HAMILTON'S WATER TREATMENT PLANT– A REVIEW OF RECENT PERFORMANCE

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ABSTRACT

The Hamilton Water Treatment Plant upgrade cost $23 million and was constructed over a 20 month period in 2006 and 2007. The existing plant was a conventional plant with coagulation, sedimentation, and sand filtration followed by disinfection. It had a capacity of 85ML/d.

The main drivers for the upgrade were taste and odour issues related to algae, protozoan compliance criteria associated with the then proposed DWSNZ, and a requirement for increased capacity.

The plant draws water from the Waikato River, which has a number of treatment plants (both water and wastewater) upstream of the Hamilton Water Treatment Plant, and has had historic problems with algal blooms related to a number of factors including the river temperature profile, slow moving water, and relatively high nutrients loads in the river.

The upgrade included new higher rate sand filters, new chemical dosing and storage systems, introduction of Granulated Activated Carbon (GAC) filtration and low pressure UV disinfection, and a new plant controls system. The design capacity was 106 ML/d.

There are many water authorities in New Zealand that are moving towards a similar treatment process train and given the length of time the plant has been running it is timely to review the performance of the plant.

KEYWORDS

Water treatment, Upgrade, GAC, BAC, UV, Algae

1 INTRODUCTION

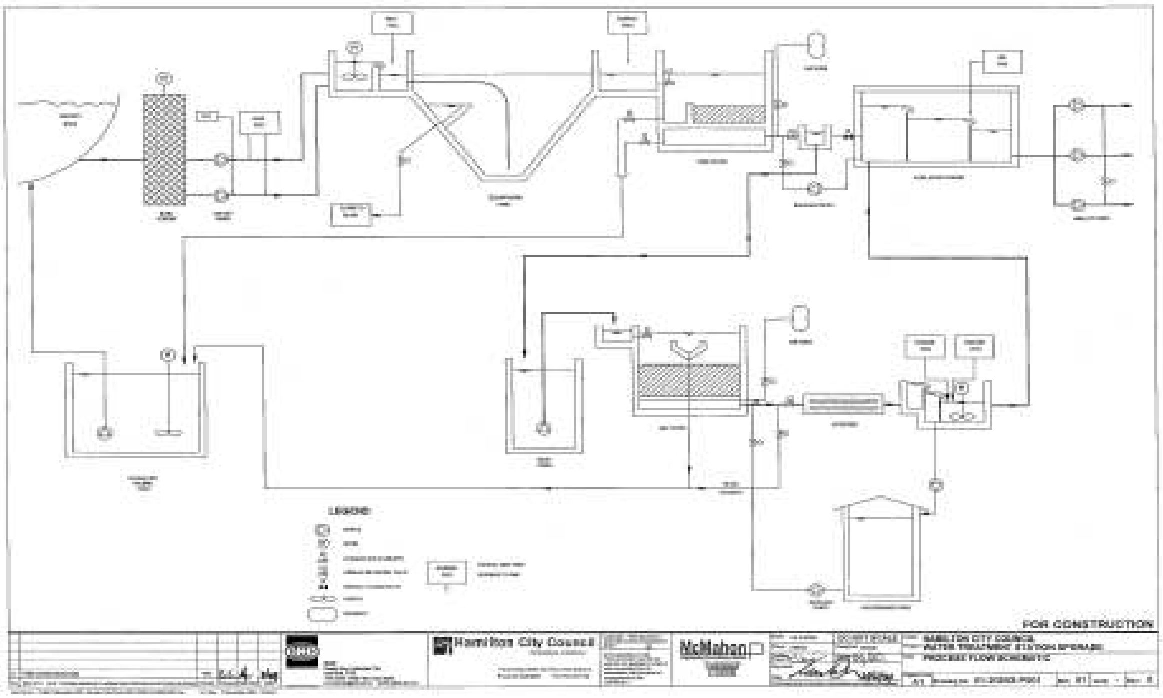
Hamilton is a major service centre and is located within the Waikato region in the upper central North Island of New Zealand. The Hamilton City Council (HCC) Water Treatment plant (WTP) is situated on the southern bank of the Waikato River within the city boundary.

The treatment plant was constructed in 1971 as a standard Patterson Candy (PCI) design with coagulation, rapid sand gravity filtration and chlorine gas disinfection. At the time of construction the plant capacity was 64 ML/day but this was increased to approximately 85ML/day with the addition of polymer dosing in the 1980s.

