ENERGY USE REDUCTION AND PROCESS OPTIMISATION THROUGH WASTEWATER SIMULATION MODELLNG

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ABSTRACT

Aeration control is a fundamental aspect of wastewater treatment plants. An aeration control strategy must be developed taking into account the physical, hydraulic, biological and loading characteristics of the individual treatment system. New Plymouth District Council (NPDC) has been working with Beca Infrastructure Ltd (Beca) to develop an aeration control strategy for the New Plymouth Wastewater Treatment Plant.

After an initial assessment of the treatment plant a dynamic process simulation model of the plant was developed. All current operational and control strategies at the plant were fully incorporated into the model and extensive influent and process characterisation was undertaken. Proposed control strategies were evaluated and compared using the calibrated model, which was also used to demonstrate the benefits of further process upgrades.

The modelling investigation showed that implementing an aeration control system using existing aeration equipment would result in significant cost and energy savings. Total nitrogen in the plant effluent will be reduced, and this should in turn result in an improvement in process stability. Further assessment of basin hydraulics and testing of aeration equipment and basin response to disturbances is necessary to finalise a control strategy. The model continues to be refined and used by NPDC and Beca as a development tool for the plant.

KEYWORDS

Wastewater, Aeration Control, Optimisation, Energy, Cost, Simulation, Modelling

1 INTRODUCTION

1.1 BACKGROUND

The goal of optimised aeration control in a biological wastewater treatment system is to provide sufficient dissolved oxygen (DO) to the biomass to achieve treatment goals while using the minimum of power (Gerksic, 2006). Aeration is an energy intensive process, and the use of excessive aeration energy is both costly and environmentally undesirable. Under and over-aeration of the wastewater can also result in process instability, leading to deterioration in effluent quality and operational difficulties. Poor and/or inappropriate DO control can play a major part in changing the biomass ecology (Dexter, 2001) and lead to the proliferation of undesirable microorganisms.

Development of an optimised aeration control strategy is a challenging process, as oxygen demand is a complex process that varies over time. For any wastewater plant employing aerobic and/or anoxic processes, it is necessary to develop a strategy that takes into account the reality of dynamic loading and changing environmental conditions (such as temperature). This strategy must take into account the physical, hydraulic, biological and loading characteristics of the individual treatment system.

The New Plymouth Wastewater Treatment Plant (WWTP) is a dual carrousel basin plant (using the recirculating oxidation ditch principle), operated with anoxic and aerobic zones in order to achieve nitrogen removal. NPDC own and operate the plant, which receives wastewater from three catchments in the New Plymouth area, septage loads, and substantial trade waste discharges. Future plans for the plant include the introduction of wastewater from two other townships, which will also include trade waste discharges.

Aeration capacity at the New Plymouth WWTP has already been upgraded to allow for planned increases in future loading but an aeration control strategy has not been implemented. Aeration equipment consists of two 75kW Simcar surface mechanical aerators and four 15kW Triton Aire-O_2 aspirating aerators in each basin. The Simcar aerators are equipped with variable speed drives. Control of the aerators is manual, with operators turning aerators on and off in response to plant parameters, such as a drop in alkalinity or a large overnight spike in DO. The plant produces almost completely nitrified effluent; however effluent nitrate is higher than desired in terms of oxygen recovery through denitrification. The plant suffers from periodic Nocardia foams and solids washouts from the secondary clarifiers. These have typically occurred during summer months and during process upsets such as reduced wasting due to sludge processing equipment being offline. A recent occurrence of Nocardia (Photograph 1) may have been influenced by construction activities that temporarily lowered the operating water level in the basins, thus reducing the efficiency of the surface aerators. The plant is very sensitive to such disturbances. Plant SCADA data shows that the DO profile around the basin is not consistent, with very low DO around much of the basin during the day, and high oxygen spikes occurring at night. Development of an aeration control strategy was necessary for the following reasons:

- Improvements to the stability of plant biology
- Recovery of alkalinity and oxygen from nitrate through denitrification
- Improvements to plant operational efficiency - energy and cost savings
- Potential reduction in the incidence of sludge bulking
- Production of an effluent with lower total nitrogen.

It was desired to make the best possible use of existing equipment before undertaking any further upgrades to the plant. An aeration control strategy had previously been proposed, and NPCC required validation and analysis of the strategy. It was decided to develop a calibrated dynamic simulation model for the plant, as this would enable more fundamental understanding of the plant to be developed. In this way, different strategies could be tested without risk to the plant operation. The most effective and efficient strategies could then be put forward for implementation. The model was seen as a tool that, once calibrated, could be used on an ongoing basis for future design work.

