COST-EFFECTIVE PROCESS UPGRADE AT THE SOUTH ROCKHAMPTON STP FOR IMPROVED NITRIFICATION

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ABSTRACT

The South Rockhampton Sewage Treatment Plant (SRSTP) was recently upgraded from a conventional activated sludge design to a Modified Ludzack-Ettinger (MLE) design to improve nitrification and overall removal of nitrogen. This upgrade was required to ensure that the three Rockhampton STPs can continue to meet the combined environmental licence limits for nitrogen. The rationale, scope of work and challenges faced, for the completion of this upgrade are described below. The end result of this project was a cost-effective upgrade that met the objective of improving nitrogen removal.

1.0 INTRODUCTION

Nitrogen removal from wastewater is necessary because of the significant adverse environmental impact of this nutrient on receiving waters. Rockhampton's STPs discharge effluent into the estuarine reaches of the Fitzroy River approximately 50 km upstream from the river mouth.

There are three STPs in Rockhampton under the responsibility of Rockhampton Regional Council and its business unit, Fitzroy River Water. The West Rockhampton STP (WRSTP) is a trickling biofilter design constructed in 1962, the South Rockhampton STP (SRSTP) is a conventional activated sludge plant and was constructed in 1983, and the North Rockhampton STP (NRSTP) is an extended aeration design and was built in 1986. The WRSTP and SRSTP were not designed to achieve nitrogen removal but the NRSTP consistently achieves nitrogen removal to produce an effluent with total nitrogen (TN) of typically 5 mg/L.

For these three STPs the environmental licence includes a combined mass load limit for effluent TN discharged to the Fitzroy River. During 2013-2014 the three Rockhampton STPs were not consistently meeting the weekly mass load limit of 1,380 kg for total nitrogen, with the SRSTP contributing by far the largest proportion of this mass load of TN released to the Fitzroy River. The main reason for this poor performance was the inability of the SRSTP to achieve significant levels of nitrification.

Given the SRSTP's poor nitrogen removal performance, it was clear that an upgrade to the process was critical to ensure compliance with licence conditions into the future. Consultancy firm Sinclair Knight Merz proposed an upgrade strategy based on achieving an effluent total nitrogen concentration of 5 mg/L that would cater for the increased loading forecast for the next 10-15 years. This proposal involved major modifications to existing tankage and infrastructure and included a redesign of the existing primary sedimentation tanks and aeration tanks to operate in series rather than parallel as well as construction of additional sludge transfer pumping systems. With an estimated cost of $10 million, this option was considered unfavourable within Council's current budget position.

As an interim upgrade, Fitzroy River Water used Biowin® an alternative strategy to upgrade the SRSTP to a Modified Ludzack-Ettinger (MLE) design.

This upgrade would only require modifications to the internal structures of the aeration tanks and aeration components and no changes to current parallel tank flow configuration thus greatly reducing total project costs. Sinclair Knight Merz was commissioned to validate this alternative upgrade strategy for the SRSTP. The cost of this upgrade option was estimated to be $900,000, about one tenth of the earlier proposed upgrade option.

2.0 DISCUSSION

2.1 Objective and Scope of Process Upgrade

The objective of the process upgrade was to improve nitrification and hence to deliver improved nitrogen removal to consistently achieve final effluent total nitrogen <13 mg/L. This target was estimated as being required to ensure that the weekly combined load limit for effluent TN for the current loading of approximately 19,000 equivalent persons (EP) and for future increases in loading up to 27,000 EP. Table 1 shows the current and projected future loadings at each STP and their potential impact on combined effluent TN.

