PROCESS OPTIMISATION OF AN UPFLOW SLUDGE BLANKET CLARIFIER THROUGH THE INSTALLATION OF TUBE SETTLERS

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ABSTRACT

Flocculation and clarification at the Airey's Inlet Water Treatment Plant is achieved via an upflow sludge blanket clarifier. Raw water characteristics and the mode of plant operation made it difficult to achieve acceptable sediment removal through the clarifier. High solids loadings on downstream filters resulted.

In October 2001 tube settlers were installed to optimise clarifier performance. The result was a significant improvement in clarifier performance and, in turn, treated water quality. Theoretical calculations of tube settler performance correlate well to the actual performance of the clarifier.

KEY WORDS

Upflow sludge blanket clarifier, tube settlers, process optimisation.

1.0 INTRODUCTION

The Aireys Inlet Water Treatment Plant (AIWTP) is a 2 ML/day plant, commissioned in 1991 and consisting of:-

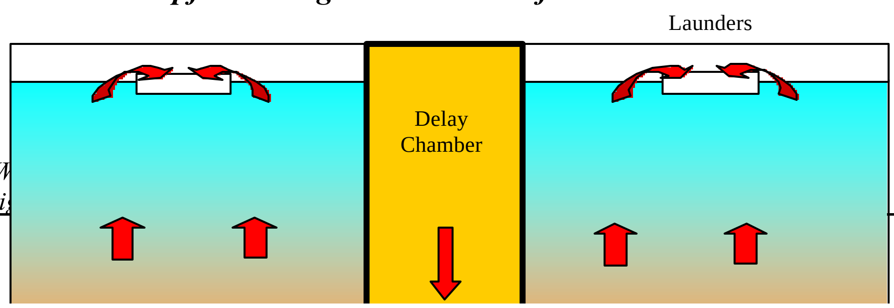
- Pre-oxidation (Sodium Hypochlorite addition);
- Flocculation and Clarification (Upflow sludge blanket clarifier using Aluminium Sulphate as a coagulant, polymer as a flocculation aid and Soda Ash for pH correction);
- Filtration (Closed gravity sand filters);
- Disinfection (Sodium Hypochlorite addition) and pH Correction (Soda Ash addition); and
- Clear Water Storage (2.4ML covered basin).

Raw water is sourced from the Painkalac Creek, which is high in colour, organic content and turbidity. Typically the raw water has a colour between 300-500 Pt/Co, UV 254 Absorbance between 0.6 and 0.9 units/cm and Turbidity between 14 and 35 NTU.

The key process element of the Airey's Inlet treatment train is the upflow sludge blanket clarifier. Sludge blanket clarifiers incorporate both flocculation and sedimentation in one unit. Chemically dosed water enters a central delay/distribution chamber where mixing and initial floc formation occurs. Flow is then distributed across the bottom of the clarifier through distribution arms. Launders collect clarified water at the top of the clarifier.

Turbulence produced by the water inflow promotes flocculation in the lower zone of the clarifier. As solids accumulate a suspended sludge layer (blanket) forms. Clarification is achieved through agglomeration within the blanket and by maintaining an upflow velocity less than the settling velocity of the floc particles.

Figure 1: ***Upflow Sludge Blanket Clarifier***



Distribution
Arms

The performance of the Airey's Inlet upflow sludge blanket clarifier was compromised by:-

- Intermittent operation of the plant. During winter months plant operations are reduced to two twelve-hour runs a week. Sludge blanket units perform best under continuous and constant flow conditions;
- Hydraulic shock loading of the clarifier on plant start-up, due to the on/off operation of the inflow pumps;
- Uneven inflow distribution and temperature gradients within the clarifier; and
- The light nature of floc produced from the raw water.

The result was floc carry over from the clarifier, placing high loads on the filters and in turn affecting treated water quality.

A number of process optimisation options were investigated, including AC Clarification, lower capacity inlet pumps, variable speed drives and actuated valves on the inlet pumps and installation of tube settlers. Tube settlers were selected as the preferred option and installed in October 2001.

2.0 DISCUSSION

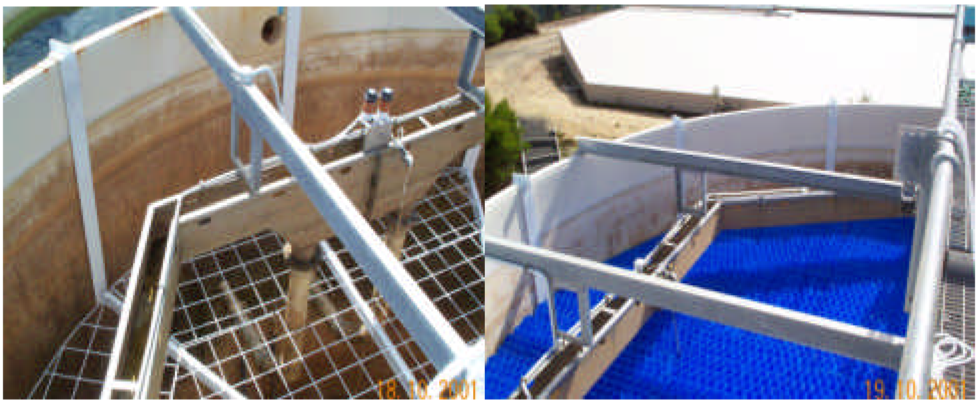
The amount of sediment removed by a clarifier is controlled by the overflow rate (flow rate/surface area). Tube settlers are used as a means of increasing the surface area of a clarifier and, in turn, improving sediment removal.