Photograph 1: Nocardia foaming at the New Plymouth Wastewater Treatment Plant

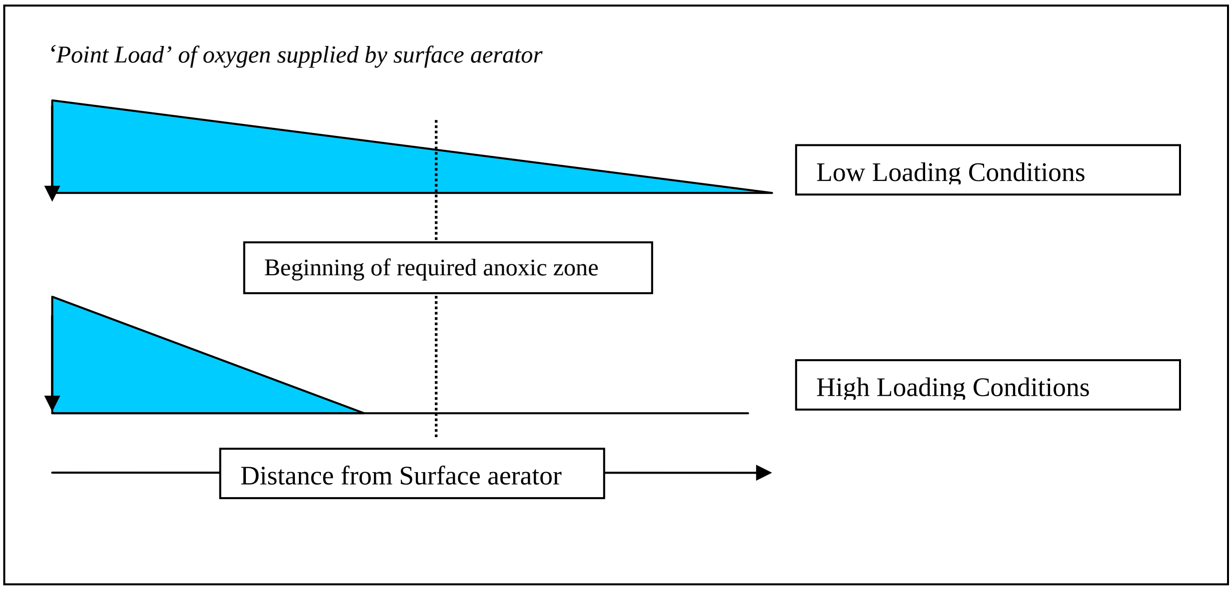
1.2 CARROUSEL BASIN CHARACTERISTICS

In contrast to other biological nutrient removal processes, which have separated compartments for aerobic and anoxic processes, the carrousel basin does not have fixed zones. The DO concentration profile in a carrousel basin using surface aerators can be approximated as a point loading, followed by a decline as the biomass utilises the DO. The shape of the DO decline, and hence the fraction of the basin that is maintained in an aerobic state, varies with changing influent load and conditions in the basin. The aerobic volume must be sufficient to allow nitrification of influent Total Kjeldahl Nitrogen (TKN). There must also be sufficient anoxic volume (and substrate available within this volume) to allow denitrification. The required anoxic and aerobic volumes will change diurnally and over the long term. At high loads, a relatively greater aerobic volume (and therefore mass fraction) is required to nitrify, while at low loads a greater anoxic volume is required as the rate of denitrification will be slower due to more limited substrate for the biomass.

Basin hydraulics also have a significant effect on the effectiveness of oxygen transfer, and hence nitrogen removal, in particular the ditch velocity and dispersion and mixing patterns within the basin. Aeration equipment often has the additional use of providing mixing and flow momentum, and there must be sufficient turndown to maintain a flow velocity of at least 0.2 – 0.25 m/s (Hartley, 1997). Basin velocity and mixing patterns can be strongly influenced by surface aeration equipment, which makes the control of oxygen transfer more difficult.

Without taking these factors into account, over and under aeration of the wastewater can easily occur, as shown in Figure 1, and/or process stability problems develop.

Figure 1: Dissolved oxygen profile in a carrousel basin with a constant applied oxygen load. Under low loads, there is too much oxygen infiltrating the anoxic zone. At high loads, the oxygen demand is demand is much higher and there is a risk that the aerobic fraction of the biomass will be insufficient to nitrify the incoming load. The aerobic and anoxic mass fractions will be opposite to the ideal scenario.

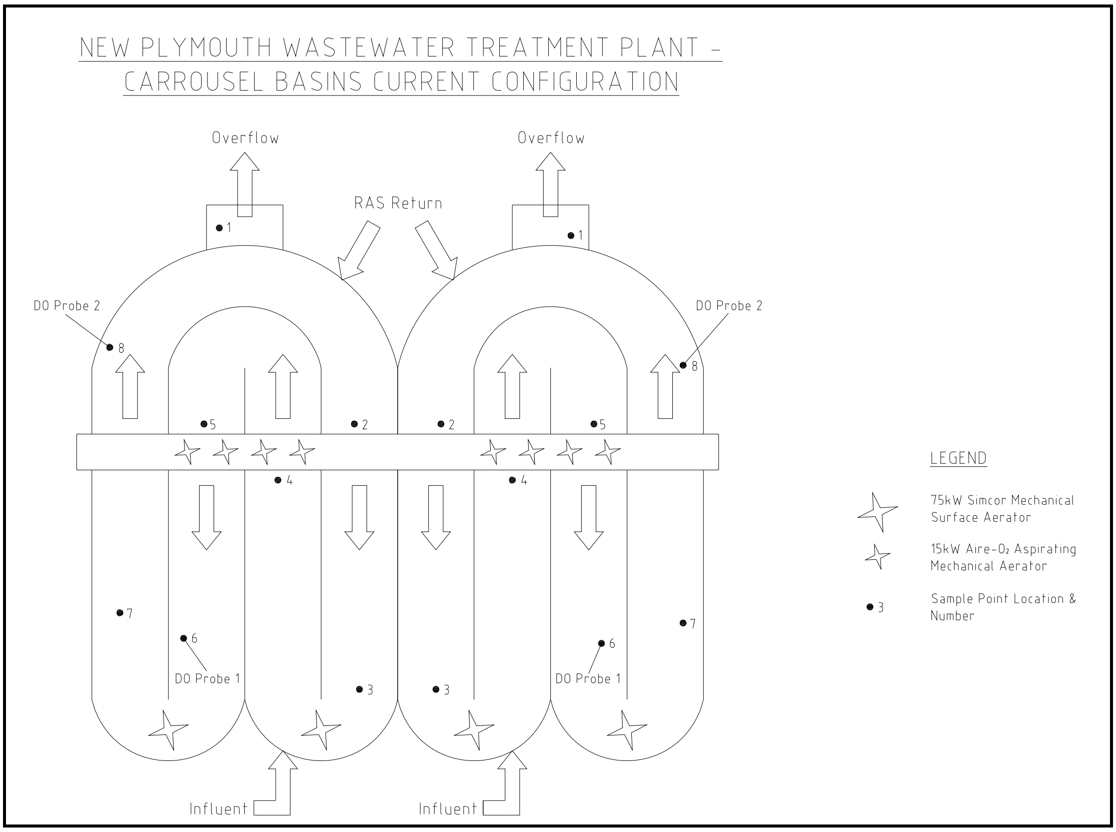


2 MODEL CONSTRUCTION AND CALIBRATION

2.1 PLANT PROCESS DESCRIPTION

Raw wastewater and septage is passed through 6mm milliscreens and a grit removal chamber. The flow is then split in two, being passed to one of two carrousel basins, with each having a volume of 9,500m^3. A clarifier follows each carrousel basin, and the two treatment paths are not intermixed in any way. Return activated sludge (RAS) and waste sludge (WAS) are removed from the underflow of the clarifiers. The treated effluent from both clarifiers is combined and is then passed through chlorine disinfection before discharge. A third clarifier is under construction, which will result in the two separate treatment paths becoming completely mixed, through a common RAS return. The mixed liquor suspended solids (MLSS) in the basins is currently maintained at 2000 – 2300 g/m^3, and the sludge age is kept to between 6 and 10 days. The hydraulic retention time of the system under present flows is approximately 24 hours. The hydraulic configuration of the carrousel basins is shown in Figure 2, which also shows the location of aeration equipment. Influent currently enters the basins into a fully aerobic zone. This is not ideal for nutrient removal. However it was desired to improve the aeration control as much as possible with the existing configuration while future strategies were considered.

