SAND REMOVAL: PAST INDUSTRY OPERATION IN PRESENT WATER TREATMENT PROCESS

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ABSTRACT

During the 1950's pumice sand was dredged from a section of the Waikato River near Tuakau. This sand was used for commercial purposes, primarily to support the booming residential construction industry in Auckland.

In 2002, the Waikato Water Treatment Plant (WTP) was commissioned with intake infrastructure installed in the Waikato River. The location of the plant's inlet screens was determined based on the depth of the river and distance from the underlying sand banks. However, bathometric data has shown that the sand banks in the river are constantly on the move, and the plant experiences periods of heavy sand loading in the water abstracted by the Waikato WTP. The presence of sand in the abstracted water reduced process efficiency/performance and ultimately the plant's capacity. These periodic events caused damage to equipment and the sand itself was extremely expensive to remove from the installed process units, with the confined space entry required to do so.

To address the sand loading issue, multiple measures have been implemented, most prominent of which is a sand separation system.

This system consists of six LAKOS sand hydrocyclone systems, capable of operating together, at the maximum plant capacity (175,000 m^3/day treated water production). The hydrocyclones produce a raw water supply with a significantly reduced quantity of entrained sand, and graded river sand.

The graded sand separated from the raw water is of excellent quality, and has been used as a construction material during recent upgrades to the WTP. Now, over half a century later, Watercare is currently investigating a number of future beneficial uses for this valuable resource.

This paper outlines the sand removal options considered for Waikato WTP, those implemented (in addition to the sand separation system, this also includes installation of a sand mobilisation pump in the raw water wet well), the lessons learnt and outcomes from this process.

KEYWORDS

Water treatment, river source, sand removal, hydrocyclones

PRESENTER PROFILE

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1 INTRODUCTION

Watercare Services Limited (Watercare) operates the Waikato Water Treatment Plant (WTP) on the Waikato River, and experience sand as a byproduct of the raw water source.

The location of the Waikato WTP raw water intake is on a fast moving corner of the Waikato River, near Tuakau. This location was established based on the river's movement, depth and the distance from the underlying sand banks.

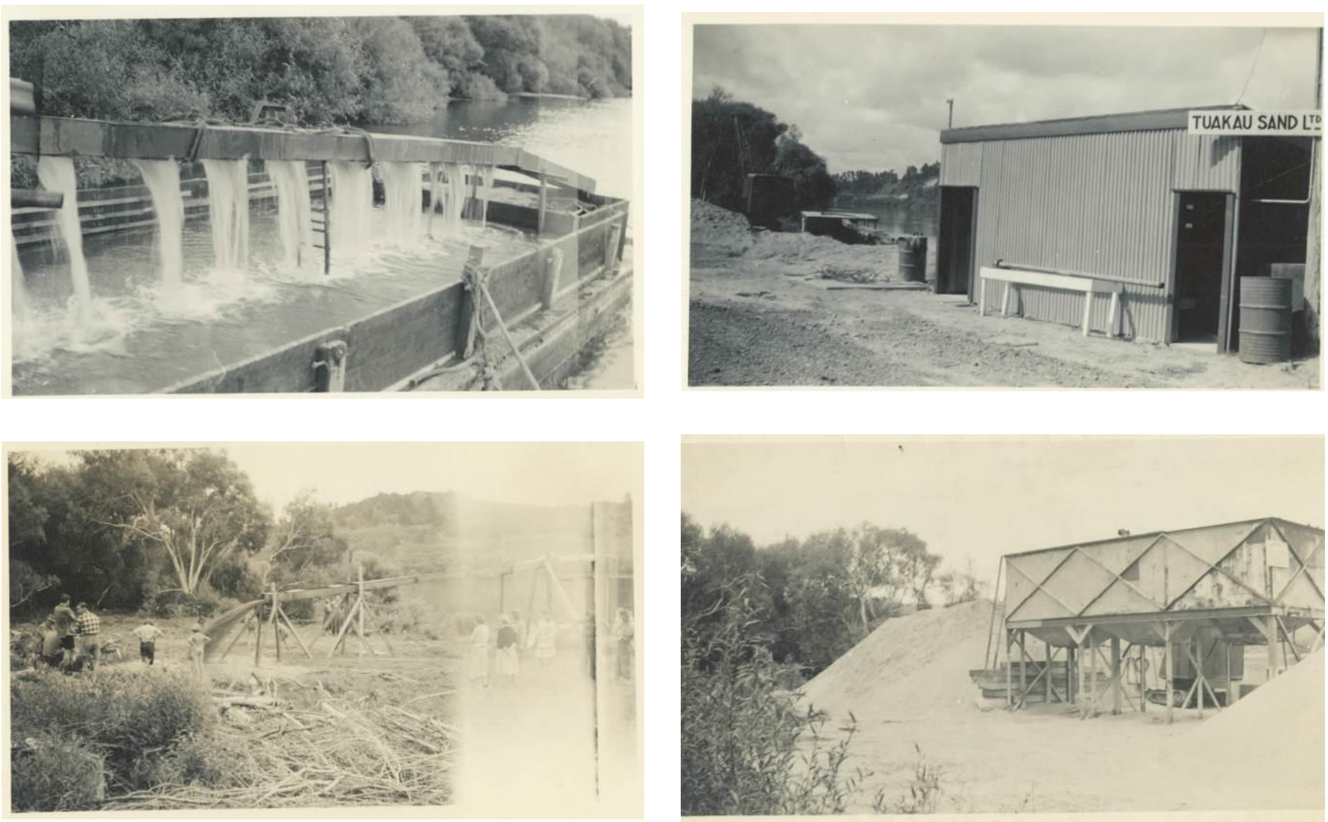
The sand banks in the river are constantly shifting, as indicated by yearly bathometric data. As a consequence, the initial plant processes are inundated with sand for periods of time, constraining treated water production.

