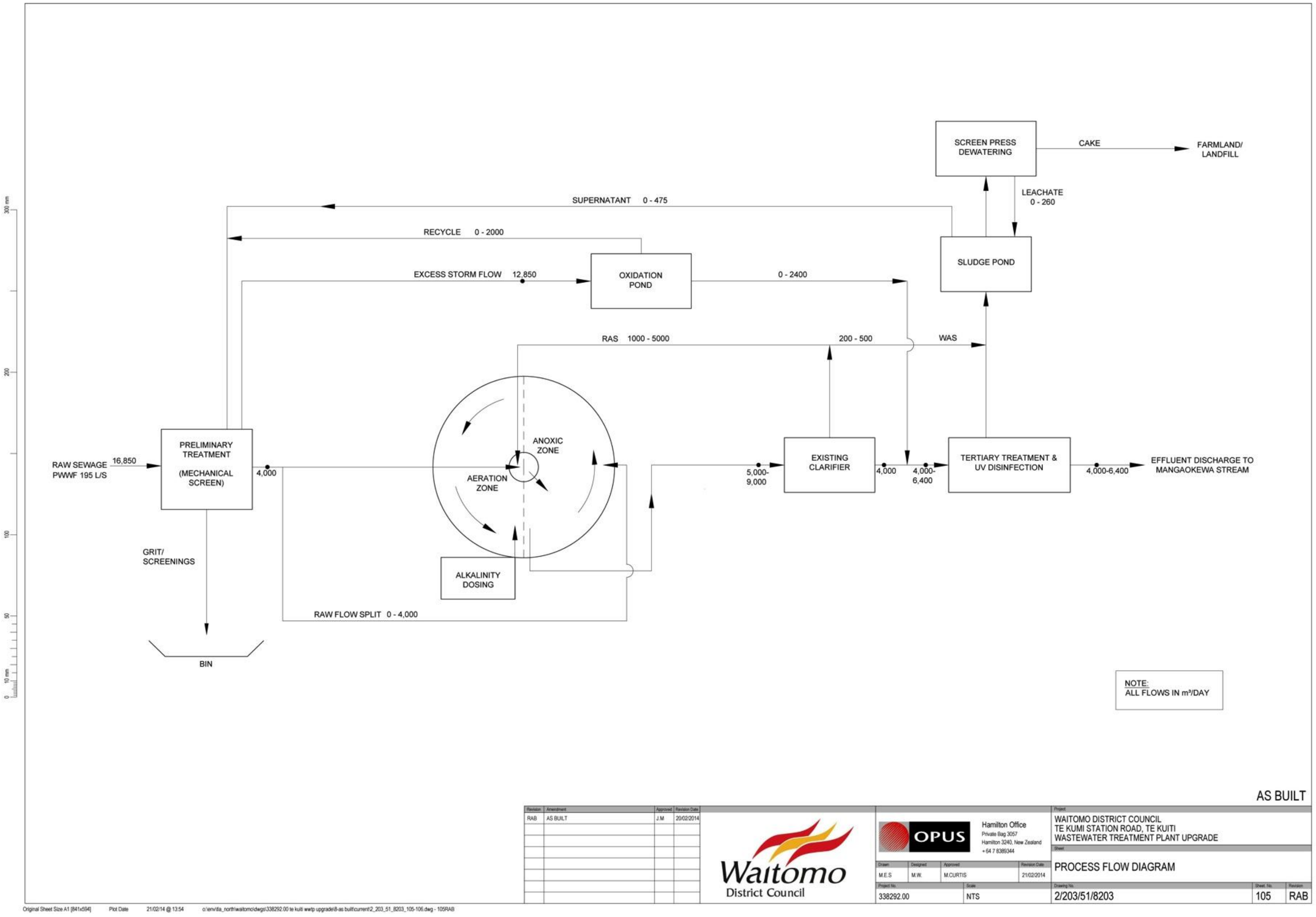
Photograph 1: AS Reactor Earth Bund

Figure 1: Activated Sludge Reactor Layout Sketch



Sketch 1: Te Kuiti WWTP Activated Sludge Reactor Layout

Figure 2: Process Flow Diagram for the Upgraded Te Kuiti WWTP



Photograph 2: Unfilled Geoweb Erosion Protection

Photograph 3: Filling of Geoweb Erosion Protection

Photograph 4: Filled Geoweb Erosion Protection

The wastewater from the inlet works flows by gravity into the anaerobic zone that is a circular zone in the centre of the reactor separated from the outer annulus of the reactor by a curtain structure (refer to Photograph 5). The return activated sludge (RAS) from the secondary clarifier also discharges to this zone.

Photograph 5: Curtain Structure for Anaerobic Zone

The outer annulus of the reactor is the oxidation ditch eliminating the need for internal recycle pumping requirements required by many other biological nutrient removal (BNR) systems. The oxidation ditch arrangement has both anoxic and aerobic zones for BOD and TN removal. The volume fractions of the aerobic and anoxic zones can be adjusted by increasing/decreasing the dissolved oxygen (DO) setpoint and controlling the number of aerators in service.

The hydraulic retention time (HRT) within the reactor under average flow conditions is approximately 3 days which provides some buffering ability for diurnal and daily influent load variability.

Seasonal influent load variability is accommodated by adjusting the reactor water level set point to increase/decrease the three reactor zone volumes. The water level is controlled by the clarifier pump station. Controlling the sludge age (SA) by increasing/decreasing the wasting rate is another mechanism for accommodating the seasonal variability.

Mixing within the anoxic zone is provided by eight mixers:

- Three directional mixers on floats provide mixing and the current that pushes the mixed liquor (ML) around the oxidation ditch (refer to Photograph 6, Photograph 7). These mixers are controlled by variable speed drives (VSD's) to allow control of the ML velocity rotating around the reactor annulus and hence the mixing characteristics and the cyclic hydraulic retention time (HRT) within the aerobic and anoxic zones.

