REDUCTION OF HIGH/LOW LEVEL ISSUES IMPACTING UV DISINFECTION SYSTEM - EDMONTON WWTP

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ABSTRACT

As the water industry continues to become more technologically advanced and with greater penalties for license infringements, utility providers typically turn to new technology or consultants for answer to performance related issues. Despite having their place, these “hi-tech” and “expert recommended solutions” are not always necessary and sometimes a “low-tech” solution may be the best fit.

The ultraviolet disinfection system at Cairns Regional Council’s Edmonton Wastewater Treatment Plant experiences a significant number of high and low level events due to the modulating penstocks being unable to react quickly enough to fluctuations in inflow. These occurrences have the potential to reduce the lifespan of the ultraviolet tubes as well as risk license breaches through insufficient treatment.

The Operators, assisted by technical staff from Cairns Regional Council Water & Waste Treatment trialled a hybrid weir located upstream of the ultraviolet disinfection system to address the level issues. Results from this trial showed significant reductions in both high level alarms and low level occurrences. Given the success of the trial Cairns Regional Council is currently moving to install a permanent weir solution based on the prototype.

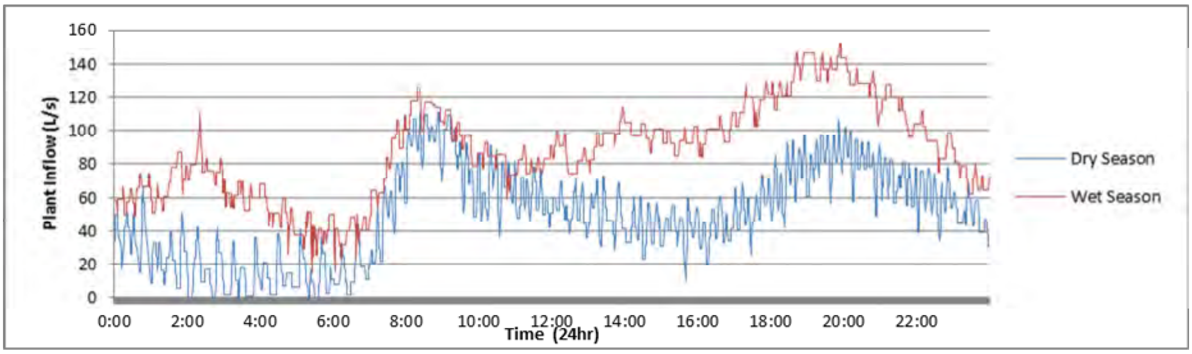
1.0 INTRODUCTION

Cairns Regional Council (CRC) provides water and wastewater utility services to the approx. 170,000 residents in the region. Due to its location, environmental protection, sustainability and optimisation is at the forefront of CRC Water & Waste (W&W)’s focus. Environmental protection is also strongly enforced in the region and wastewater discharge heavily regulated. In 2007/08, 4 of CRC’s 6 wastewater treatment plants (WWTP) underwent major upgrades as part of the extensive Cleaner Sea’s Alliance (CSA) project in order to meet tighter licencing requirements.

Wastewater treatment plants are typically highly refined and require all processes to be working effectively in order to maintain operation within licence. Besides perhaps unexpected breakdowns or malfunctions of equipment, arguably the most disruptive influence on a plant’s operation is fluctuations in inflow. Although steps were taken under the CSA upgrades to account for these fluctuations, due to the relatively unique nature of the Cairns climate these are not always 100% effective.

The Cairns Region is situated within the tropics and therefore has 2 distinct seasons, the Wet Season from typically November to March and the Dry Season from April to November. Average annual rainfall for the city of Cairns is 1960mm, with falls of over 150mm in 24hrs not uncommon. These factors are coupled with periods of almost no flow during the early hours of the morning during the Dry Season in catchments predominantly consisting of new suburbs with low groundwater table levels. Despite the best efforts of Operators, major variations in flow are often not able to be counteracted and are felt right the way through the plant.

The activated sludge plant at Edmonton WWTP, located 13km to the southwest of the Cairns CBD is affected by flow fluctuations. It which features a 6.6ML Oxidation ditch, secondary clarifier, tertiary treatment via ultraviolet disinfection (UV) and phosphorous removal by aluminium sulphate dosing. The plant services a catchment of approximately 30100 EP comprising predominantly residential loading with some emerging light industry. It is fed by a single major pumping station which further exacerbates the flow fluctuation issue. Figure 1 shows the Wet and Dry Season diurnal flow patterns.



