SHIFTING SANDS: THE NITTY-GRIT-TY BEHIND RECENT IMPROVEMENTS AT THE LOWER MOLONGLO WATER QUALITY CONTROL CENTRE

Steven Buck, *Senior Process Engineer,* Icon Water

ABSTRACT

Icon Water had not holistically upgraded the grit capture and transport functions at the Lower Molonglo Water Quality Control Centre (LMWQCC) since 1978. The grit removal system had underperformed. The grit system was imposing an unsustainable burden upon site-based personnel, requiring extremely labour-intensive annual cleaning with and the grit transfer lines blocked frequently, particularly in wet weather. Grit carryover also occurred frequently during wet weather that significantly disrupted downstream solids handling processes, particularly dewatering centrifuges and multiple hearth furnaces.

Modernising the existing grit removal system has significantly improved its operability, particularly during wet weather. The amount of manual labour required to clean each tank has more than halved, as has the amount of grit removed from each tank during cleaning. This project has been a prudent investment that has improved the resilience of Canberra's primary wastewater treatment plant.

This paper outlines concept development and design, construction, commissioning, and early-life operational experience of the recently refurbished system. Of particular interest is the role played by computational fluid dynamics (CFD) in the design phase, novel construction approaches, and how contemporary online instrumentation and revised process control logic allows system performance to be accurately monitored and optimised.

1.0 INTRODUCTION

Icon Water built the Lower Molonglo Water Quality Control Centre (LMWQCC) in 1978. LMWQCC is Canberra's principal wastewater treatment plant. The plant removes gross solids using 3 mm (nominal) screens and a dedicated grit removal system. Primary sedimentation, biological treatment (using a Modified Ludzack-Ettinger process), dual media filtration, disinfection and dechlorination follow before treated wastewater is discharged into the Molonglo River. All solids are dewatered in decanting centrifuges and then incinerated in multiple-health furnaces.

Grit and large organics deposit in one of two baffled tanks, each with three separate grit collection hoppers. This grit is fluidised with a mixture of water and compressed air, then pumped periodically to a dewatering classifier and fed directly to a specific location in a multiple hearth furnace. Each tank contains a series of baffles and aeration diffusers to assist with grit collection and to permit self-cleansing of the grit tank.

The success of these styles of grit tanks and pumping systems relies on:

- a "tumbling" flow path within the tanks, made possible through precise control of airflows and careful selection of coarse bubble aeration diffusers
- excellent fluidisation ("spreading") of the grit to allow it to be pumped out of the tank
- maintaining sufficient velocity in the grit pumping lines to prevent solids deposition
- proper flushing of the grit lines after each pump run

Icon Water had retained its original grit capture and transport systems at LMWQCC until this year. These processes underperformed, resulting in:

- The need to remove between 80-110 tonnes of grit from each tank as part of routine annual tank cleaning and inspections. Each grit tank is a confined space, and grit removal would take five (5) maintenance staff five (5) working days to complete
- Regular blockages within the grit transport lines, particularly during wet weather and upon system changeovers
- Reactive maintenance costs that increased at an increasing rate (particularly between 2014 and 2018) as the original galvanised steel components corroded and failed
- Excessive grit carryover during wet weather into the primary clarifiers, creating difficulties when operating dewatering centrifuges (centrifuges becoming unbalanced) and multiple hearth furnaces (through blocking ash transport routes and increased fuel use)

Key elements of the grit system such as fluidisation and diffuser pipework and supports for the tanks baffles had also become dilapidated after nearly 45 years of continuous service, with multiple air and water leaks. Icon Water had implemented some operational and system changes in the intervening years (such as installing fine bubble diffusers in the grit tanks); however, these changes were poorly documented and often did not consider the entire system's functionality.