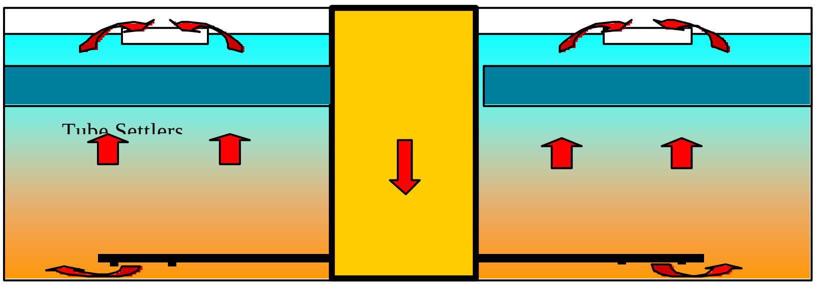
Tube settlers are a lightweight structure composed of closely spaced tubes on an incline (usually between 40 and 60 degrees). Clarifier upflow is passed through these tubes. Settling within these tubes and contact clarification of fine floc results in a build-up of particles on the tube surfaces. Particles combine to form agglomerates which become heavy enough to slough against the upward flow and slide down the tube slope to join the sludge blanket below.

2.1 The Installation

Tube settlers for the Airey's Inlet clarifier were sourced from Aquagenics Pty Ltd. They are supplied in module form - each being 1 meter wide by 1 meter long by 0.67 meters high. The modules are arranged on a supporting framework to form a layer within the clarifier. Figures 2 and 3 show the supporting framework, module installation and settler positioning at Airey's Inlet.

Figures 2 and 3: ***Supporting Framework/Module Installation and Settler Positioning***





The supporting framework was designed by Barwon Water and fabricated and installed by a local engineering company. The framework is held up by a number of 'hooks' over the top rim of the clarifier tank. This was done to minimise the installation time. The entire installation was completed in three days. The clear water storage was filled to capacity prior to installation of the tube settlers to allow for the three days the plant was off line. If required the plant could have been brought back on line on the first day once the framework was installed.

The tube settlers are suspended at a height 700mm below the top water level.

2.2 Operational Outcomes

A significant improvement in plant performance has been achieved through the installation of tube settlers. Graph 1 and table 1, compare typical plant runs pre and post tube settler installation. In addition to improving solids removal under stable operating conditions the tube settlers have eliminated the sludge blanket carry over that was previously evident for the first three and a half hours of plant run.

In conjunction with the increase in surface area brought about by the tube settlers a number of other factors contribute to the improved performance. These include:-

- A distributing pressure loss created by the tube settlers improves flow distribution and so improves clarifier area utilisation;
- A concentration of sludge particles occurs below the tube settlers and acts as a secondary sludge blanket; and
- The tube settler layer reduces sunlight penetration into the clarifier and therefore reduces the temperature gradient across the clarifier height.

Graph 1: ***Clarified Water Turbidity Comparison***

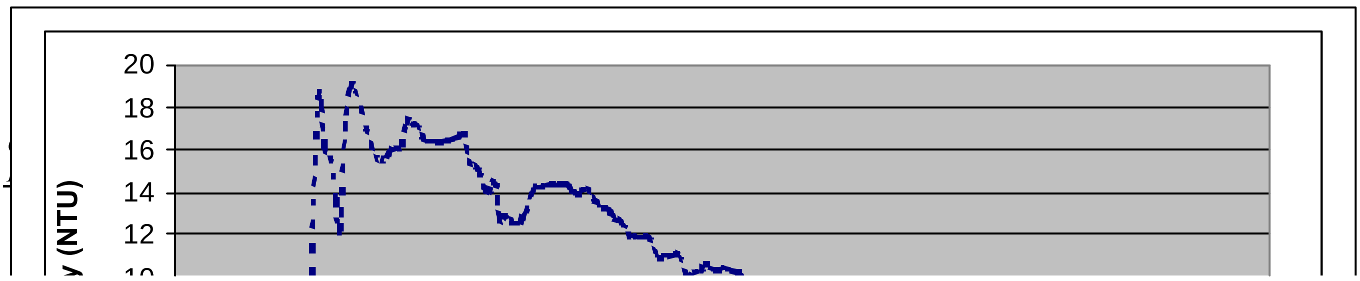


Table 1: ***Clarified Water Turbidity Comparison***

	Clarified Water Turbidity (NTU)	
	Pre Tube Settlers	Tube Settlers
Average	8.5	3.22
Maximum	18.98	6
Minimum*	2.3	1.48
After Blanket Settles	5	3.8

*excluding first 10 minutes.