<u>Figure 1:</u> ***Diurnal Inflow Edmonton WWTP.***

A number of initiatives have been successfully implemented since the CSA upgrade to reduce the flow fluctuation including modifications to the operation of the feeding pump station network to limit peaking/slack periods at the plant and modifications to the oxidation ditch operating levels to allow for flow buffering. Despite this work, issues associated with fluctuating flows still hinder the operation of the UV system.

The Operators had minimised the problem, however it required the use of service water. The Operators are extremely motivated to improve and optimise their plant and therefore brought the issue to the Treatment team to see if it could be further investigated.

2.0 BACKGROUND

The UV system at the Edmonton WWTP was installed as part of the CSA upgrade to treat effluent discharged from the plant, it comprises 2 open channels with a bank of UV tubes in each. Flow enters these channels by overtopping a 2.5m wide concrete weir in the Lift Pump Station (Lift PS weir), the depth of flow within the UV channels is controlled by modulating penstocks at the tail end of each channel.

Maintaining constant flow depth in the UV channels is critical to ensure effective disinfection of the effluent and the system operates within a very narrow operating range (depth), outside of which high or low level alarms are triggered. In the event a high level is recorded in one of the channels for more than 15 sec. a high level alarm is triggered and the second channel is brought online to assist. Under low level conditions however, a low level alarm is activated and the channel is shut down until flows increase as a self-protection feature of the system aimed at preventing damage to the UV tubes. This does however pose a risk that effluent that has not undergone sufficient disinfection may be discharged to the environment with the potential to cause environmental harm and a breach of licence.

Previous investigations into the issue identified the Lift PS pump as a major contributing factor to the problem, this pump transfers water from the Lift PS (upstream of the Lift PS weir) to the Chlorine Contact Tank where it is chlorinated for use as plant service water. When this pump operates during low or no-flow periods it quickly drops the water level in the Lift PS and causes water to suddenly cease to overtop the Lift PS weir.

The modulating penstocks of the UV channels are unable to actuate quickly enough to react to the stoppage of feed flow and a low level event occurs, similarly the reverse eventuates once flow returns to the channels, a high level event results. The pump was reduced to its minimum allowable speed in order to reduce its flow rate and the penstocks were checked for correct operation. Experiments were also done to dead band settings and level probe heights all without significant improvement in the frequency of high and low level events.

The Operators' solution to minimise the risk of a licence breach and nuisance alarms was to place a ¾" running hose in the duty channel to provide a relatively small, constant base flow. Although this solution worked quite well it was not 100% effective and required the running of the hose 24 hours/day, 7 days/week. This used additional treated service water which in turn resulted in more frequent operation of the Lift PS pump, service water pumps and an increase in the total volume of water needing to be chlorinated.

The recent investigation found that high level alarms occur throughout the year and at all times of the day whereas the risk of low level events in the UV channels is greatest predominantly during the dry season and times of extremely low plant inflow (typically between 3am and 5am).

To remove the issue sufficient storage needed to be provided for the Lift PS pump to avoid it completely stopping flow to the UV system, and the rate of change of flow (both spikes and troughs) reduced. Investigation into possible simple solutions arrived at a flow controlling device, or weir as the most appropriate.

Preliminary calculations indicated that it was theoretically possible to entirely remove the no-flow events but 2 weirs would be required, one at the existing Lift PS weir and another controlling the clarifier outfall. Management support was only obtained for the installation of 1 weir, however. This weir was therefore intended to reduce level related UV system issues as best as possible, but it was not a requirement that it remove 100% of the issues in order to be considered successful.

A contributing factor in the decision to investigate the issue in-house and proceed with trialling a weir (which was perceived as a low-cost option) was the fact that the plant is expected to undergo another upgrade in the foreseeable future. This upgrade will likely feature modifications to assist with flow buffering which may alleviate the issues currently experienced with the UV system.

3.0 PROTOTYPE DESIGN

The following key criteria was agreed amongst the team for design of the prototype weir –

- Must reduce the rate of change of flows to UV channels to that able to be handled by modulating penstocks;
- Is not to result in adverse effects on up or down stream system;
- Function/functionality is to be able to be replicated by a permanent solution;
- Able to be fine-tuned in situ;
- Able to be installed and removed easily during scheduled shutdowns for clarifier cleaning, by personnel standing on grated platform above the existing weir (no confined space entry required) - No drilling into concrete required for fixings;
- Sufficiently durable to withstand flow rates of up to 150L/s and be in place for 1 – 2 months; and
- Low cost, incorporating recycled/surplus materials wherever possible.

In size the weir a number of aspects were assessed included the hydraulic grade line for the plant to understand available freeboard of the various upstream processes, flow rates into the Lift PS; and the Lift PS pump flow rate.