2.0 DISCUSSION

Icon Water undertook a project for a holistic refurbishment of the grit capture and transport systems at LMWQCC in 2022/23. The concept and design phases occurred between 2018 and 2020, with construction initially scheduled to begin in 2023. However, an extended period of wet weather emphasised the business impacts of poorly performing grit capture and transfer systems on LMWQCC. After a reprioritisation, Icon Water completed its grit systems upgrade at LMWQCC in early 2023.

The design team worked closely with engineering, operational and maintenance teams to accurately define and describe the issues with the system and determine the root causes of underperformance. They also applied learnings from upgrades completed at Melbourne Water's Eastern Treatment Plant. Eastern Treatment Plant and LMWQCC have very similar grit tank designs.

The project scope of works included:

- modifying the tank aeration piping system to incorporate online air flow measurement
- replacing the entire hopper water fluidisation system and increasing its capacity, providing more precise control of water flows, and improving fluidising water delivery into the hoppers
- incorporating online solid volume measurement instruments into the grit transfer piping system
- trialling a floor treatment for one cell to reduce grit accumulation on the floor
- replacing of the grit tank diffusers, and the associated droppers, headers and supports in each of the six (6) grit tank cells
- replacing the existing timber baffles inside each grit tank cell
- improving line flushing within the grit pumping systems (the existing "flushing water" flow was insufficient for flushing the grit lines and made problems worse)

The project scope excluded replacing the original grit pumps, isolating pinch valves and grit dewatering cyclones and classifiers. A study by Icon Water's Engineering Services team concluded that there was sufficient grit pumping capacity to support projected loads to 2060, and that grit line velocities was appropriate to prevent solid deposition.

Icon Water utilised contemporary approaches in the delivery of this project, which are detailed below.

2.1 Use of computational fluid dynamics (CFD) from the concept design stage

The solid and fluid flows within the grit tanks are difficult to verify, especially as grit is typically pumped to dewatering grit classifiers before being fed directly to the multiple hearth furnaces at LMWQCC. It can also be diverted to collection bins for disposal via landfill, although this is more costly for Icon Water to dispose of.

The concept design relied heavily on CFD to optimise the location and shape of the tank baffles, the diffusers' design and placement, and the required airflow rates. The analysis confirmed that each cell in a grit tank captures different quantities of material, with the most material collected in the innermost cells (Cell 3 of Grit Tank 1 and Cell 4 of Grit Tank 2, see Figure 1 for more information).