Increasing the surface area means that plant flow rates can be increased whilst still maintaining an acceptable overflow rate. Previously, operating the plant above 25L/s resulted in significant carry over. With the tube settlers installed good clarifier performance has been achieved at flow rates as high as 33L/s.

This means that in addition to water quality improvements the tube settlers have provided a capacity upgrade. The ability to run the plant at higher flows has reduced the plant run time required which translates to operational savings. The operation savings generated will see the project pay for itself within an eighteen month period.

2.3 Theoretical Evaluation

The theoretical evaluation of the performance of the tube settlers is provided in Figure 4.

Figure 4: ***Theoretical evaluation of the performance of the tube settlers***

The overflow rate (S_o) is the vertical rise rate within the clarifier. S_o can also be termed as the critical velocity as any particles with a slower settling velocity than S_o will carry over. The calculations below show that tube settlers decrease the critical velocity and in turn increase the fraction of particles removed. For the Airey's Inlet case S_o was decreased by a factor of 6.75.

1.2 Overflow Rate (Critical Velocity) Without Tube Settlers (S_o):-

$$S_o = \frac{\text{Flow (Q)}}{\text{Area (A)}} = \mathbf{0.725 \times 10^{-3}\ m/sec}$$

1.3 *Overflow Rate (Critical Velocity) of Tube Settlers (S_o'):-* The overflow rate of the tube settlers is calculated using the following method,

$$\frac{S_o'}{Vo} = \frac{AB}{BD} = \frac{W/\cos\theta}{H/\sin\theta + W/\cos\theta\sin\theta}$$

1.3.1 Multiplying by $\cos\theta$ then $\sin\theta$ gives

$$\frac{S_o'}{V} = \frac{W\sin\theta}{H\cos\theta + W} \text{………Eqn. 1}$$

1.3.2 Also, for a unit depth

$S_o = q/CD = q/((w + t)/\sin\theta)$

$S_o = q\sin\theta/(w + t)$…………………Eqn. 2

Also,

$V = q/W$………………………….Eqn. 3

Substituting Eqn. 3 into Eqn. 1 gives,

$S_o' = q\sin\theta/(H\cos\theta + W)$………….Eqn. 4

Substituting Eqn. 2 into Eqn. 4 gives,

$$S_o' = \frac{S_o (W + t)}{(H\cos\theta + W)}$$

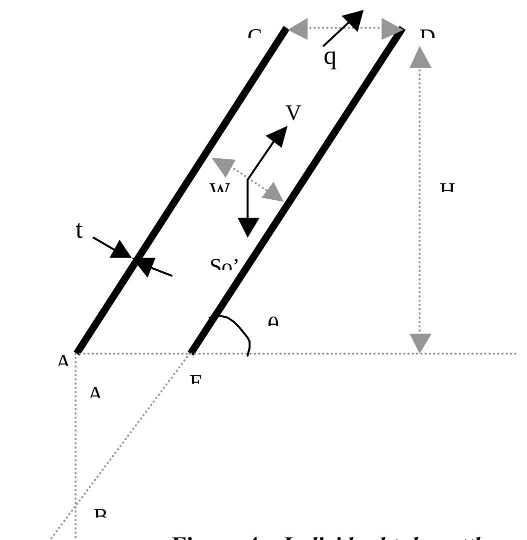


Figure 4:- ***Individual tube settler***

1.3.3 Using the dimensions of the Airey's Tube Settlers

S_o' = S_o/6.75 = **0.1074 x 10^{-3} m/sec (6.75 times lower than without tube settlers)**

Re<2000 and Fr>10^{-5} therefore laminar flow conditions apply.

1.4 Detention Times:-

The detention time within the settlers can be calculated as,

$T = (H/\sin\theta)/V$ = 895 seconds or **15 minutes.**

The detention time required without tube settlers to achieve a similar value to S_o' would be,

$T = H/S_o'$ = 6238 seconds or **104 minutes.**

In other words to achieve an equivalent critical velocity to the tube settlers under normal flow conditions a detention time of 104 minutes would be required. The tube settlers reduce the detention time required by **7 fold**.