The WTP upgrade (Upgrade) cost $23 million and was constructed over a 20 month period in 2006 and 2007. The main drivers for the upgrade were taste and odour issues related to algae, protozoan compliance critieria associated with the then proposed Drinking Water Standards New Zealand (DWSNZ), and a requirement for increased capacity.

The plant draws water from the Waikato River, which has a number of other treatment plants (both water and wastewater) upstream of the WTP, and has historic problems with algal blooms related to factors including the river temperature profile, slow moving water, and relatively high nutrients loads in the river.

Figure 1: Treatment Flow-sheet post Upgrade



Studies confirmed that prior to the upgrade, the total WTP capacity was limited by the filtration process. Water demand forecasts based on population projections indicated that Hamilton water consumption would increase substantially over the next 10 year period, eventually exceeding the WTP capacity. To comply with the current and expected future DWSNZ guidelines, in particular stringent protozoa compliance criteria, it was necessary for the HCC filtration process to consistently produce high quality water with a turbidity of less than 0.1 NTU. Historically, the ability of the conventional filters to achieve this benchmark consistently over a variety of source water conditions was uncertain.

The upgrade included new higher rate Porous Ceramic Dual Media (PCDM) sand filters, new chemical dosing and storage systems, introduction of GAC filtration and low pressure UV disinfection, and a new plant controls system. The design throughput is now 106ML/d. Provision was also made for a future pre GAC ozone dosing installation, if required, without the requirement for any extra pumping. At completion it was the largest GAC and UV plant in Australasia. The majority of the upgrade works are shown in Photograph 1 below. Figure 3 illustrates the dual media nature of the PCDM sand filters.

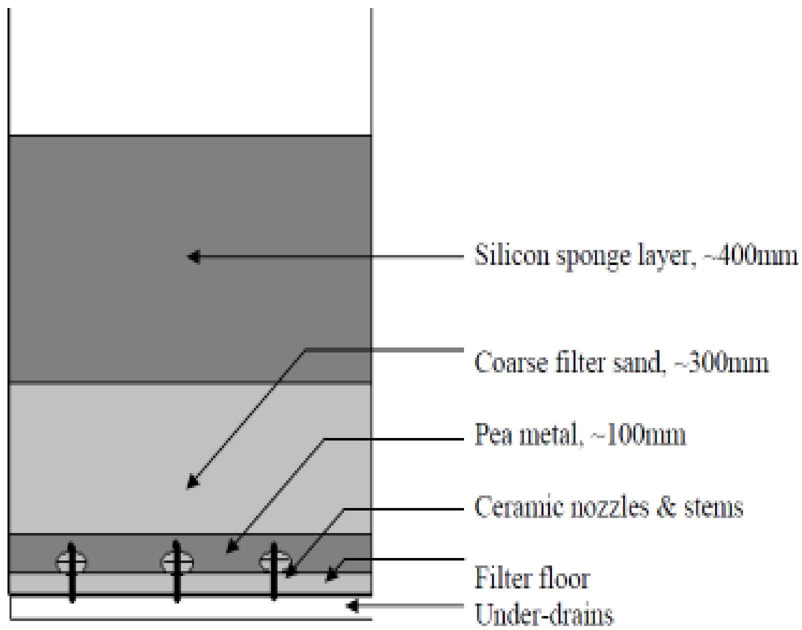
This paper will briefly discuss the upgrade process, review some of the lessons learnt, and highlight the areas where subsequent improvements were made.

This paper will also review the algal events that have occurred in the Waikato River since the upgrade and will discuss how the plant has coped with these events. Since completion of the upgrade there have been 4 summers. Summers are generally the time of year where the algal issues have historically affected the plant. Over this time there have been 3 minor events and one event which would have historically been considered a problem for the plant.

The paper also reviews the changes in characteristics of the GAC filters, as they have essentially moved from a GAC to Biological Activated Carbon (BAC) mode of filtration.

Photograph 1: Overall Upgraded Facilities

Figure 3: PCDM Sand Filter Schematic



2 DISCUSSION

2.1 THE UPGRADE

2.1.1 PROJECT VISION AND OBJECTIVES

At the start of the upgrade project it was decided to adopt a project vision which would be used to assist with any decision making during the course of the project. The project vision was defined as *"A world class Water Treatment Plant that delivers the water needs of the city and exceeds or meets the Drinking Water Standards of New Zealand at the lowest whole of life cost"*. In meetings the vision was discussed again prior to making any major decisions to ensure that decisions reached were made for the right reasons.