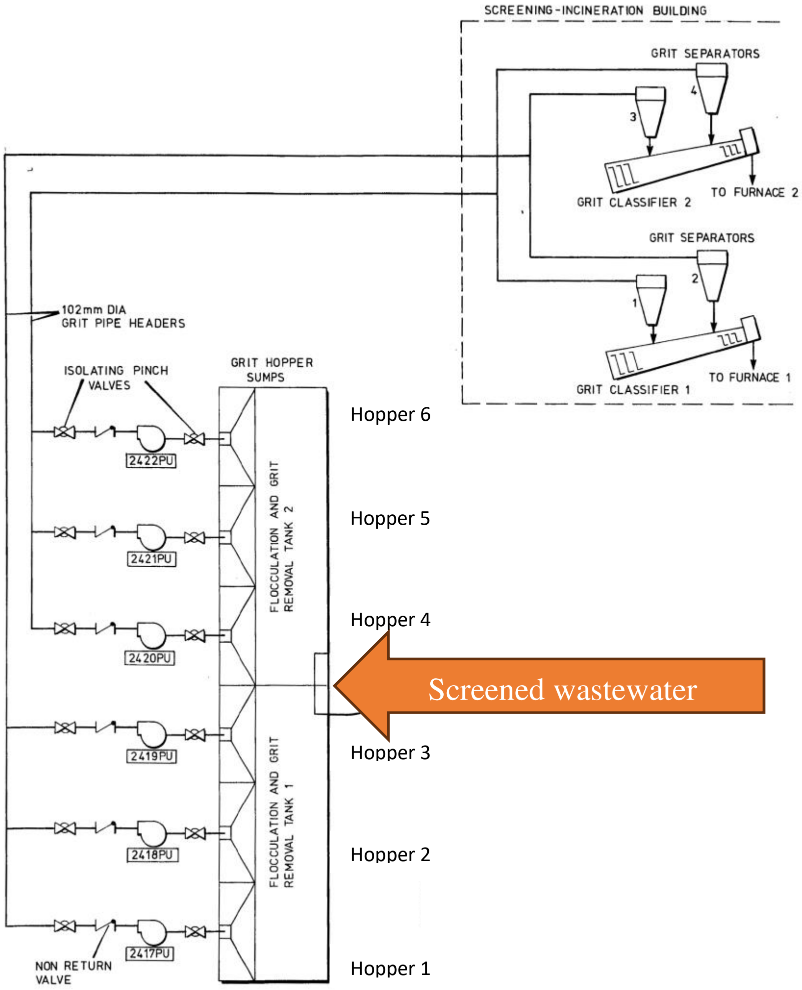

Table 1: *Schematic of the LMWQCC grit tanks and pumping system*

This discovery prompted the upgrade project to reverse the existing grit pumping sequence for Grit Tank 1, such that Pump 3 would run first, followed by Pump 2, and finishing with Pump 1. This change has "automated" and improved the grit transfer line flushing, allowing operations teams to isolate the existing "flushing water systems".

The results from the CFD modelling broadly defined the final design of the tank baffles and diffuser arrays and the airflow requirements within the Grit Tanks. Using CFD also:

- significantly shortened the data gathering needed for the design phase
- allowed simulation and optimisation of the design under wet weather conditions
- provide baseline settings that were used (and not changed very much) during the process commissioning and optimisation stages

2.2 Minimal scaffold construction

The construction phase of this project occurred during an extended period of wet weather. Minimising downtime and potential process interruptions was essential to the success of this project.

To access the upper areas of the tank, the constructors used a custom-built access platform lowered from above the tank. On multiple occasions, work within the Grit Tanks had to stop during wet weather. Unlike traditional scaffolding, this platform was readily removable from the tanks and quickly reinstalled afterwards.

2.3 Contemporary online solids measurement instrumentation

The project installed online microwave total solids meters on each grit pumping line to continuously monitor the volume of solid material removed from each grit hopper.

These instruments allow operational teams to spot grit removal problems in their infancy (rather than finding 80-110 tonnes of material inside the tank during an annual inspection). They were also invaluable during the project's commissioning and initial optimisation phases, as the design and operations teams could observe the grit removal and transport processes in real-time.

Icon Water chose this instrument to minimise maintenance requirements (less cleaning when compared to insertion-type devices). Microwave-based suspended solids meters have proven reliable and successful in other applications across the business.

2.4 Benefits realisation

Table 1 describes the benefits sought and realised from this project, including direct and indirect cost and labour savings associated with the refurbished grit capture and transport systems at LMWQCC.

2.5 Future optimisation opportunities

After nearly twelve months of operation, Icon Water has identified the following opportunities to enhance grit capture and transport system operations further:

- tweaking airflows within each cell of the Grit Tanks to best balance grit deposition across the tanks
- fine-tuning pumping intervals and run times to balance grit line flushing with electricity costs
- using only water to fluidise the grit before pumping and decommissioning the mostly original compressed air fluidisation system
- consider permanently operating both Grit Tanks together, which would halve the grit deposition rate in each tank. Icon Water traditionally operated only one Grit Tank at a time, except during wet weather. The reduced cleaning effort now makes full-time dual-tank operation with annual inspections feasible
- model the impact of removing the final outlet flow control gate from each Grit Tank to determine whether there is likely to be any improvement in system performance

3.0 CONCLUSION

Long-overdue upgrades to the grit capture and transport systems at LMWQCC highlighted that Icon Water had normalised their underperformance. This project alone has more halved the manual labour required to maintain the system whilst dramatically improving the reliability of both the grit pumping and downstream solids handling systems.