Interestingly, sand has been mined from the Waikato River since the 1940s, with up to one million meters cubed extracted per year (recorded in 1974) (Waikato River Authority, 2014). The main purpose of this has been to support the New Zealand construction industry.

In recent years Watercare have been able to separate the sand prior to the treatment process, and in doing so we have been able to reduce operational costs and create an opportunity to utilise the sand for construction and maintenance tasks.

2 HISTORY

Sand has been dredged from a number of locations on the Waikato River close to the Waikato WTP intake, including the Tuakau Sand Limited operation from the late 1950s through the mid-1970s.



Photograph 1: Various images of the historical Tuakau Sand Limited operation

Nearby and more long term was the Puni sand dredging operation, which ran from the 1950s to 2012 (Winestone Aggregates, 2013). The sand source at Puni had been used for concrete production up until 2004, when the quality deteriorated to a point where it was producing a bleeding alkaloid reaction in the concrete.

Photograph 2: Puni sand dredging operation in 1989 (The Fletcher Trust, 2018)

In 2012, the Puni operation was relocated 12 km upstream to Pukekawa, where it continues to dredge sand.

The Pukekawa dredging operation is just 600 m downstream of the Waikato WTP intake. It is our assumption that this nearby activity has disturbed the river bed by the plant intake, increasing the sand bank movement and the sand loading on the plant.

3 BACKGROUND

The Waikato WTP raw water system consists of four intake screens suspended in the Waikato River, hydraulically feeding into the raw water wet well, constructed in the river bank. Five submersible pumps and one vertical pump (recently installed) transfer raw water from the wet well to the plant, approximately 45 m up hill.

The plant process consists of sand separation, coagulation, clarification, membrane filtration, activated carbon filtration / contact, chlorine contact, fluoridation and pH correction.

Sand accumulates in the raw water wet well when the plant is operating at low flows (below 75 MLD), and mobilises as the plant ramps up, transferring in to the sand downstream treatment processes. This caused the following issues, which are detailed further in the subsections below:

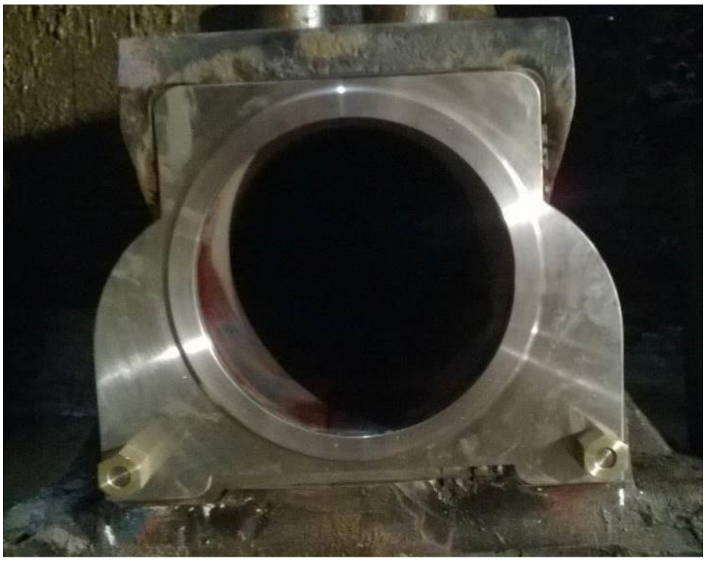
- Sand prematurely wearing the raw water submersible pumps, resulting in loss of flow capability.
- Sand was accumulating in the raw water wet well.
- Sand was accumulating in the clarifier inlet channels and bases.

3.1 PUMP WEAR

The abrasive sand wear on the submersible pumps was observed during routine maintenance inspections, when it was identified that the pump pedestals were abraded (refer to Photograph 3 below). This was reflected by the pump performance, and backflow could be observed in the wet well when the level was low.

This has been addressed by re-facing the pump flange, modifying the duct foot pedestal and installing sacrificial pedestal pump faces on each of the submersible pumps (refer to Photograph 4 below). These are checked every couple of years, and can be replaced by divers as necessary.

Photograph 3: Abraded pedestal face from sand wear



Photograph 4: Pedestal face plate mounted on each pump to counter sand abrasion

3.2 RAW WATER WET WELL SAND ACCUMULATION

The raw water wet well is separated into two hydraulically connected chambers; the inlet chamber and the submersible pump chamber. The chambers are separated by a 3,000 mm baffle wall suspended 500 mm above the bottom. Typically the water level in the raw water wet well sits at approximately 5,000 mm, so the baffle wall is usually fully submerged.

The inflow to the wet well is pulled beneath the baffle wall by the suction of the submersible pumps, and the sand was settling out in the inlet chamber on the way. This was leading to significant sand accumulation in the inlet chamber, which was eventually blocking the gaps beneath the baffle wall and reducing the raw water capacity when the wet well was operating at low levels (i.e. below 3,000 mm). Low levels generally occur during summer / droughts when the river level is low and the WTP flow maximised.

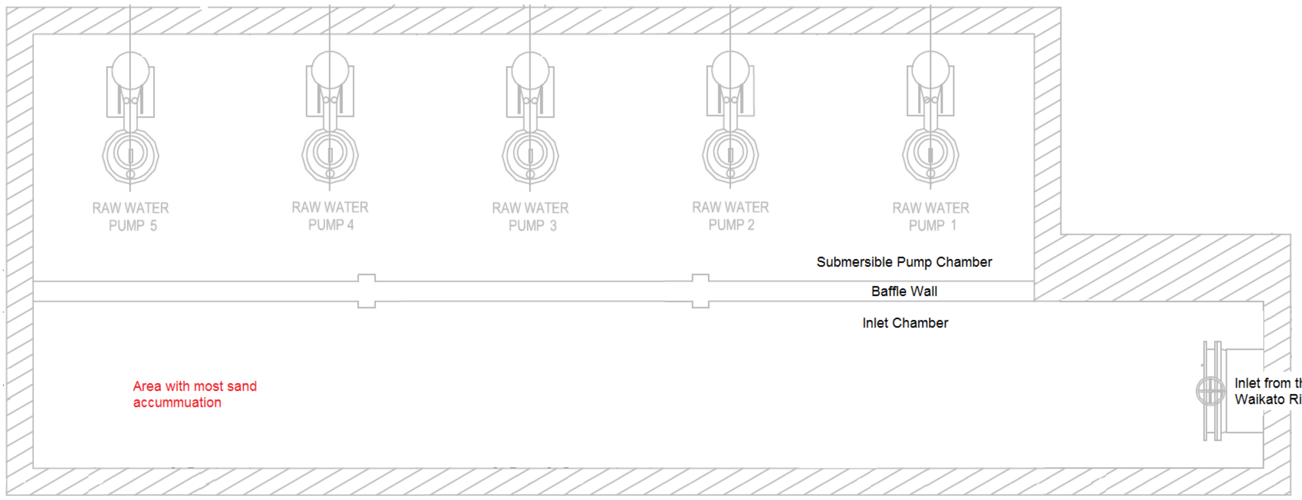


Figure 1: Raw water wet well layout (prior to installation of the vertical turbine pump), with the area with most sand accumulation indicated in red text

To address this, divers were required to relocate or dispose of the accumulated sand, and plant restrictions or shutdowns were required to enable these works.