There were also a number of project objectives that were agreed prior to the start of the project. These were:

- To comply with the DWSNZ

- To ensure the WTP capacity until 2023 (106ML/d)
- Minimise corrosivity of the treated water
- Deliver a world class, fully automated treated water supply with advanced pathogen protection (Cryptosporidium), effective taste and odour removal and effective toxin management systems.
- Maintain the public health grading of the Hamilton Water Supply

The chosen vision itself was the result of a group discussion and consensus between the client (HCC) and Consultant (GHD). The inclusive nature of the discussions was one of the defining factors for the upgrade project. This offered a greater degree of ownership to HCC, including the plant operators, and resulted in a sense of buy-in, rather than the feeling that changes were being forced upon them.

Photograph 2: The UV Units

2.1.2 PROJECT OUTCOMES

Upon the official opening in early 2007 the project was deemed to be a success for the following reasons:

- The project objectives were all met
- The upgrade was completed on time
- The upgrade was completed on budget
- The water quality at commissioning met the project objectives
- There were minimal disruptions to customers throughout the entire upgrade process and compliance with the Drinking Water Standards of New Zealand was maintained throughout the project.
- The operators, client, contractor and consultant were all happy with the project outcomes

The project won a Silver award at the ACENZ Awards in 2008.

Photograph 3: The GAC Filters

2.1.3 LESSONS LEARNT

There were a number of lessons learnt throughout the project that have been identified. These can be divided into two groups: lessons related to construction and those related to commissioning or technical issues.

The construction issues that were identified included:

- There is shortage of contractors in New Zealand who have experience with large water retaining structures. The required levels of workmanship are higher than those required for buildings, where plaster or interior walls can mask defects. There were issues with cracks and weeps, especially at the interfaces between concrete pours. Waterstops were not always placed correctly and concrete compaction was an issue in places.

- The placing of the GAC via eduction is a long slow process. The flow rates estimated by suppliers are at optimum conditions, and that is not often the reality on site.

- Many of the contractors have a small number of essentially project management staff and the contractors are very reliant on the level of sub-contractor that they employ. In this sense solely reviewing previously completed projects can be deceiving unless the same subcontractor and contract manager are proposed for the particular project in question.

- On older plants, the historical services plans should be taken as indicative only. The knowledge of the operators was much more useful than consulting plans. Many on-site minor works are never as-built, and for buried services this can create issue when least expected.

The commissioning and technical issues identified included:

- The amount of washing of the GAC to remove fine particulates and dust was underestimated by the suppliers. This is a very time consuming process, and creates a large amount of discoloured wash water that requires disposal. The disposal especially was an issue. This resulted in delays as the washwater tank was left to settle so that the volume and quality parameters were compliant with resource consent criteria and acceptable for discharge to the river outfall.

- A lot of time and effort is needed in the design of lime systems due to the difficulties associated with handling lime. There have been a variety of issues occur as a result of the new lime dosing system, mainly due to the tendency of lime to block pipes and fittings as well as managing the effects of Lime's abrasive characteristics which has resulted in significant wear and tear on asset condition. A number of improvements have been implemented ranging from reducing the size of some pipe work to increase flow rates (reduce blockages), increase the support structures around lime mixers shafts, repairs to lime tanks bitumen lining as well as introducing extra flexibility to move lime between tanks to allow for maintenance outages.

- The entire GAC filter and pipe gallery building was designed to be naturally ventilated, however it still experienced very high humidity levels inside the building. This resulted in repeated issues with the ballast units for the UV system and was identified as potentially compromising warranty provisions. To better control moisture in these ballast units air-conditioned glass enclosures have been built and placed over the UV units. This is illustrated in Photograph 4 below.

- The architectural feature in the GAC filter hall using "HCC Corporate blue" exterior glass creates a striking effect, especially at night with the interior lights on. The purpose of this glass was to lower light levels in the filter gallery, and thus limit algae growth on the filters. The growth of algae has still occurred however, and the light gray walls of the filters show up the algal growth and staining from activiated carbon very easily. Darker epoxy on the walls would have limited this problem.

Photograph 4: UV Ballast Covers

2.2 PLANT PERFORMANCE

As stated above the traditional period where the Hamilton WTP had experienced quality issues with the raw water was summer through to early Autumn. The reason for this is because summer is traditionally the time when the Waikato River system experiences elevated algae populations. The treatment quality from the plant during these periods, and the associated customer perception is discussed below.