- There are also two directional mixers fixed to the reactor bridge.

- Three non-directional down-draft mixers (refer Photograph 7 in background).

Photograph 6: Directional Floating Mixer

Photograph 7: Directional Floating Mixer in Operation

Mixing within the anaerobic zone is provided by two mixers fixed to the reactor bridge.

On-line probes are installed on a float located within the anoxic zone (refer

Photograph 8) to monitor the oxidation/reduction potential (ORP), dissolved oxygen (DO), and nitrate. These outputs provide guidance for denitrification optimisation.

Photograph 8: On-line Probes Mounted on Float

An on-line ORP probe is also installed in the anaerobic zone to check that this zone is achieving anaerobic conditions.

Aeration within the reactor is provided by seven aerators:

Four 45kW floor mounted aspirator aerators (refer Photograph 9,

- Photograph 10).

- Three 37kW high speed floating surface aerators (refer Photograph 11).

The floor mounted aspirators are essentially noise free and overcome the noise complaints received about the previous aerators. The surface aerators only come on when the oxygen demand exceeds the capacity of the four aspirator aerators. The three surface aerators provide oxygen to the reactor area beside the earth embankment, an area that the floor mounted aerators would not perform so well in.

Photograph 9: Floor Mounted Aspirator Aerator

Photograph 10: Floor Mounted Aspirator Aerator in Operation

Photograph 11: High Speed Floating Aerator

During low load periods when the oxygen demand is low, the DO concentration is controlled by restricting the number of aerators that operate at one time. To avoid large step changes in the amount of oxygen introduced as an additional aerator comes on line, the aerator goes through some intermediate steps before the aerator is on 100% of the time. Initially the aerator runs for 5 minutes and then stops for 10 minutes. The next step is 10 minutes on and 5 minutes off and the final step is the aerator runs continuously. By doing it this way there are no large oxygen increase steps leading to over-aeration or under-aeration when the oxygen demand is reducing and the aerators need to be stepped down.