3.3 CLARIFIER SAND ACCUMULATION

The sand accumulation in the clarifiers greatly impacts their capacity, with the clarifier performance deteriorating as the sand volumes grew and sand blocking distribution lateral inlets (refer to Photograph 5). This resulted in a throughput reduction from 42 MLD per clarifier to 30 MLD per clarifier, and fouling of the downstream membranes.

The sand accumulates in the clarifier distribution channels and beneath / amongst the distribution laterals (refer to Photograph 5 and 6), of the Waikato WTP's superpulsator clarifiers (refer to Figure 2). Removing the sand from these areas required the clarifier to be drained, confined space entry into the depths of the clarifier and vacuum loading trucks to extract the sand and sludge slurry. This was an expensive and time intensive procedure, which was required up to two times per year per clarifier (i.e. up to eight clarifier cleans per year).

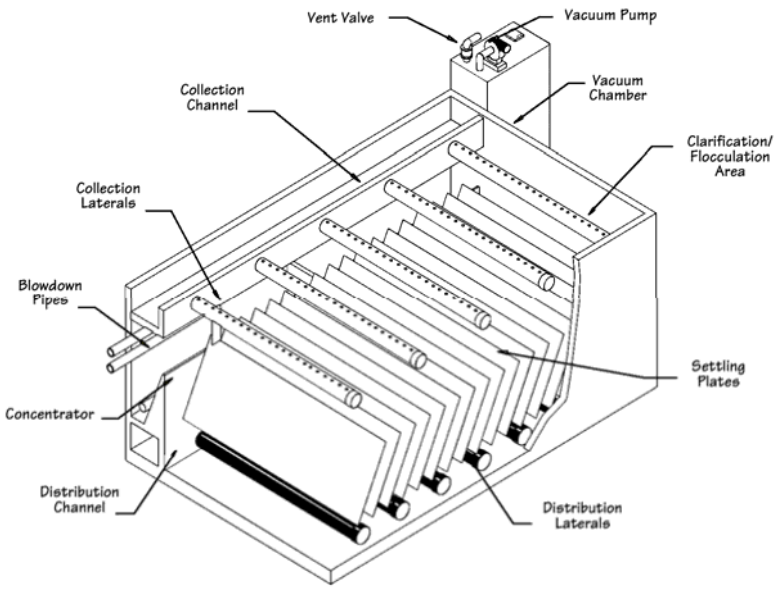


Figure 2: Schematic of superpulsator clarifiers operated at Waikato WTP

Photograph 5: Sand accumulation in the clarifier inlet channel

Photograph 6: Sand accumulation in the clarifier base

4 UPGRADES

Investigations were undertaken to address the sand loading issues, with the primary objectives as follows:

- Removal of sand prior to the main treatment process.
- Mobilisation of sand in the wet well to avoid sand accumulation.

These objectives were addressed separately under different projects, and are detailed further in the subsections below.

4.1 SAND SEPARATION SYSTEM

Three primary sand removal system design options were considered:

- Settlement tank – similar to a horizontal flow clarifier with reduced residence time.
- Vortex separator – open vessel with sand slurry pumped from the base.
- Hydrocyclone units – pressurised vortex separators with sand slurry discharged by the static head on the units.

The consultant (CH2M Beca Limited) and Watercare undertook an options workshop to establish which option should proceed to preliminary design. The hydrocyclone system was selected based on the following:

- Pressurised system, enabling positioning below the hydraulic grade line.
- Minimal site works with no piling required.
- Modular design enabling redundancy and future expansion.
- Lowest disruption to plant operation and services.
- Lowest capital cost.

4.1.1 SELECTED SYSTEM

The hydrocyclone system option was further developed in preliminary and detailed design, and a product supplied by Claude Laval Corporation (LAKOS) was selected. This design stage included procuring and running a trial LAKOS unit onsite. The results of the trial proved consistently high removal efficiencies of over 96.5%.