2.2.1 DWSNZ COMPLIANCE

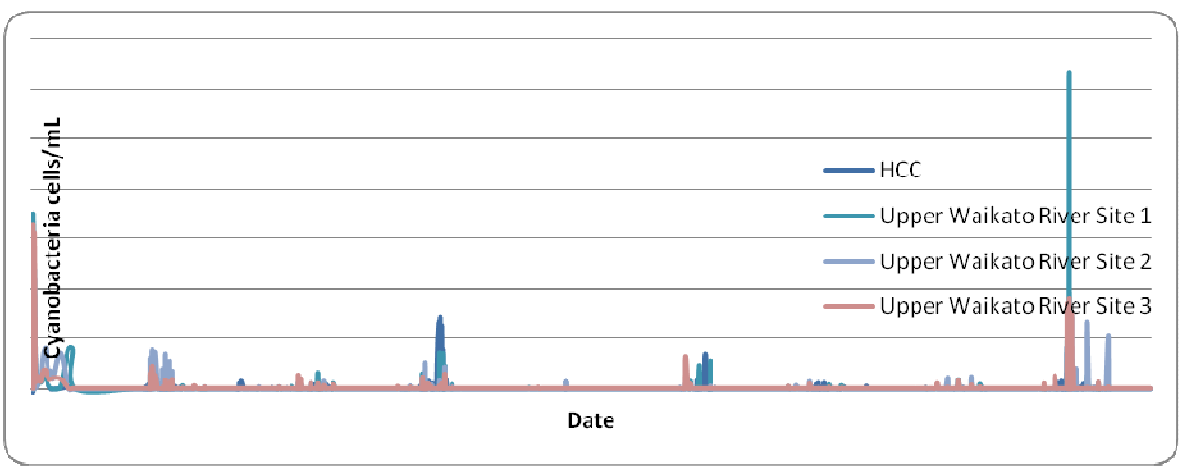
The plant has achieved full compliance with DWSNZ 2005 since completion. The catchment protozoa risk assessment completed on the Waikato River indicated that 4 log removal of protozoa is required by the Hamilton Treatment Plant to ensure compliance with the DWSNZ. As a result of the upgrade, the plant is able to achieve an up to 7.5 log removal credit rating for protozoa removal which gives maximum flexibility and redundancy and ensures a multi barrier approach is achieved. This 7.5 log credit is made up of the following; 3 credits for coagulation, sedimentation and filtration processes, 0.5 – 1 credit for enhanced filtration (individual/combined), 0.5 credit for second stage filtration (GAC), and 2 – 3 credits for Ultraviolet light disinfection.

2.2.2 HISTORICAL WATER QUALITY

Prior to the upgrade HCC received large numbers of taste and odour complaints from end-users on a sporadic basis, particularly during periods of elevated algal cell counts in the Waikato River.

In Figure 4 below the overall number of cyanobacteria cells from 2003 to today detected at the Hamilton Water Plant intake and at three upstream sampling sites. The graph clearly indicates periods during which significantly high levels of cyanobacteria cell counts were present in the Waikato River System.

Figure 4: Waikato River Cyanobacteria Cell Counts



2.2.3 2010-2011 ALGAL SEASON

The most significant algal event that has occurred since the completion of the plant upgrade occurred in the 2010-2011 summer season. The analysis identified algal species that have potential to produce toxins. Table 1 below, illustrates the types of algae observed.

Table 1: 2010-2011 Algal Tests by Potential Toxin Producing Species

Date sampled	River Intake Cyanobacteria (cells/mL)	Dominant Species	Post Coagulation Cyanobacteria (cells/mL)	Post Sand filter Cyanobacteria (cells/mL)
9/11/2010	155	Microcystis flos-aquae Dolichospermum sp.	3	<1
22/11/2010	40	Microcystis sp. Dolichospermum planctonicum Phormidium sp.		
9/12/2010	1242	Microcystis sp. Dolichospermum spiroides Microcystis aeruginosa Dolichospermum planctonicum Microcystis cf. wesenbergii	<1	<1
16/12/2010	650	Microcystis flos-aquae Microcystis wesenbergii Microcystis sp. Plus 4 other taxa each <8 cells/mL		
21/12/2010	1519	Microcystis sp. Microcystis aeruginosa Microcystis wesenbergii Anabaena sp. Anabaena planktonica	2	<1
30/12/2010	444			
5/01/2011	8335	Microcystis aeruginosa Microcystis flos-aquae Dolichospermum circinalis Dolichospermum planctonicum	<1	21
7/01/2011	4991	Microcystis sp. Leptolyngbya sp. Pseudanabaena cf. mucicola Licrocystis aeruginosa Anabaena planktonica Anabaena sp. Microcystis wesenbergii		
12/01/2011	4798		8	<1

Figure 5 shows the overall numbers of blue-green algal cells per ml through the season at various points through the treatment train.