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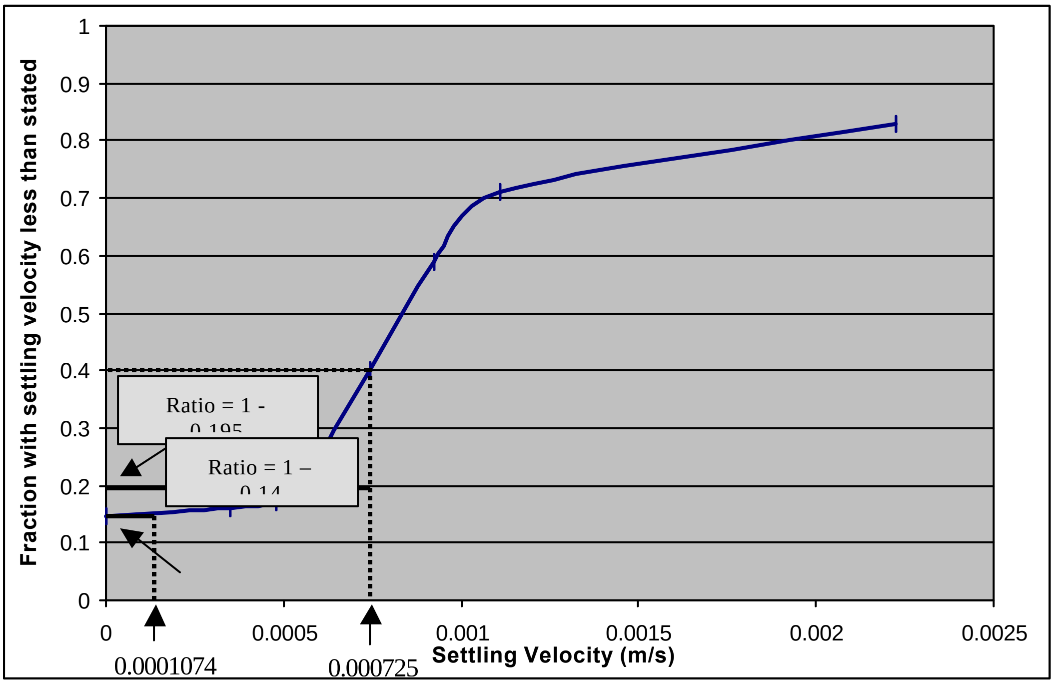
achieve a uniform distribution of particles at the beginning of the experiment. Samples were then collected from ports at pre-determined time intervals, and analysed for turbidity. The output of the experiment is the settling curve for the floc particles shown below.

<u>Graph 2:</u> ***Airey's Inlet Floc Particles Settling Curve***



Removal ratios for given overflow rates (S_o) can be estimated from the curve. Vertical lines have been drawn on the graph at points corresponding to the Airey's S_o values for pre and post tube settler installation. The removal ratio is then estimated by drawing a horizontal line between the 'vertical S_o line' and the y-axis at a point where the area between the line and the settling curve is equal both above and below the line. As marked on graph 2 the removal ratio prior to tube settler installation was 0.805. Installation of the tube settlers increased this ratio to 0.86. The table below uses these removal ratios to obtain an expected clarified water turbidity pre and post tube settler installation.

<u>Table 2:</u> ***Theoretical v's Actual Turbidity Removal***

	Average Raw Water Turbidity (NTU)	Removal Ratio	Theoretical Clarified Turbidity (NTU)	Actual Clarified Turbidity* (NTU)	Correlation b/w Theoretical and Actual
No Tube Settlers	25.5	0.805	4.97	5	0.99
With Tube Settlers	25.5	0.86	3.57	3.8	0.94

* under stable conditions. Sourced from table 1.

The results show a good correlation between theoretical turbidity values and the actual operational results.

It should be noted that the above calculations relate to type I (Discrete) and type II (Flocculant) settling only. That is, the zone above the sludge blanket.

3.0 CONCLUSION

In conclusion, a significant improvement in the performance of the Airey's Inlet upflow sludge blanket clarifier has resulted from the installation of tube settlers. Clarified water turbidity levels under stable operating conditions have dropped from 5NTU to 3.8NTU. The extended period of blanket carry-over after plant start-up has been eliminated bringing the average turbidity over a run down from 8.5NTU to 3.22NTU.

The improved performance is the result of a combination of an increase in clarifier surface area, even distribution of up-flows, formation of a secondary sludge blanket and reduced temperature gradient.

On a theoretical basis the tube settlers were found to reduce the overflow rate by a factor of 6.75. Field experiments showed a good correlation between the theoretical analysis and the actual operating results. Settling curve analysis can be used to provide a good indication of tube settler performance.

In addition to water quality improvements the tube settlers have allowed the plant to be run at a flow rate 8L/s faster than previous. This equates to an operational saving that will see the project pay itself off within 18 months.

4.0 ACKNOWLEDGEMENTS

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5.0 REFERENCES

The following resource was referenced in the development of this paper:-

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