Figure 2: New Plymouth Wastewater Treatment Plant – Current Configuration of Carrousel Basins, showing aeration and sampling location details



2.2 MODEL DEVELOPMENT

As the model is designed to be used as part of an ongoing strategy by NPCC, it was necessary to ensure that it was well calibrated and that an accurate picture of current loads and plant process behaviour was developed. The modelling package GPS-X (Hydromantis Inc) was used as it provides an open simulation environment that allows the user to program in any operational and control strategies that are not already built in to the process units, via the Advanced Control Simulation Language (ACSL) interface.

The activated sludge model ASM2d was selected for use. This model has been previously used to assess the performance of oxidation ditches (e.g. Beck et al 2003) with good results. Although the fate of phosphorus through the plant was not of primary interest, use of this model allowed checks to be made against measurements of orthophosphorus around the plant.

Preliminary treatment was included in the model for visual completeness only. Each carrousel basin was modelled as a 16 zone plug flow oxidation ditch. Each zone was represented by a Continuously Stirred Tank Reactor (CSTR). One fundamental assumption used in biological reactor modelling is that a CSTR is completely mixed. Thus in the model all process variables, such as DO, entering one of the 16 CSTR zones are immediately distributed evenly through the entire volume. The value of the process variable used in model calculations throughout the zone is the ‘fully mixed’ value. Therefore it is important to select the zone volumes to reflect the scale of the process reaction taking place. This will smooth out the model response to the ‘fully mixed’ principle. The volumes of each zone were selected to reflect the observed process zones. For example, the zones containing DO probes had a relatively small volume, so dilution effects from the CSTR ‘complete mix’ principle were minimised.

The secondary clarifiers were modelled as reactive clarifiers, and their biological kinetics were sourced to the upstream carrousel basins. Return centrate from the belt presses was included to ensure the model was providing a satisfactory solids balance over the plant. Empirical removal rates were selected, as it was not required to model the sludge processing in detail.

In a carrousel basin, the hydraulic flow patterns are likely to vary around the basin, depending on proximity to the mixer/aerators. In some zones, flow may approach a more plug flow pattern (stratification of the biomass had been noted at the New Plymouth plant prior to installation of the Aire-O_2 aerators). This will affect the concentration of parameters within the reactor, including dissolved oxygen and therefore uptake rate and demand profile along the basin. While a calibrated model could be utilised for assessment of the biological processes in the tank, assessment of the detailed hydraulics within the basin itself could not be undertaken with a biological process model.

2.3 PLANT AND INFLUENT CHARACTERISATION

Accurate characterisation of the entire plant results in more accurate mass transfer in the model. All plant physical dimensions and operational controls and procedures were input to the model. This included modelling of RAS and WAS control. Of particular interest was the basin velocity, as this has a direct influence on the maintenance of anoxic and aerobic zones in a basin. The basin velocity was tested using visual procedures (a version of ‘poohsticks’ using oranges) and a portable velocity meter. Mixing in the basins was observed to be reasonable.

An S:CAN on-line instrument was installed in the plant influent line, immediately after the grit trap. The instrument was completely submerged and left to collect data for three months. The S:CAN works using photometrics, a technique which uses individual absorbance spectra in the ultraviolet and visible light spectra to characterise different components of a wastewater. The instrument employs statistical methods of polynomial adaptation to known spectra and/or statistical analysis of a reference database, in order to achieve this. If properly calibrated it can eliminate uncertainties associated with traditional methods such as sampling errors and biochemical degradation. The instrument also provides continuous data, enabling analysis of dynamic trends over a period of time.

Grab sampling of the influent was undertaken to validate the S:CAN data. The S:CAN data was generated every two minutes, data from +/- 30 minutes around the time of manual sampling was analysed. The data was found to be in reasonable agreement, therefore it was possible to use the S:CAN data to characterise plant loads for the following parameters:

- COD
- filtered COD
- Total Suspended Solids
- Haem – a blood component used to track the loading of slaughterhouse waste to the plant.

Other dynamic influent information collected via manual sampling was ammonia, TKN, orthophosphorus $CBOD_5$ and $CBOD_{20}$. Important influent parameter fractions were also analysed from these manual samples. Plant SCADA data provided influent flow information.

The S:CAN and SCADA data were edited to produce 40 day data files at 10 minute intervals that could be used as direct inputs to the model. In addition, diurnal profiles for all parameters were developed from S:CAN and SCADA data so that longer simulations could be run. The length of time the S:CAN instrument was in place meant that these could be developed with confidence, as it gave the chance to analyse diurnal trends over the entire data collection period. Once data collection and analysis were complete, the influent specification model used for GPS-X was developed. A suspended solids/COD based model was selected, as a lot of data was available for these parameters.