The final sand separation system consists of the following process:

- Six LAKOS JPX 4200 sand hydrocyclone units to separate sand from raw water (refer to Photograph 7).
- Sand collection trough, running the length of the sand hydrocyclone units to capture purged sand slurry.
- Grit classifier to dewater sand slurry (refer to Photograph 8).
- Sand collection bay to store classified sand.

Photograph 7: LAKOS sand hydrocyclone units and sand collection trough

Photograph 8: San collection trough feeding into the top of the grit classifier

4.1.2 PROCUREMENT

Three main contracts were tendered for these works:

- A supply contract with LAKOS for the sand hydrocyclone units.
- Purchase order agreement with Brickhouse Technologies Limited for the grit classifier.
- An installation and construction contract with Brian Perry Civil Limited for the site works and installation.

4.1.3 LAKOS THEORY AND CONTROL

The LAKOS sand hydrocyclone units use the centrifugal action of the incoming raw water to form a vortex, with this centrifugal action separating the sand / grit from the flow. Sand is then discharged as a slurry through a motorized pinch valve (referred to as purge valve) using the static pressure on the unit. The units are pressurised, and are positioned below the hydraulic grade line.

The units have a nominal flow turndown of 2:1, and units are taken on and off line based on the raw water flow. The vortex formation and sand removal efficiency is flow based, so the flow dependent control enables the units to operate within their performance flow band.

4.1.4 COMMISSIONING AND OPERATION

The sand separation system was commissioned and brought into service in February 2017. Since then we have improving operational efficiency, and made some system modifications.

Details of these matters are included in the following subsections.

Sand Accumulation

Sand accumulation occurs at times within the sand collection trough. When operating at plant flows over 75 MLD, the sand is mobilised in the raw water wet well and pumped up the raw water main.

The sand collection trough gradient to the grit classifier inlet was constrained to 2%, which has impacted the effectiveness of the discharge.

Initially the purge valves were equipped with diffusers on the discharge. The vertical discharge through the outlet diffusers was not creating sufficient velocity to fluidise the sand and carry the sand slurry the length of the trough. This resulted in significant sand accumulation in the sand collection trough (refer to Photograph 9).

The diffuser on one unit was removed and a temporary flexible 45º bend installed. The resulting directional velocities encourage flow and reduced sand build-up in the sand collection trough. As a result of the trial, six piped 45º bends were fabricated and installed (refer to Photograph 10).

Photograph 9: Sand accumulation with the diffusers on the purge valve outlets

Photograph 10: Purge operation with 45º bends installed on the purge valve outlets

Sand still accumulates in the sand collection trough when the plant flow increases and mobilises more sand from the raw water wet well. During these periods of time, the purge settings require manual adjustment to ensure they are occurring more frequently and for a longer duration. This ensures all of the sand has time to discharge and flush the length of the sand collection trough.

If insufficient purge duration is allowed, there will be no flush of water following the slurry to encourage the sand the length of the trough. It also can damage the pinch valve actuators, as closing on sand can prevent the valve from reaching its limits, and the units do not have torque limits.

System Headloss and Raw Water Pump Performance

The headloss across the sand hydrocyclone units is greater than what was originally anticipated based on the technical information and specifications.

An increase in headloss across the sand hydrocyclone units is experienced with increased flow and while still running within the design range. This increase in headloss compromises the pumping capabilities of the raw water pump station.

It is assumed that this increase in headloss is due to insufficient back pressure on the units. A minimum back pressure of 30 kPa is required, however, this is not always achieved as is plant flow dependent.

When discharging to near atmospheric conditions (as is usually the case at Waikato WTP), the sand hydrocyclone units can act as a pressure-reducing device. This increases the pressure loss across the unit and can reduce removal efficiency.

It has been recommended by LAKOS to create further back pressure by throttling the sand hydrocyclone unit outlet valves. However, this has the following disadvantages:

- It would further impact the raw water pump station capacity and power consumption.
- The sand hydrocyclone unit outlet valves are the sole point of isolation between the sand separation system and clarifiers. If they are used for throttling purposed, they will wear and compromise isolation of the sand separation system and individual units.