The system is more susceptible to over/under-aeration at low loads. For example, going from one aerator to two aerators on 100% of the time is a doubling of the oxygen input. However at the high load end when, say 6 of the 7 aerators are running and the 7^{th} aerator comes on line the oxygen input only increases by approximately one sixth. Refer to Figure 3 for the aerator sequencing schedule. This schedule was produced prior to plant commissioning and has been modified slightly to improve the performance of the system. To minimize the possibility of the biomass settling on the reactor floor the aerators are rotated to provide mixing across the total aerobic zone.

Figure 3: Aerator Control Sequence

AERATOR CONTROL LOGIC

		Aerator 1		Aerator 2		Aerator 3		Aerator 4		Aerator 5		Aerator 6		Aerator 7							
STEP	MIN STEP TIME	Aerator On (Y/N)	Cycle Time	Aerator On (Y/N)	Cycle Time	Aerator On (Y/N)	Cycle Time	Aerator On (Y/N)	Cycle Time	Aerator On (Y/N)	Cycle Time	Aerator On (Y/N)	Cycle Time	Aerator On (Y/N)	Cycle Time	AERATION INCREASE	INCREASE DELAY	INCREASE GO TO STEP	AERATION DECREASE	DECREASE DELAY	DECREASE GO TO STEP
STEP 0(RESET)	6 Minutes	N	0 mins on	N	0 mins on	N	0 mins on	N	0 mins on	N	0 mins on	Y	5mins on, 10mins off	Y	5mins on, 10mins off	DOSTEP < DO_SV	10 Minutes	STEP 1	DOSTEP > DO_SV	10 Minutes	STEP 0
STEP 1	6 Minutes	N	0 mins on	N	0 mins on	N	0 mins on	N	0 mins on	Y	5mins on, 10mins off	Y	5mins on, 10mins off	Y	5mins on, 10mins off	DOSTEP < DO_SV	10 Minutes	STEP 2	DOSTEP > DO_SV	10 Minutes	STEP 0
STEP 2	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	N	0 mins on	Y	5mins on, 10mins off	Y	5mins on, 10mins off	Y	5mins on, 10mins off	DOSTEP < DO_SV	10 Minutes	STEP 3	DOSTEP > DO_SV	10 Minutes	STEP 1
STEP 3	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	N	0 mins on	Y	5mins on, 10mins off	Y	5mins on, 10mins off	Y	10mins on, 5mins off	DOSTEP < DO_SV	10 Minutes	STEP 4	DOSTEP > DO_SV	10 Minutes	STEP 2
STEP 4	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	N	0 mins on	Y	5mins on, 10mins off	Y	10mins on, 5mins off	Y	10mins on, 5mins off	DOSTEP < DO_SV	10 Minutes	STEP 5	DOSTEP > DO_SV	10 Minutes	STEP 3
STEP 5	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	N	0 mins on	Y	10mins on, 5mins off	Y	10mins on, 5mins off	Y	10mins on, 5mins off	DOSTEP < DO_SV	10 Minutes	STEP 6	DOSTEP > DO_SV	10 Minutes	STEP 4
STEP 6	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	N	0 mins on	Y	10mins on, 5mins off	Y	10mins on, 5mins off	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 7	DOSTEP > DO_SV	10 Minutes	STEP 5
STEP 7	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	N	0 mins on	Y	10mins on, 5mins off	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 8	DOSTEP > DO_SV	10 Minutes	STEP 6
STEP 8	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	N	0 mins on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 9	DOSTEP > DO_SV	10 Minutes	STEP 7
STEP 9	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	Y	5mins on, 10mins off	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 10	DOSTEP > DO_SV	10 Minutes	STEP 8
STEP 10	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	Y	10mins on,5mins off	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 11	DOSTEP > DO_SV	10 Minutes	STEP 9
STEP 11	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	N	0 mins on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 12	DOSTEP > DO_SV	10 Minutes	STEP 10
STEP 12	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	Y	5mins on, 10mins off	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 13	DOSTEP > DO_SV	10 Minutes	STEP 11
STEP 13	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	Y	10mins on, 5mins off	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 14	DOSTEP > DO_SV	10 Minutes	STEP 12
STEP 14	6 Minutes	Y	5mins on, 10mins off	N	0 mins on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 15	DOSTEP > DO_SV	10 Minutes	STEP 13
STEP 15	6 Minutes	Y	5mins on, 10mins off	Y	5mins on, 10mins off	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 16	DOSTEP > DO_SV	10 Minutes	STEP 14
STEP 16	6 Minutes	Y	5mins on, 10mins off	Y	10mins on, 5mins off	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 17	DOSTEP > DO_SV	10 Minutes	STEP 15
STEP 17	6 Minutes	Y	5mins on, 10mins off	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 18	DOSTEP > DO_SV	10 Minutes	STEP 16
STEP 18	6 Minutes	Y	10mins on, 5mins off	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 19	DOSTEP > DO_SV	10 Minutes	STEP 17
STEP 19	6 Minutes	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	Y	100% on	DOSTEP < DO_SV	10 Minutes	STEP 19	DOSTEP > DO_SV	10 Minutes	STEP 18