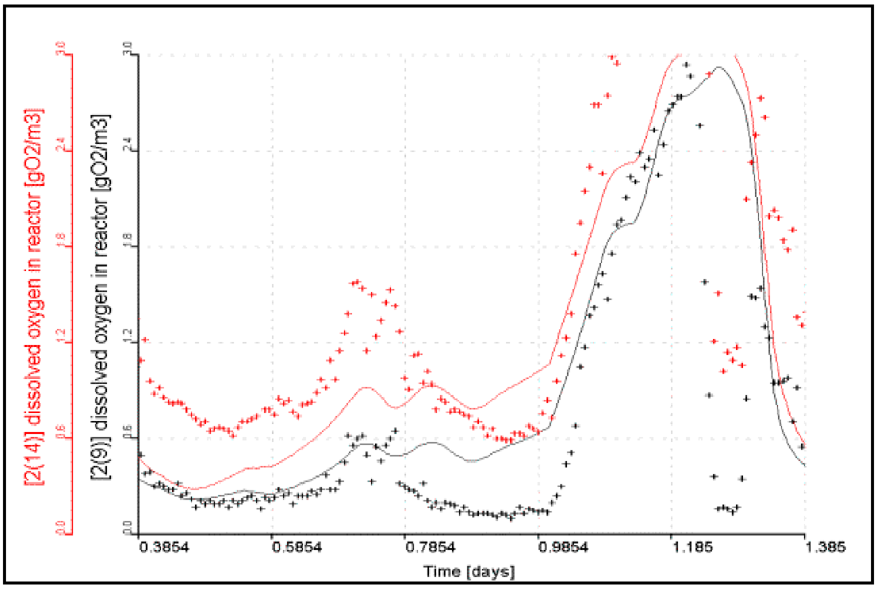
At the same time as the influent characterisation, collection of online and manual data from around the plant was collected for calibration purposes. Plant SCADA data provided DO readings from the meters currently installed in the basins (see Figure 2 for location of the meters). Operators collected samples from the sample points shown in Figure 2, in the clarifier effluent and in the final effluent at different times of the day. Parameter profiles were developed in this way for DO, Ammonia and Nitrates. Grab samples were taken for alkalinity and orthophosphorus. Additional plant data included MLSS and SVI measurements

2.4 MODEL CALIBRATION

Model calibration was undertaken using the procedure outlined by De Pauw et al, 2003. Convergence to a mathematical steady state solution with a carrousel plant model is difficult due to the high recirculation flows. The model was run on diurnal profiles with reduced recirculation flows until steady state conditions were achieved. The recirculation rate was then increased and the model allowed to run for a further period of time (20 – 30 days simulation time). The model predicted nitrate level in the effluent was consistently found to be 3 - 4 g/m^3 too high, and was most sensitive to the level of dissolved oxygen in the wastewater and the basin velocity, (measured basin velocities had ranged between 0.3 and 0.5 m/s, depending on proximity to one of the aerators).

The mechanical surface aeration model used needed calibration. Information available for the Simcar aerators was manufacturer’s data, which included estimations of shaft power use and Clean Water Oxygen Transfer Efficiency (SOTE). Power draw and estimated SOTE was available for the aspirating aerators. The model oxygen transfer rate needed to be adjusted in order to provide a reasonable match with plant SCADA data (in agreement with a previous report on the aerators, which had stated that the SOTE for the Simcar aerators needed to be derated). Reasonable agreement was obtained with plant SCADA data in terms of dissolved oxygen, both at the DO meter locations and in profile around the tank. During low load periods, the model consistently tended to slightly overestimate the DO in zone 9 of the carrousel basin (DO probe 1 in Figure 2 above). The only factors that it displayed sensitivity to were the oxygen transfer rate and basin velocity. The model did agree with the SCADA data in that the DO probe immediately downstream of the aspirating aerators consistently displayed a lower DO than the one downstream of the second Simcar aerator (Figure 3).

Figure 3: GPS-X Model dissolved oxygen concentration (solid lines) against SCADA data DO meter measurements (dotted points)



Other minor changes to the model default parameters were made; for example the denitrification reduction factor was increased from 0.6 to 0.8 (the value reported by Gujer et al, 2000). The model was then run with data files as inputs to check the results. A new data file set was then used to check that model performance was reasonable. Evaluation of alternative aeration control strategies was performed using developed diurnal profiles. The model provided good agreement with parameter profiles (Figure 4) and overall effluent quality (Table 1), and was considered suitable for evaluating WWTP performance under current load conditions.

Figure 4: GPS-X Model ammonia and nitrate profile from Carrousel basin 1. The rise in ammonia from <1g/m^3 to around 3 g/m^3 after morning peak loads is reflected in measured sample from several days (typical values shown as blue circles on the figure).

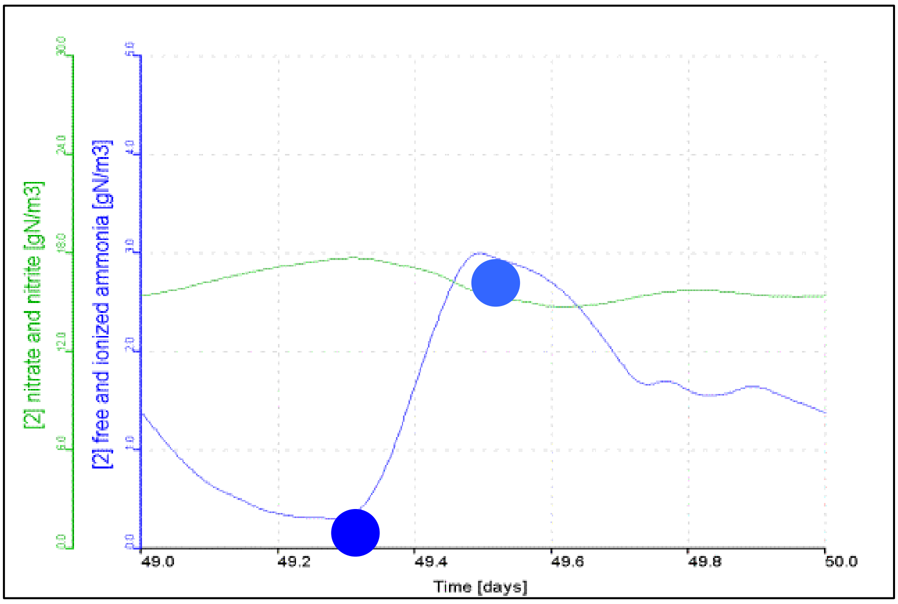


Table 1: Diurnal Data Profile Effluent Check

PARAMETER	**WWTP MEASURED AERATION BASIN DATA (8AM)**	**GPS-X MODEL DIURNAL PREDICTION (8AM)**	**WWTP MEASURED AERATION BASIN DATA (1PM)**	**GPS-X MODEL DIURNAL PREDICTION (1PM)**
$CBOD_5$	<5 g/m^3	3.5 g/m^3	Not measured	4 –6 g/m^3
Ammonia	<1 g/m^3	<1 g/m^3	<4 g/m^3	<4 g/m^3
Nitrate	10 – 15 g/m^3	13-16 g/m^3	10 – 15 g/m^3	16 – 18 g/m^3
Suspended Solids	5 g/m^3	4 g/m^3	Not measured	7 g/m^3