A high flow plant trial was undertaken to verify that the maximum plant capacity of 175 MLD treated water production could be met. This was achievable when operating the raw water pump station with no redundancy.

Figure 3 displays data from the high flow trial, and compares actual headloss to the expected headloss based on LAKOS literature as the plant flow increases. The actual headloss remains consistently higher than the literature envisages.

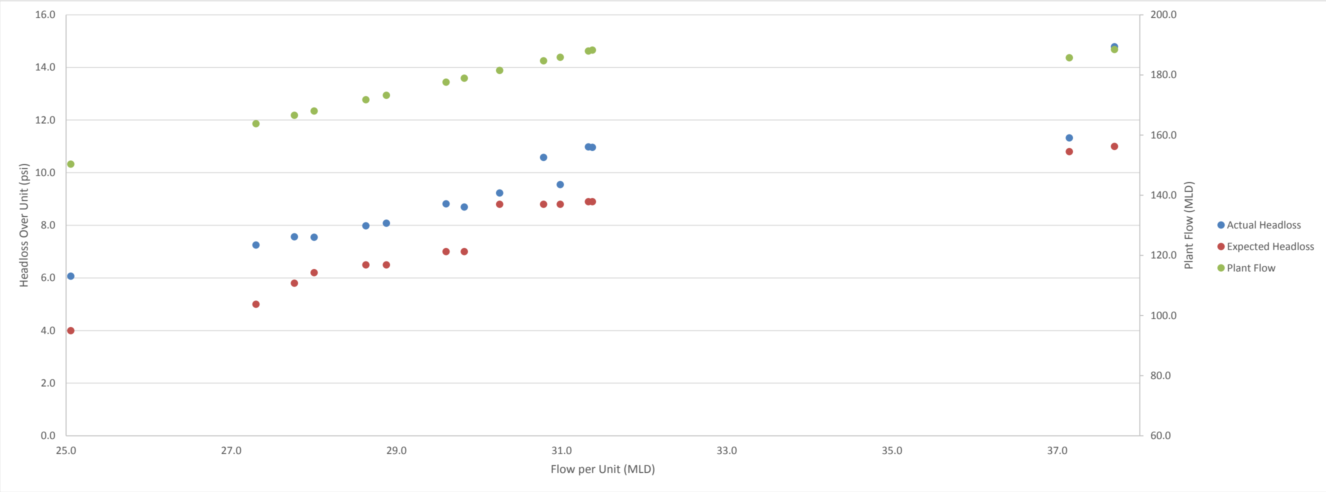


Figure 3: Actual and expected sand hydrocyclone unit headloss during the high plant flow trial

Vibration

Vibration was apparent on start-up of the sand hydrocyclone units at design flows. Some of this could be attributed to the elevated pressure loss across the units, with the units operating as a pressure-reducing device.

Cross bracing structural members were installed on the platform structure (refer to Photograph 11) used to access the sand hydrocyclone units' outlets to address the vibration and provide stability.

Photograph 11: Diagonal cross bracing installed on the sand separation system platform structure

Vibration measurements were taken pre and post cross bracing installation, and the addition has decreased the vibration to an acceptable level.

LAKOS has recommended periodic inspections of the sand hydrocyclone units, outlet valves and discharge pipework to ensure the possible pressure-reducing effect is not damaging the system.

4.2 SAND MOBILISATION

In addition to protecting the submersible pumps by installing the sacrificial pedestal pump faces, sand mobilisation from the raw water wet well to the sand separation system was required.

To increase the raw water capacity and encourage sand mobilisation in the inlet chamber, a vertical turbine pump has been installed in the inlet chamber. This pump is designed to operate as a baseload pump, and is fabricated of materials which are resistant to sand abrasion.

Computational fluid dynamic (CFD) modelling was undertaken by the pump supplier (KSB New Zealand Limited) prior to pump installation. Through this modelling the velocity profile of the raw water well during 180 MLD operation (five out of six raw water pumps running) was developed (refer to Figure 4). The velocity measurements are taken 50 mm from the bottom of the wet well (i.e. a realistic sand level), and velocities over 20 mm/s are assumed to be strong enough to transport sand.

With the installation of the vertical turbine pump the CFD modelling indicates that the region which was previously most problematic for sand accumulation will now have sufficient movement and velocity to mobilise sand.