NOTES:

Don't have two adjacent aerators on their off-cycle for more than 5 minute intervals eg Aerators 5&6, or, 5&7, or, 1&7. This is not an issue with surface aerators 2, 3 and 4.
The above configuration will need to be modified during the commissioning period and/or when the high/low load periods occur
The on/off cycle time that initiates when the aerator is turned off and on needs to be independent of the step so that when a step occurs, adjacent aerators don't start turning off at the same time
The "min step time", "increase/decrease delay", and DO averaging will need to be confirmed during commissioning
Some form of derivative control may be required to make the system more reactive if a sudden load change occurs eg the meatworks discharge a large load over a short period of time

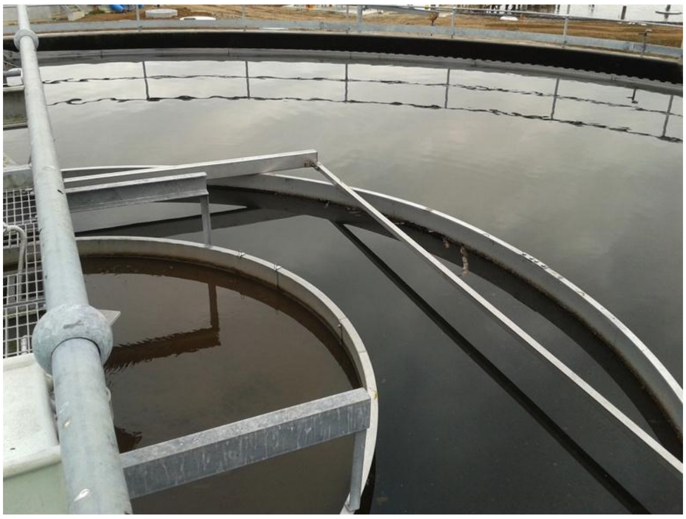
Another float with a DO probe is installed within the aerobic zone. The probe monitors the DO and provides feedback to the aerator controller.

A lime dosing system has been installed to control the reactor pH. A pH probe mounted on the bridge monitors the ML pH and provides feedback to the lime dosing controller.

The ML is fed to an existing 22m diameter secondary clarifier by a 3-pump pump-station. The clarifier has a two stage circular baffle system. The existing inner baffle helps flocculate the ML and reduce velocities. A second baffle ring was installed to improve the clarifier performance (refer Photograph 12 pre-installation and Photograph 13 post installation). The floor of the clarifier slopes to the centre of the clarifier. The settled solids are pushed to the centre of the clarifier by scrapers that are attached to rotating arms. The settled sludge (RAS) is returned to the activated sludge reactor by gravity via an automated weir (new).