Table 1: ***Current loadings prior to the upgrade of SRSTP and projected loadings at each STP showing the potential benefit of the upgrade for future inflows.***

Current loadings at each STP (pre-upgrade of SRSTP)			
	NRSTP	**SRSTP**	**WRSTP**
Ave. Daily flow (ML)	10.5	5.0	1.2
Effluent TN (mg/L)	5	30	30
Weekly TN load (kg)	376.5	1050	252
Total (kg/week)	1,669.5 (Licence limit = 1,380 kg/week)		

Projected loadings at each STP by 2025 (post-upgrade at SRSTP)			
	NRSTP	**SRSTP**	**WRSTP**
Ave. Daily flow (ML)	11.5	5.5	1.2
Effluent TN (mg/L)	8	12	30
Weekly TN load (kg)	644	462	252
Total (kg/week)	1,358 (Licence limit = 1,380 kg/week)		

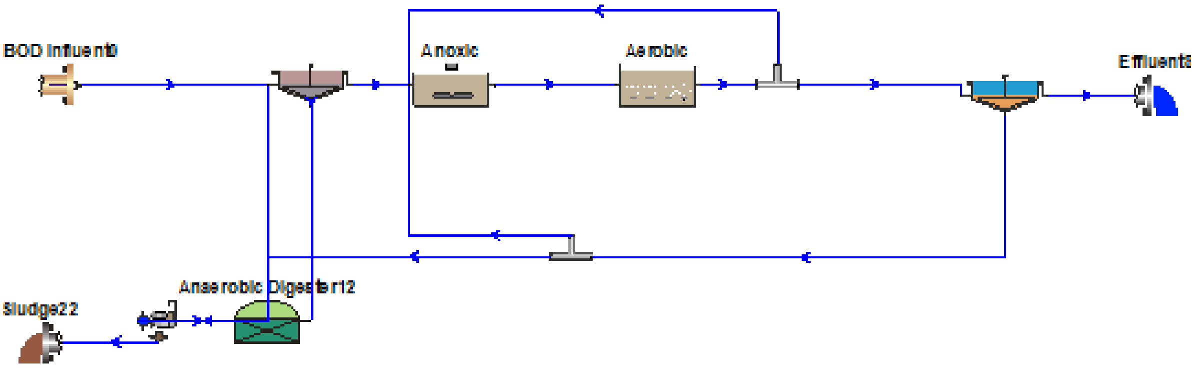

Figure 1: ***Configuration of SRSTP used for Biowin® Modelling.***

Sinclair Knight Merz provided validation using independent Biowin® process modelling that the alternative upgrade to an MLE process was able to achieve improved nitrification and nitrogen removal. The process upgrade was expected to achieve complete oxidation of ammonia to reduce the impact of this chemical species on receiving waters.

In brief, the scope of works to achieve this process upgrade included the installation of fine bubble diffused aeration and associated blower and air delivery pipework, creation of new anoxic zones for improved denitrification, installation of an internal sludge recycle for increased denitrification and sludge retention, and the installation of a new programmable logic controller (PLC) to enable control of aeration around a dissolved oxygen set point and flow pacing of sludge pumping.

2.2 Creation of a Fine Bubble Diffused Aeration Zone

An increase in aeration capacity for improved nitrification was a major objective of this upgrade. A total of 80 Aerostrip® diffusers manufactured by Aquaconsult were supplied and installed by Hydroflux Huber. These diffusers measure 4 m in length and were spaced tightly at 55 cm centres on the upstream end of the aeration zone and more widely at 110 cm in the down steam end just prior to the outflow weirs. Diffusers were installed into each aeration tank which measured 15 m (length) x 10 m (width) x 3.6 m water depth with a process volume of approximately 0.5 ML. Following installation, standard oxygen transfer testing was performed under clear water conditions by the contractor to confirm that the performance of the new aeration system matched the process design requirements.

2.3 Installation of Blowers and Pipework

Air is delivered to the diffusers via one of two newly installed Aerzen GM60S 110 kW positive displacement blowers. The blowers were housed in a purpose built elevated shed constructed adjacent to the process tanks and above the Q100 flood level. Air is delivered via suitably sized spiral wound stainless steel pipe supported on steel frame above the bioreactor walkways. Overhead position of this pipework was chosen to avoid clashes with the existing wall and walkway structures, with downcomers constructed at regular intervals to connect to header pipes on the tank floor to supply the diffusers. PLC control of aeration was setup using dissolved oxygen sensors to control blower speed via variable speed drives to achieve a selectable dissolved oxygen set point.