3 AERATION CONTROL MODELLING

During the data collection period it was noted that the plant effluent alkalinity was often low (50 – 90 g $CaCO_3/m^3$), especially in the morning period. This had also been reflected in the model output. Plant operators had the goal of trying to maintain 80g Alkalinity as g $CaCO_3/m^3$, but this was difficult to achieve in practice. At the time of site visit, Nocardia foams were evident in both basins, and the pH in the basins had lowered from around 7 to around 6.5 (it is thought that construction activities related to the third clarifier and a Thermal Dryer shutdown had provided the catalyst for this). Nitrate levels in the basins were high (10 – 20 g/m^3) as a result of almost complete nitrification, but limited denitrification. Filamentous Nocardia bacteria are competitive under conditions of low DO, pH and limited carbon source (Daigger et al, 2003). It has also been noted (Thomas and Ostarcevic, 1997) that high nitrate levels can favour the formation of bulking sludge. Additional factors that contribute to their growth are sewage septicity and low temperatures. The WWTP receives septage loads from several industrial sources.

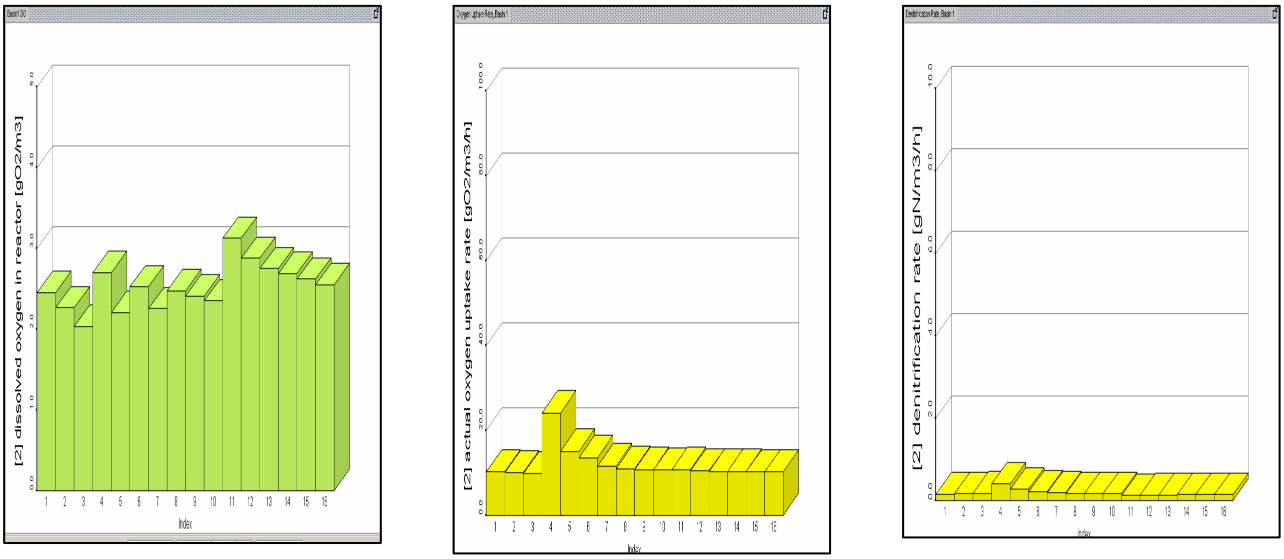
Proposed future aeration control strategies needed to take into account the conditions that lead to Nocardia proliferation, and ensure the chances for this were minimized. Establishment of a useful anoxic zone to denitrify, and restriction of the aeration during low loading periods were primary goals.

3.1 EXISTING AERATION

During summer, all aerators are usually left running on full speed all or most of the time as the level of DO measured in the basins is typically very low. During winter one of the Simcar Aerators is turned off for a few hours overnight to minimise oxygen spikes. Simulating the summer operating procedure generated a baseline effluent quality, operating cost and energy consumption. Cost information was generated based on current pricing information supplied by NPCC.

This scenario showed that the plant is over-aerated during the night, when influent loads are less. The oxygen uptake rate (OUR) is comparatively low, and denitrification almost non-existent at this time (Figure 5). This profile is confirmed by SCADA data, which shows large peaks in DO concentration during the night. The entire basin is aerobic; but because loads are so much lower most of this oxygen is essentially ‘wasted’ and serves no purpose other than to maintain endogenous respiration of the bacteria (during this time the F:M ratio drops to below 0.1, from an average of 0.16). Because of the swings in DO concentration during the day, denitrification is continually limited. This scenario demonstrated the need for aeration control to maintain a dedicated anoxic zone.

Figure 5: Model predicted DO profile, OUR and denitrification rate in carrousel basin 1 under existing aeration control, low loading



As shown in Figure 3, DO measured at the second DO probe is consistently higher than the first. This is a reflection of oxygen demand in the basin, and showed that the second aerator is likely to be providing too much oxygen all of the time. This is inefficient in terms of energy consumption, and means that maintaining a dedicated anoxic zone is difficult, due to carry through of DO.