Photograph 12: Secondary Clarifier Before Installing the Second Stilling Ring

Photograph 13: Secondary Clarifier With Second Stilling Ring Installed



As discussed in the Introduction section the ultraviolet transmissivity (UVT) from the secondary clarifier can be poor at times due to interferences from soluble and colloidal material contained in the ML and oxidation pond effluent. Therefore a chemical dosing system was installed pre-clarifier. The chemicals are stored in pods and small chemical dose pumps inject the chemicals (Aluminium sulphate, PACl, Polymer) into the flocculator.

When necessary this system can also be operated to improve:

- The ML settling characteristics.
- The clarifier effluent turbidity.

- The clarifier effluent TSS.

- The removal of total phosphorous

2.3 TERTIARY FILTRATION AND DISINFECTION

A continuous gravity fed sand filter with continuous sand wash, was installed to reduce the clarifier and oxidation pond effluent TSS and further improve the effluent UVT for effective disinfection. The system also provides a safety net if the suspended solids in the clarifier effluent is high due to a process upset with the secondary system.

An in-pipe duty/standby UV system was installed. The lamp sleeves have an automated wiper and chemical cleaning system. On-line UVT and intensity meters are installed and the system is dosed paced. The effluent from the UV discharges to the Mangaokewa Stream via a gravity pipeline and outfall structure.

Automated bypass systems direct the effluent to the oxidation pond if the tertiary system is out of service and/or the filter effluent turbidity is too high. Turbidity meters are installed on both the secondary clarifier and tertiary filter effluent lines. The effluent bypassed to the oxidation pond is returned to the inlet works at the appropriate time.

2.4 SLUDGE MANAGEMENT

Waste activated sludge (WAS) is produced by the activated sludge system and discharged to the Sludge pond on a daily basis.

To minimize the capital cost for sludge treatment and minimize odours, the Waste Activated Sludge (WAS) is pumped to the sludge pond for stabilisation. The sludge will remain in the sludge pond for a minimum of 12 months. A 12 month stabilisation period will produce a sludge that can be categorised as a “B” grade sludge according to the New Zealand biosolids guidelines. The “B” grade biosolid can then be applied to land by incorporating it into the soil once a consent has been granted for this activity.

Following the 12 month stabilisation period the sludge is removed from the pond using a dredge that has been installed in the sludge pond (refer to Photograph 14) and pumped to one of the two new sludge storage tanks. The tanks have supernatant removal ports to reduce the water content. The supernatant is returned to the Sludge pond.

Photograph 14: Te Kuiti WWTP Dredge

The concentrated sludge in the sludge storage tank is then mixed using the mixer pumps prior to transfer to the new rotary press. The filtrate from the press is returned to the sludge pond and the cake discharges into a skip for

3 UPGRADE PERFORMANCE RESULTS

3.1 PLANT RESPONSE TO LOAD VARIABILITY

The new activated sludge reactor was seeded in July 2013 during the low load period. A full low load season has not been experienced yet. However the consenting data shows that the plant complied fully with both the "Operative" and the "Proposed" numerical consent conditions (refer to Table 3 above) between the period October 2013 to March 2014 inclusive (refer to Table 4: Consent Compliance Data that includes the High Influent Load Period October 2013 to March 2014.) with the exception of meeting the "Proposed" *E.coli* consent condition. The plant has therefore performed very well during the peak load period.

Table 4: Consent Compliance Data that includes the High Influent Load Period October 2013 to March 2014.

Contaminant	**Median**	**90^{th}%-ile**	**Maximum**
Total nitrogen (g/m^3 TN)	6.2	16	17
Total Nitrogen Load – Nov 2013 to Mar 2014 inclusive (kg/d TN)	20.7 (Ave)	-	-
Total ammoniacal nitrogen (g/m^3 TAN)	0.4	2.5	5.1
Total phosphorous (g/m^3 TP)*	3.3	4.5	6.7
$cBOD_5$ (g/m^3 $cBOD_5$)	2.5	4.4	6.9
Total Suspended Solids (g/m^3 TSS)	10.4	16.2	25
E.coli (cfu/100mL)	550	5700	12,000

* From a typical raw influent TP concentration of between 40-60g TP/ m^3.