2.4 Creation of Anoxic zone

The original design of the SRSTP included two parallel bioreactors each 30 m long. Each tank was modified by constructing a stainless steel dividing wall in order to create separate aeration and anoxic zones with the anoxic zone located upstream of the aeration tank where the diffusers were installed. Inflowing screened sewage from the primary sedimentation tanks as well as the return activated sludge flows each enter at the upstream end of each anoxic zone. Due to budget constraints the existing mixer aerators were retained to continue to provide sludge mixing despite the unwanted introduction of small amounts of air into this zone. These mixer aerators are targeted for replacement with dedicated mixers that are expected to have significantly lower power consumption.

2.5 Installation of Internal Sludge-Recycle Pumps

A submersible axial flow propeller pump (Sulzer VUPX) was installed in the downstream end of each of the two aeration tanks. These pumps were installed vertically in 500 mm diameter stainless steel columns which connect via an elbow to discharge pipework. Mixed liquor is pumped and channelled from the downstream aeration zone to the upstream anoxic zone. The raw sewage inflow enters at the head of this zone alongside the recycled mixed liquor.

The raw sewage provides the organic carbon source consumed during denitrification. With limiting dissolved oxygen in this zone denitrification becomes the more energy efficient pathway for oxidation due to the high levels of nitrate present in the mixed recycled liquor. Thus significant denitrification within the bioreactor will reduce Total N of final effluent.

2.6 Process Control System Upgrade (PLC program)

A new PLC (Allen-Bradley ControlLogix) was installed to upgrade the process control at the SRSTP. A functional description prepared by Sinclair Knight Merz was used to program the PLC with MLE process control parameters, which included flow paced dosing of sludge pumping, sludge wasting and DO set point control via adjustment of blower motor speed. New Supervisory Control and Data Acquisition (SCADA) pages were created to display the new process equipment and to provide an operator interface for monitoring and control.

2.7 Maintaining STP Operation During the Upgrade Works

The requirement to maintain continuous operation of the SRSTP during the completion of the process upgrade posed a number of challenges. These challenges included the draining and cleaning of each of the bioreactor tanks in turn to complete the installation works whilst directing total inflows through only have of the parallel tank volume. The heavy rainfall and an extended power outage associated with Tropical Cyclone Marcia led to high inflow events that required some bypassing of parts of the SRSTP process in order to avoid tank overflows. A number of latent conditions due to corrosion of weir structures and pipework within the tanks required repairs to be completed which further delayed the construction and installation works. At the same time one of the secondary sedimentation tanks was off-line in readiness for refurbishment of the travelling bridge/scraper. This further reduced the overall hydraulic capacity of the SRSTP and posed additional challenges to operators.

2.8 Results of Process Upgrade

Data presented in Figure 2 shows a significant improvement in nitrification and overall improvement in removal of TN. A brief period prior to TC Marcia's arrival in late February and then the subsequent period post-upgrade in March shows a decrease in levels of effluent TKN to values of typically less than 10 mg/L apart from one event in August where TKN levels increased due to sludge carryover during a brief problem with secondary sludge handling. Concentrations of effluent ammonia measured post-upgrade were consistently less than 1 mg/L and often less than 0.1 mg/L. Effluent TN was typically reduced by more than half with average effluent TN approximately 15 mg/L. Overall effluent NOx increased post-upgrade due to the improved nitrification and therefore greater concentrations of nitrate produced. As stated above, the use of the mixer aerators for mixing in the anoxic zone, along with some pending works (e.g. upgrade and flow pacing of secondary sludge pumps) means that the anoxic zones are not yet fully optimised for denitrification, hence the relatively high effluent NOx. Despite this, the improved nitrogen removal performance post-upgrade has helped to ensure that the three Rockhampton STPs now consistently meet the combined weekly mass load discharge limit for effluent TN.

Another positive outcome from the project was better retention of sludge during high rainfall events with the internal sludge recycle pumps operating in flow-paced mode preventing sludge washout.

Other beneficial outcomes included a reduction in electricity usage due to the greater efficiency of the fine bubble diffused aeration, and a reduction in chlorine gas usage due to improve sludge settling and overall process consistency. The total cost of completion of the project was $1.1 million, slightly above the $900,000 estimate, although this estimate did not include the PLC upgrade.