In order to arrive at the final prototype design various weir configurations were modelled using MS Excel. When investigating options for a sole underflow gate style solution the base formula used was that for flow from a sluice gate (Equation 1), with the solution modelled as a broad-crested weir where the flow depth was less than the gate clearance (refer Equation 2).

$$Q_{Gate} = C_d A\sqrt{2gy1}$$

Where;
Q_{Gate} = flow under weir (m^3/s)
C_d = discharge coefficient (value of 0.55 used)
A = area under sluice gate (m^2)
g = acceleration due to gravity ($9.81 m/s^2$)
y1 = Water depth upstream of gate (m)

Equation 1: ***Sluice Gate Equation[2].***

$$Q_{b.c.weir} = C_{wt}\, b\sqrt{2g}\, bH^{\frac{3}{2}}; \quad C_{wt} = 1.125\left(\frac{1+H/P_w}{2+H/P_w}\right)^{\frac{1}{2}}$$

Where;
$Q_{b.c.weir}$ = flow over broad-crested weir (m3/s)
H = free surface level height weir crest (m)
b = weir width (m)
P_w = total upstream flow depth (m)

Equation 2: ***Broad-Crested Weir Equation[2].***

For the modelling of an overtopping weir a v-notch weir was selected due to the more gradual variation in discharge flow rate that would occur when incoming flows varied. Equation 3 was initially used to model this option. Investigation into the available freeboard however found that the total height of the weir should not exceed 200mm above the existing level. A v-notch configuration was not able to be found that would retain an acceptable volume to buffer the operation of the Lift PS pump yet not be over topped during high flows. To model an over topped v-notch weir the equation for a sharp-crested weir (Equation 4) was used in conjunction with Equation 3. Although this is not technically accurate due to the complex viscous effects applicable under this scenario it was considered sufficiently for this particular investigation.

$$Q_{V-notch} = C_{wt}\frac{8}{15}Tan\left(\frac{\theta}{2}\right)\sqrt{2g}\, H^{\frac{5}{2}}$$

Where;
$Q_{V\text{-}notch}$ = flow through v-notch (m^3/s)
C_{wt} = weir coefficient (value of 0.58 used)
H = free surface level height above base of v-notch (m)
ϕ = angle between sides of v-notch (deg)

Equation 3: ***V-notch Weir Equation[2].***

$$Q_{weir} = C_{wt}\frac{2}{3}\sqrt{2g}\, bH^{\frac{3}{2}}; \quad C_{wt} = 0.611 + 0.075\left(\frac{H}{P_w}\right)$$

Where;
Q_{weir} = flow over sharp crested weir (m3/s)
H = free surface level height weir crest (m)
P_w = total flow depth (m)

Equation 4: ***Sharp-Crested Weir Equation[2].***

From the properties exhibited by each of the different types of weirs through theoretical modelling is was decided that a hybrid weir would be adopted containing both an underflow gate as well as v-notches as it represented most beneficial properties in combating both high and low levels. Once theoretical investigation was complete fabrication of the prototype commenced.

The design incorporated an adjustable underflow gate at about the same level as the existing concrete weir; with two v-notch overtop weirs. The operating principle of the prototype was that at average flow rate (15L/s) during low flow periods, the v-notch weirs overtop 90% full with 5L/s passing through the underflow gate. As the Lift PS pump commenced operation the level upstream of the weir would drop and the flow over the weir (to the UV system) would reduce, but at a slower rate due via v-notches and reduced weir cross section. As flow would cease to over top the v-notches it would continue to discharge through the underflow gate, this flow would reduce as the upstream water level dropped until the level was below that of the invert of the gate and flow to the UV system would stop. The reverse likewise occur once flow into the Lift PS increased or the pump stopped.

The underflow gate featured bolts to accurately adjust the gap height and adjust flow rate while the weir was in situ. Despite the weir being sized to accommodate peak flows, the gate itself was also designed to be easily removed whilst in service and the opening sized to allow for minimal backing up of the system under peak flows if the gate was removed. This feature was to ensure the weir would not contribute to the magnitude of any unforeseen events and ensure Operator confidence in leaving the bulk of the structure in place during high flows.

4.0 PROTOTYPE CONSTRUCTION

The prototype was constructed jointly by the Operators and technical staff in the onsite workshop. It was comprised predominantly of recycled or surplus materials such as form ply, disposable timber pallets, Laminex sheeting off-cuts, old chain, rope, reinforcing bar, paint, construction adhesive and an old aluminium road sign. The only items needing to be purchased especially for the prototype were screws for fixing the materials together. Figure 2 shows the finished product which was able to be installed during a scheduled shut down for a clarifier clean, without the need for access into the confined space.