Similarly, during the off-peak period April 2014 to June 2014 (inclusive) the plant complied fully (refer Table 5) with both the "Operative" and the "Proposed" numerical consent conditions with the exception of *E.coli*. The upgraded plant meets the Operative Consent Condition for *E.coli* but not the “Proposed” consent condition (ie < 200cfu/100mL as 90^{th} %-ile).

The amount of TN removal required during the off-peak period (Apr - Nov inclusive) is considerably less than during the peak period months Nov – Mar (inclusive) based on the proposed consent conditions (refer to Table 3).

Table 5: Consent Compliance Data for the Low Influent Load Period April 2014 to June 2014 (inclusive)

Contaminant	**Median**	**90^{th}%-ile**	**Maximum**
Total nitrogen (g/m^3 TN)	12.0	16.6	19.0
Total Nitrogen Load – Nov 2013 to Mar 2014 inclusive (kg/d TN)	51.2 (Ave)	-	-
Total ammoniacal nitrogen (g/m^3 TAN)	1.0	3.9	8.3
Total phosphorous (g/m^3 TP)*	2.0	3.0	4.6
$cBOD_5$ (g/m^3 $cBOD_5$)	2.2	3.6	5.3
Total Suspended Solids (g/m^3 TSS)	7.4	12.8	16.0
E.coli (cfu/100mL)	100	2280	3400

During the low load period it is more difficult to achieve the amount of nitrogen removal achieved during the high load period. The main reasons for this are:

- the denitrification rate is reduced by the lack of available readily biodegradable BOD,
- Anoxic conditions are more difficult to achieve due reduced BOD loads, a higher DO concentration in the raw influent and pond returns; and reduced mixed liquor concentration.

Despite the reduced denitrification process performance during the low load period the plant easily meets the proposed consent limit for TN of 73kg/d TN (average).

A different control philosophy has now been established for both the low and high load periods to ensure that the final effluent complies with the resource consent conditions. The main changes made during the low load period are:

- Reduce the reactor ML water level to the minimum level.
- Maintain the MLSS at between 2000 - 2500 g/m^3.
- Reduce the DO setpoint to between 0.5-0.6 g/m^3.
- Minimise the pond returns.
- Monitor the anoxic zone oxidation-reduction potential (ORP) and adjust the DO set point to achieve an ORP of somewhere between -50mV and +50mV.

The main changes made during the high load period are:

- Increase the reactor ML water level to the maximum.
- Maintain the MLSS at between 3000 - 3500 g/m^3.
- Increase the DO setpoint to 1.0 g/m^3
- Monitor the anoxic zone oxidation-reduction potential (ORP) and adjust the DO set point to achieve an ORP of somewhere between -50mV and +50mV.

3.2 AERATION PERFORMANCE AND EFFECTIVENESS OF AERATION CONTROL

- The aerator sequencing as per Figure 3 provides very good mixing within the aeration zone.
- The DO tends to be cyclic over a short period (approximately 10 minutes but that has been smoothed out by using a rolling average DO for control and the aerator step delay has extended to prevent the aerators stepping to the next level too quickly and creating DO instability.
- There have not been any noise complaints.

3.3 UV SYSTEM PERFORMANCE AND EFFECTIVENESS OF MEASURES TAKEN TO ADDRESS LOW UVT

The UV system has experienced some difficulty complying with the proposed resource consent condition for *E.coli* which is 200cfu/100mL as a 90th%-ile. The system was designed to achieve the resource consent limit at a UVT down to 25%. The UV system may not be able to comply with the consent condition at such a low UVT figure. It may be necessary to operate the chemical dosing under these conditions to improve the UVT to some greater limit. Some further improvements to the UV reactor are planned to improve the UV performance.