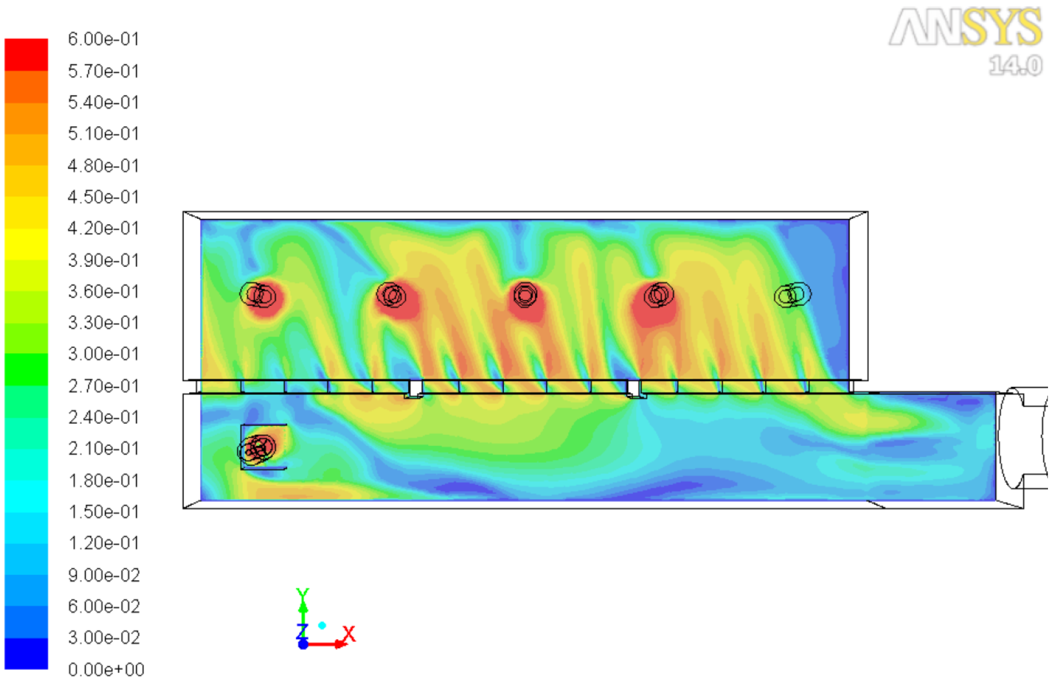


Figure 4: Velocity profile of the raw water wet well at 180 MLD operation with five pumps running, including the baseload vertical turbine pump in the inlet chamber

5 PERFORMANCE

5.1 SAND SEPARATION SYSTEM

Evaluation of the sand separation system performance is complicated by difficulties obtaining representative samples (sand loading is very low), and the plant production variability (the Waikato WTP can be operated at flows less than 75 MLD for several months at a time).

As a consequence, the performance of the sand separation system has been based largely on inspection of the clarifiers.

Historically the clarifiers were periodically removed from service for sand removal. The first clarifier to be cleaned post-commissioning of the sand separation was clarifier 1. Following 16 months of operation with the sand separation system upstream of it, clarifier 1 was inspected. The presence of sand in the clarifier was negligible, and the performance requirement of 95% removal has definitely been achieved on a visual basis.

Given that one of the prime objectives of the project was removal of sand prior to the main treatment process, the sand separation system has been very successful.

Photograph 12: Sand collection bay

5.2 SAND MOBILISATION

The vertical turbine pump was brought into service in December 2017, and has been operating as the baseload pump since.

No raw water wet well entries or inspections have been completed since its commissioning.

6 CONCLUSIONS

The sand separation system is effectively removing the sand loading from the raw water prior to the treatment process, ensuring extended process performance and significant maintenance savings.

The sand is being mobilised from the raw water wet well to the sand separation system, ensuring the extended reliability of the submersible pumps' performance and reduced maintenance.

Since February 2017, classified sand from the sand separation system has been utilised for construction activities onsite and sand bags for the Watercare wastewater transmission team. The quality of the sand extracted ensures they will be future applications and no disposal cost for Watercare.

Reuse of this byproduct from the treatment process provides a resource for construction and operation activities, reduces truck movements and eliminates disposal costs.

ACKNOWLEDGEMENTS

Priyan Perera, Mason Dale, Waikato WTP Operational Team

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