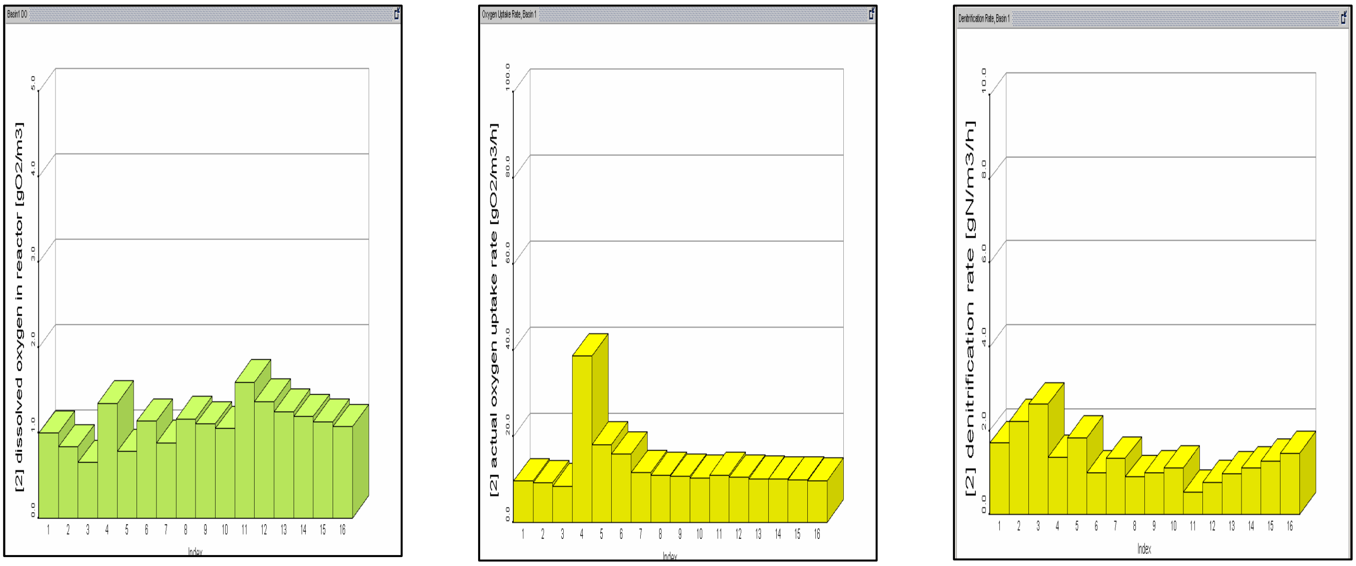
This scenario also demonstrated the sensitivity of the basins to the hydraulic characteristics. If the modelled basin velocity was lowered to 0.25-0.3 m/s from 0.4 (the measured average), the oxygen profiles improved, but there was still too much oxygen going into the reactor. The Aire-O_2 aerators are mounted at a 45^o angle, and they provide additional momentum to the flow. Adjusting the angle of these aerators would reduce the basin velocity.

3.2 SIMPLE FEEDBACK CONTROL

A simple control system was modelled that could be easily implemented using existing equipment. The turndown of the Simcar aerators was estimated based on the available frequency on the variable speed drive. The goal was to improve denitrification in the simplest way possible. Installing a setpoint PI controller on the second Simcar aerator results in some reduction of effluent nitrates, without losing the ability to nitrify during peak loads. The controller was instructed to maintain a DO concentration of 0.5 g/m^3 at the location of DO probe 2 shown in Figure 2. There is improvement in oxygen profile and denitrification (Figure 6), but there is not sufficient turndown in the downstream aerator to maintain this zone in an anoxic state during low load periods (primarily due to the basin velocity). Installing a PI controller on both Simcar aerators gave better performance in terms of total nitrogen, but effluent ammonia was increased slightly. This system could be improved by the installation of PLC or timer control on the Aire-O_2 aerators, by turning some or all of them off overnight, which would allow the Simcar control to function better under low loads.

With an understanding of how the plant biology was likely to respond, a scaled back version of this system could be implemented manually, without the need for control programming, resulting in instant energy and cost savings. This should also result in an improvement in sludge settlability as more denitrification starts to occur.

Figure 6: Model predicted DO profile, OUR and denitrification rate in carrousel basin 1 under simple feedback aeration control, low loading



3.3 CASCADE CONTROL SYSTEM

A cascade control system had been proposed for the basins in which two separate PI loops would control the upstream and downstream aerators. The upstream loop consists of the first Simcar aerator, and all four Aire-O_2 aerators. Trim control would be applied to the setpoint of the upstream PI loop in the event that DO in the downstream zone exceeded the loop setpoint. Using this method the aerobic and anoxic mass fractions could be roughly controlled in response to changing load conditions. This system (shown in Figure 7) was aiming to maintain a consistent aerobic zone from where the influent enters the basin, and a consistent anoxic zone after the second Simcar aerator. The system was incorporated into the GPS-X model using inbuilt PI controllers and the ACSL interface.

The upstream DO setpoint had been proposed at 1.5 g/m^3 (as measured at DO probe 1 in Figure 2). The concentration of oxygen in the basin at this point rarely reaches this value. Overaeration in the aerobic fraction would therefore result as the upstream aerators tried to achieve the setpoint. This would result in carry over of DO to the anoxic volume. SCADA data from the plant, as well as the model, showed that on average, the DO at this location will rise above 1 g/m^3 for around 6 hours overnight. Thus a reduction in DO setpoint for the overnight low loads was desired, but the setpoint needed to be altered in response to early morning loads. The DO setpoint was set at 1 g O_2 m^3 and allowed to vary between 0.8 and 1.3 g/m^3. This system did show the ability to control the DO profile around the basin, shown in Figure 8. Incorporation of the Aire-O_2 aerators into the upstream loop would in reality also have the benefit of reducing the basin velocity, which would further aid in maintaining the required aerobic and anoxic volumes under low load conditions. Denitrification was increased, although this was more due to an increased ability to denitrify through the basin during periods of higher load, than due to a consistent anoxic zone. The oxygen uptake rate was also observed to increase, indicating more efficient use of available oxygen by the biomass. This system displayed the best effluent quality.

Figure 7: Aeration control using cascade controller. The location of DO meters AT-A and AT-B is shown in Figure 2. The upstream loop consists of one Simcar aerator and the 4 smaller Aire-O_2.