The chemical dosing system is capable of improving the clarifier effluent UVT to greater than 60%.

4 LESSONS LEARNT

The following list identifies a number of design matters with the Te Kuiti WWTP that are worth noting and may help with the design of future WWTP upgrades:

- There have been some problems meeting the proposed *E.coli* consent condition (<200cfu/100mL as 90th%-ile). It is recommended that if the final effluent is suspected to have low UVT, as well as recognizing the fact in the specifications, trial work should be carried to prove the effectiveness of the UV technology before entering Contractual commitments.

- Lime bridging was an issue until vibrators were installed. The vibrators have prevented any further bridging.

- Sand from the tertiary sand filter carried over into the UV system. Some form of sand trap should be installed or preferably the sand filters should be designed to prevent this occurrence.

- The cost for removing sludge from the old reactor was more than anticipated. The methodology for desludging needs to be considered very carefully to minimize the sludge removal costs.

- The ground conditions in the old reactor were very challenging in preparation for the new reactor construction. Unstable ground, high water table and tree stumps increased the construction difficulty and cost. Provide generous contingencies for earthworks when there is any uncertainty with regard to the ground conditions.

- The maximum depth of the Te Kuiti AS reactor is 3.5m. Providing a deeper reactor would allow greater flexibility with regard to reducing the reactor volume for low load conditions and also maintain a reasonable depth for efficient aeration.

- The height of the anaerobic zone curtain allows for when the reactor is at maximum water depth. When the reactor is operating at shallower depths there is some risk that air pockets can form and exert buoyancy forces on the curtain that can potentially damage the structure. Design features should be incorporated to reduce these risks.

- Some of the flowmeters were affected by air bubbles and air entrapment affecting the accuracy of the flow meter. The pipework design needs to be considered carefully to prevent this from occurring.

5 SUMMARY

The upgraded plant is performing very well. The final effluent results for the high load period January – March 2014 inclusive were as follows (Table 6):

Table 6: Te Kuiti WWTP Final Effluent Results Analysis for the High Influent Load Period – January to March (inclusive) 2014.

Contaminant	**Average**	**90^{th}%-ile**
Total nitrogen (g/m^3 TN)	5	9
Total ammoniacal nitrogen (g/m^3 TAN)	0.4	0.5
Total phosphorous (g/m^3 TP)	2	3
$cBOD_5$ (g/m^3 $cBOD_5$)	2	3
Total Suspended Solids (g/m^3 TSS)	9	14

5.1 LOW COST FEATURES

To minimize the cost, the reactor was constructed with a circular earth bund and a central anaerobic zone utilizing a curtain structure. An oxidation ditch type activated sludge (AS) process, with aeration and anoxic zones, was created within the reactor annulus. That eliminated the need for expensive internal pipe-&-pump recycles.

5.2 DESIGN FOR CONTAMINANT LOAD VARIABILITY

The new BNR plant has performed very well in terms of meeting the operative and proposed consent conditions both under high and low load scenarios. The oxidation ditch type AS process provided the flexibility to increase/decrease the reactor aerobic/anoxic fractions as the wastewater loads increased/decreased. The reactor design also allows the reactor depth/volume to be adjusted according to the load.

Online measurements of ORP, DO, Nitrate, pH, turbidity and UVT within the critical areas identify changing loads and other conditions that may affect the overall performance of the plant. This data allows the operator to respond appropriately to the changing conditions.

5.3 PROVISIONS FOR LOW EFFLUENT UVT

Chemical dosing pre-clarifier to precipitate soluble and colloidal contaminants and improve UVT prior to UV disinfection has been very successful.

When necessary this system can also be operated to improve:

- The ML settling characteristics.
- The clarifier effluent turbidity.
- The clarifier effluent TSS.
- The removal of total phosphorous

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