Figure 2: ***Completed Prototype Weir.***

5.0 RESULTS AND DISCUSSION

The prototype weir was installed on the 16th September 2015 and remained in service until 20th November 2015, where it was removed under a scheduled clarifier cleaning shutdown. The installation of the weir resulted in a twofold reduction in the average number of high level alarms per day and a fivefold reduction in the average occurrence per day of low level conditions. Figure 3 below summarises the findings of the prototype trial.

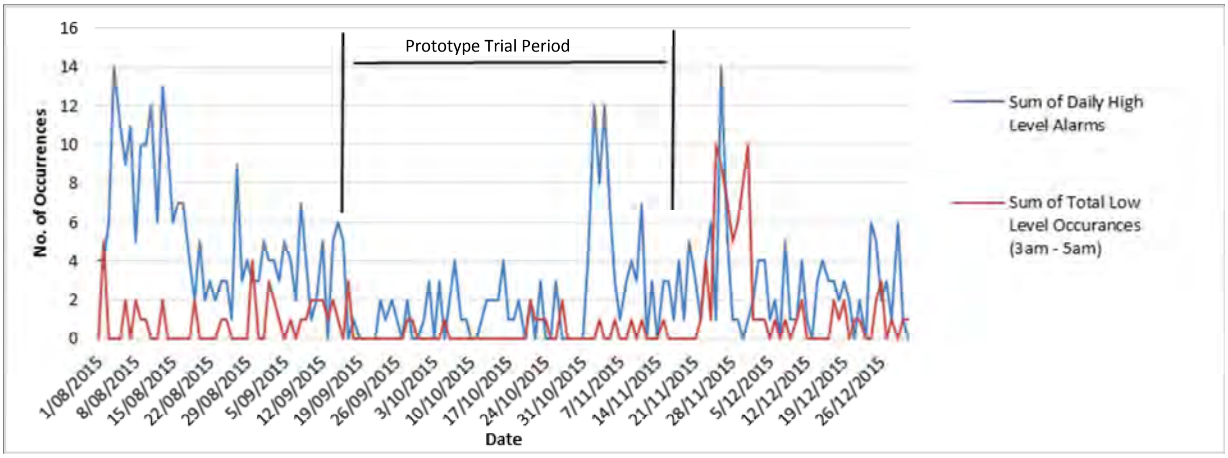


Figure 3: ***Results Graph.***

The results were presented to the Treatment Coordinator and support was received to proceed with the design and installation of a permanent weir solution. The staff involved in the prototype trial are currently progressing the construction of the permanent solution amongst their usual day to day tasks. Figure 4 shows design sketches of the permanent solution, provision has been made for ongoing fine-tuning by the Operators via retaining the adjustable underflow gate concept from the prototype.

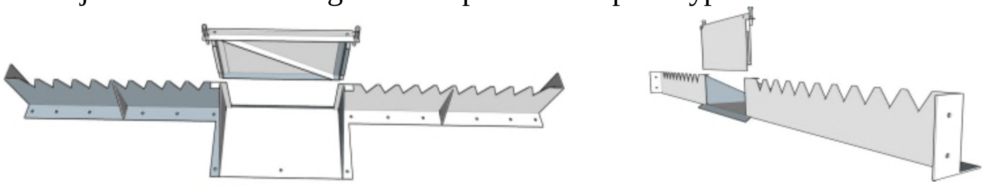


Figure 4: ***Permanent Weir Design.***

6.0 CONCLUSION

The successful installation of the prototype weir at the Edmonton Wastewater Treatment Plant shows that solutions to serious problems can sometimes be solved through utilising internal staff without the need for turning to "hi-tech" or "expert recommended" solutions. The prototype weir was built jointly by Operators and technical staff using predominantly scrap and recycled materials. Despite its relative simplicity, the prototype weir proved its ability to minimise the effect of flow variations on the plant's UV system by reducing the average number of high level alarms per day twofold and the average number of low level occurrence per day fivefold.

Given the success of the trial Cairns Regional Council Water & Waste are moving to install a permanent weir based on the prototype design. While providing some ability for fine tuning flows to the UV system, the permanent solution will represent a small one-off capital expense with virtually zero ongoing operation and maintenance costs. Although in-house engineering support was provided on this project its results are likely to be able to be replicated on other sites by operational stuff using similar methods to solving comparable, flow related issues.

7.0 ACKNOWLEDGEMENTS

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