4.0 ACKNOWLEDGEMENTS

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Table 1: ***Summary of benefits realised after upgrading the grit capture and transport systems at LMWQCC***

Benefit category	Benefit description	Benefit realised
Reduced planned and reactive maintenance costs directly attributable to the grit tanks and grit pumping system	The total number of labour hours to complete a grit tank clean has reduced by 60% (from approximately 175 hr to 70 hr).	Labour savings (non-bankable) equivalent to $9500 per grit tank clean. There have been two (2) grit tanks cleans so far
	The number of hours a vacuum truck is required for a grit tank clean has reduced by 60% (from approximately 35 hr to 14 hr)	Cost savings (bankable) of $6300 per grit tank clean. There have been two (2) grit tank cleans so far
	The quantity of grit removed from each tank has decreased by at least two thirds (-67%), from between 90-110 tonnes per tank to 30 tonnes per tank.	Cost savings (bankable) of between $14,400 and $19,200 per tank clean. There have been two (2) grit tank cleans so far
	Improved grit fluidisation results in less grit remaining within each hopper that needs to be removed manually	Captured in savings associated reduced cleaning effort
Improved worker safety when cleaning the Grit Tanks	The reduction in labour hours to clean and inspect the grit tanks has reduced the number of confined space entries and worker fatigue	Multiple studies have found fatigued workers are more likely to be injured at work than non-fatigued workers (Swaen *et.al.* 2003) and have poorer long-term health outcomes (Barton 2021).
	Reduction in hazards associated clean the grit tanks because of reduced grit deposition (smaller grit heights, less chance of becoming “bogged” in grit)	Reduced likelihood of workplace sprain and strain injuries. Deloitte Access Economics (2022) estimated that between 2008 and 2018, each workplace-related injury incurred approximately $80,000 in employer overheads
	New stainless-steel pipework is inherently more corrosion resistant the galvanised steel versions installed	Not yet realised or determined as pipework is too new
	Aeration diffuser assemblies are now a lift-out design, meaning any future repairs can be performed above ground and not in a confined space	Not yet realised as no repairs have been required to the diffuser assemblies
Improved reliability and reduced operating costs elsewhere in the plant	Grit is often diverted to landfill to extend a furnace campaign (particularly towards the end) or during a furnace interruption. Grit diversion has not happened during routine furnace operation since the grit tanks have been refurbished	Since completing the grit system upgrades, the amount of grit being disposal being disposed of at landfill has reduced by an order of magnitude.
	Reduced airflows required in the Grit Tanks	Not able to be easily quantified as there was no direct airflow measurement before the upgrade. Control valves are now more closed to achieve the required airflows than previously.
	Design was based on standard, readily available, off-the-shelf coarse bubble diffusers	Design airflow characteristics are readily maintainable, even if some diffusers need replacement
	Renewal and enlargement of the fluidisation water has improved the homogeneity of the grit being removed and fed to multiple hearth furnaces.	Likely reductions in furnace fuel usage but difficult to quantify
	Dramatically reduced grit carryover during wet weather, evident from less variability in primary sludge densities	Difficult to accurately quantify, however increased grit loadings during wet weather events in 2010 and 2012 led to glass production within the furnace (blocking the pathways for ash removal), unstable centrifuge operation (unbalanced due to heavy grit loads in the primary sludge) and a qualified increase in fuel consumption to maintain furnace temperatures (due to the primary sludge containing a greater proportion of inert, rather than combustible, solids) Operators have reported much less difficulties with both the grit and solids handling systems during wet weather post-grit system refurbishments
Reduced future maintenance costs	Diffusers do not contain a rubber or elastomeric component that can perish in the alkaline environment inside the Grit Tanks (pH >9)	Not yet realised or determined as diffusers are too new. Benefits not expected to materialise until seven (7) to ten (10) years after refurbishment
	All pipework and diffusers are now 316 stainless steel	Not yet realised or determined as pipework is too new. Benefits not expected to materialise until seven (7) to ten (10) years after refurbishment