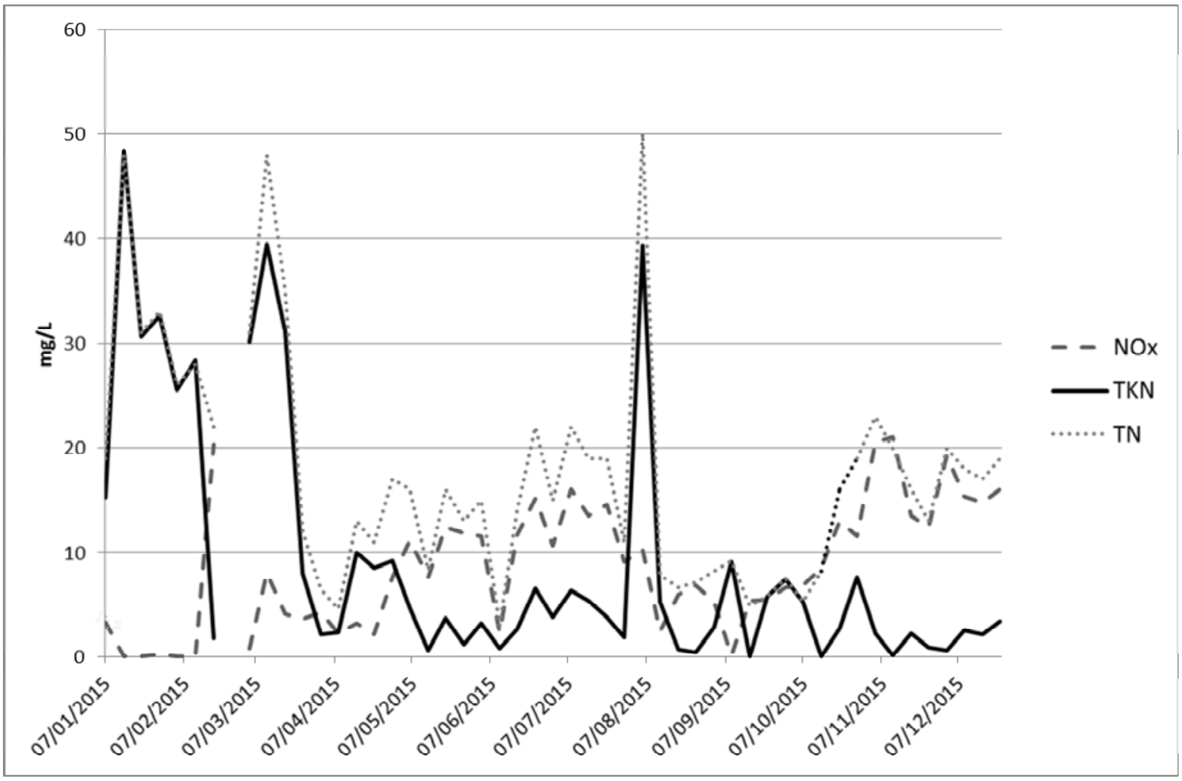

Figure 2: ***Data for effluent NOx, TKN and TN taken before and after the completion of the SRSTP process upgrade in March 2015.***

3.0 CONCLUSION

The installation of fine bubble diffused aeration provided a significant improvement in nitrification for the SRSTP. An improvement in removal of TN was also achieved. The construction of an anoxic zone has increased the removal of nitrogen by reducing nitrate levels through the addition of denitrification processes. The completion of further minor works including replacing the old mixer aerators, together with ongoing optimisation of process control parameters, will further improve denitrification. The installation of the internal sludge recycle pumps with flow paced control has significantly improved the retention of sludge during heavy rainfall events by reducing sludge wash-out. This improvement and some other process control upgrades confirm the benefit of the use of automated control for improved process performance. Savings in operating costs such as electricity and chemical usage can be achieved and represent a significant long term return on investment. A small number of other planned improvements will lead to an overall increase in the denitrification achievable within the SRSTP.

4.0 ACKNOWLEDGEMENTS

Work colleagues Noel Schneider, Mark Knickel, Murray Ball and Dr Jason Plumb are acknowledged for their involvement in this project and the preparation of the paper.

5.0 REFERENCES

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