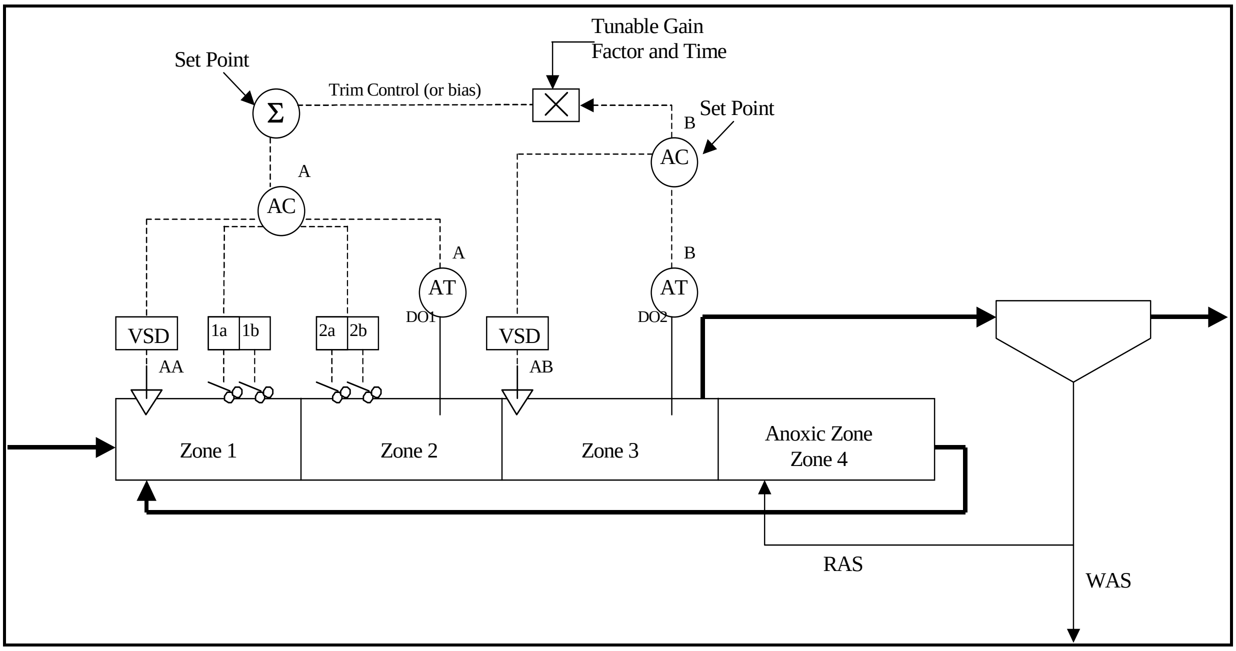
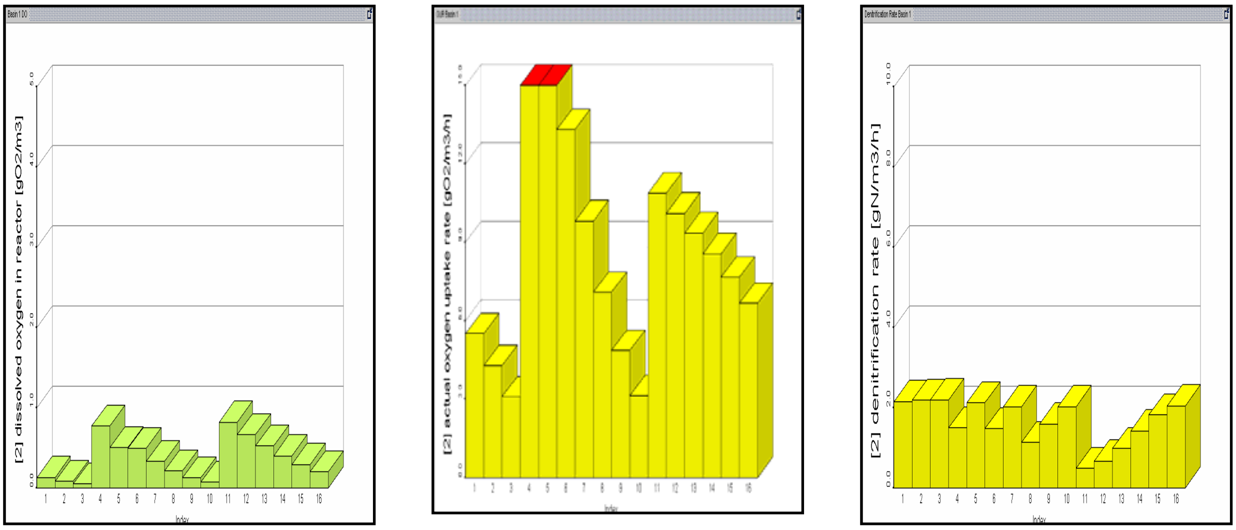


Figure 8: Model predicted DO profile, OUR and denitrification rate in carrousel basin 1 under cascade aeration control, low loading



3.4 COMPARISON OF CONTROL STRATEGIES

Estimated cost and energy savings achieved by the two evaluated control strategies are shown in Table 2.

Table 2: Model Predicted Cost and Energy Savings

CONTROL STRATEGY	25 DAY TOTAL ENERGY SAVINGS (KW)	MODEL PREDICTED YEARLY COST SAVINGS ($)
Simple Feedback Control	29000	$30,000
Cascade Control	22800	$19,500

A comparison of model predicted effluent qualities is shown in Table 3. The mean output value over the 25-day run is used.

Table 3: Model Predicted Effluent Quality using different aeration control strategies

CONTROL STRATEGY	EXISTING	SIMPLE FEEDBACK CONTROL	CASCADE CONTROL
Total Suspended Solids (g/m^3)	6.2	6.1	5.5
$_C$BOD$_5$ (g/m^3)	2.5	2.5	2.3
Ammonia (g/m^3)	2	2.9	1.3
Nitrate (g/m^3)	13	8	6.2
Total Nitrogen (g/m^3)	15	11	8
Alkalinity (gCaCO$_3$ /m^3)	80	103	95

Significant benefits in cost and energy savings, as well as effluent quality, can be made by improving the aeration control. The cascade control system did not show as much additional benefit in terms of energy use as direct feedback control, despite maintaining a better DO profile. Using the feedback control strategy, one Simcar aerator was able to be run at the lowest speed almost continuously, whereas in the cascade control model, all the aerators were used to control the DO profile around the basin, resulting in comparatively higher use of the Simcar aerators. Using cascade control, DO carryover into the second DO control zone had been reduced by the upstream PI loop, therefore the downstream Simcar needed to work harder to maintain the necessary DO setpoint.

Modelling the control systems was based on specification data of the aeration equipment. Tuning of the controllers in the model was an approximation due to lack of information on behaviour of the basins response to hydraulic disturbances. Testing of the available turndown of the existing equipment, along with the effect on oxygen profile around the basin and basin velocity is needed in order to set up and tune controllers appropriately. This testing will also determine the need for supplementary mixing capacity if turndown of existing equipment is insufficient.

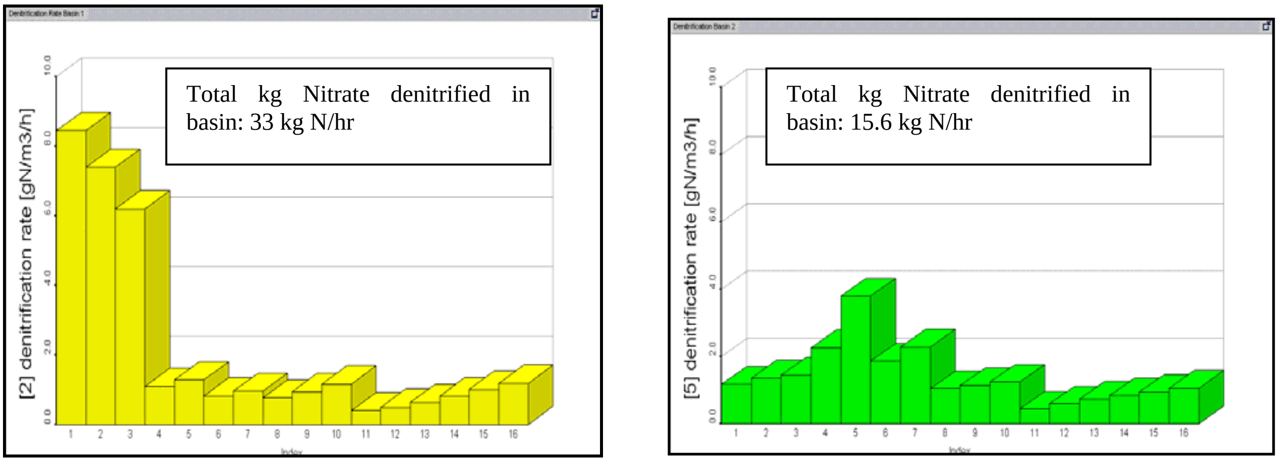
3.4.1 ENHANCED DENITRIFICATION

The Carrousel Basins normally achieve complete nitrification and partial denitrification. Increasing denitrification has these potential advantages:

- Increasing the release of oxygen from nitrate, thus reducing oxygen demand and energy input
- Recovery of alkalinity and reduced sludge bulking
- Lower Total Nitrogen in the final plant effluent

Regardless of the aeration control strategy used, from nitrogen removal and reduced sludge bulking perspectives, it is therefore more desirable to locate part, or all of the influent to an anoxic zone. This would allow both nitrification and denitrification to occur as fully as possible, and reduce the aeration demands for carbonaceous material removal. This would particularly give benefits over the summer months, where maintaining a fully aerobic zone is becoming difficult with existing equipment. The model was used to demonstrate the benefits of relocating the current influent discharge to where the RAS return is located (see Figure 2). The model predicted rate of denitrification increased substantially with a shift in influent location, as shown in Figure 9.The benefits of this strategy include a further reduction in total nitrogen and a further decrease in energy consumption. This configuration could be relatively easily accomplished at the plant.

Figure 8: Model predicted denitrification rates with influent to current location (right) and relocated to the RAS return point, using the cascade control model, under peak loads.



Total kg Nitrate denitrified in basin: 33 kg N/hr

Total kg Nitrate denitrified in basin: 15.6 kg N/hr

4 CONCLUSIONS

The use of surface aerators in a Carrousel Basin has limitations due to the variability in mixing and flow patterns that result from changing the speed of equipment, or turning it on or off. A successful aeration strategy can be developed if it allows definite anoxic and aerobic zones to develop. Basin hydraulics are an important factor in the development of an aeration strategy.

The modelling investigation showed that significant cost and energy savings could be gained by improving the use of existing aeration equipment.

Further investigation is needed to understand the performance of the aerators and basin hydraulics when running equipment at different speeds, as this has not been done to date

The simulation model provided useful insights into the plant behaviour, from a process perspective, and allowed some quantification of the benefits that would arise from implementing an aeration control strategy. Now that the basic model is built and calibrated, it can be used as a tool for future process design work, with a degree of certainty. It was crucial to undertake sufficient influent and within-process sampling to achieve this calibration. The thorough influent characterisation and calibration of hydraulic configuration meant that the time spent on parameter estimation was minimised. Improvements to the model would need to include fluid dynamics modelling to account for the variable velocities and mixing patterns in the basins.

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REFERENCES

Beck, B., Insel, G., Russell, D., Vanrolleghem, P.(2003). Evaluation of nutrient removal performance for an orbal plant using the ASM2d model. Proceedings of the Water Environment Federation Technical conference 2003.

Daigger, G., Jenkins, D., Richard, M. (1997) Manual on the causes and control of activated sludge bulking, foaming, and other solids separation problems. 3rd Edition. 2003. IWA Publishing, London pp 131- 141.

De Pauw, D., Dovermann, H., Gernacy, K. Insel, G., Nopens, Petersen, B., I Sin, G., Vanrolleghm, P., Weijers, S. (2003). ‘A comprehensive calibration procedure for activated sludge models’. Proceedings of the Water Environment Federation Technical conference 2003.

Dexter, R., (2001). Improved effluent at lower operational cost by improving dissolved oxygen control. 64th annual Water Industry Engineers and Operators conference, Bendigo

Gerksic, S., Hvala, N., Vrecko, D., (2006). Improving oxygen concentration in activated sludge process. Water Science Technology, 2006, vol 53, no 4-5, pp 282 – 291.

Gujer, W., Henze, M., Mino, T., van Loosdrecht, M,. (2000). Scientific Report no 9 - Activated Sludge Models: ASM1, ASM2, ASM2d and ASM3. IWA Publishing, London

Hartley, K. (1997) Use of the Oxidation Ditch reactor in BNR plants. Proceedings of the Biological Nutrient Removal Conference, Brisbane, Australia,1997.

Ostarcevic, E., and Thomas, M. (1997) Control of activated sludge bulking in a BNR process. Proceedings of the 17th Annual Australian Water and Wastewater association conference, Melbourne, 1997.