As can be seen from Figure 5 the intake algal cell count peaked at just over 8000 cells/ml and the treatment plant achieved good removal of the physical cyanobacteria cells through the coagulation and filtration process., However cell counts in the upper Waikato River system exceeded a level of 60,000 cells/mL as can be seen in Figure 6.

Screening cyanotoxin monitoring undertaken during this period of elevated cell counts in the Waikato River system identified low levels of microcystin present in river water up to a level of 1.5 micrograms/L for a period of approximately 1 week in early January. Corresponding monitoring of the treated water did not detect the presence of cyanotoxins indicating effective removal through the treatment process.

Figure 5: Overall Number of Cyanobacteria Algal Cells in Samples during the 2010-2011 Summer Event by Location at Hamilton WTP

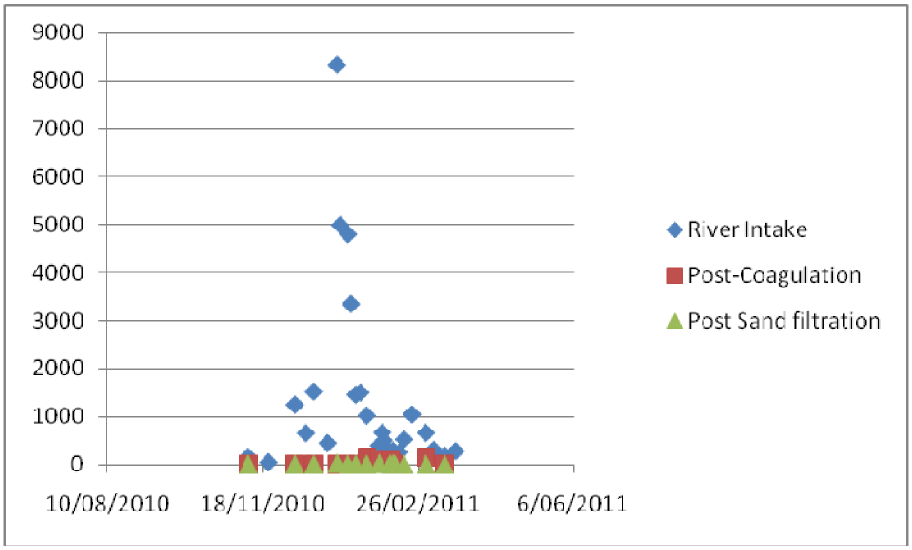
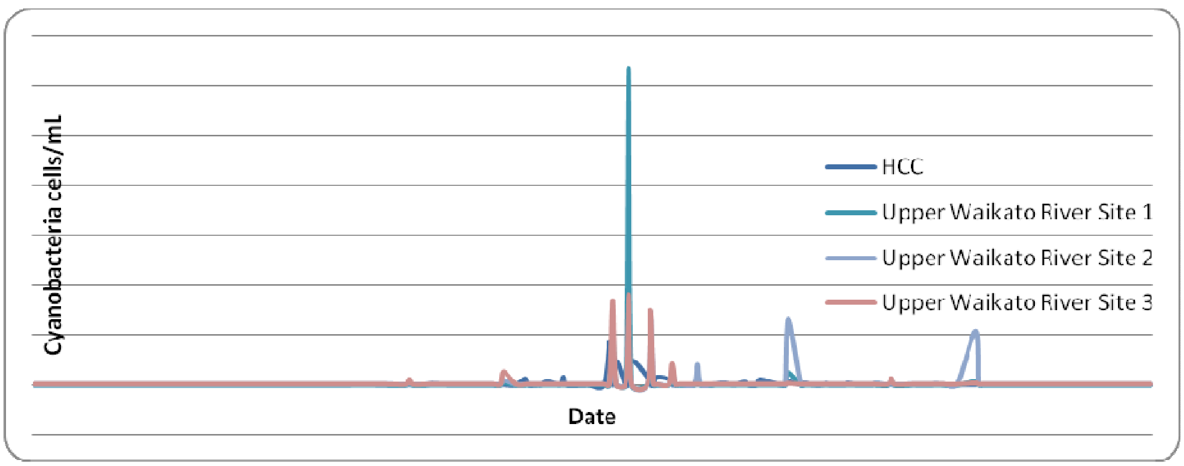


Figure 6: Overall Number of Cyanobacteria Algal Cells in Waikato River Samples during the 2010-2011 Summer Event



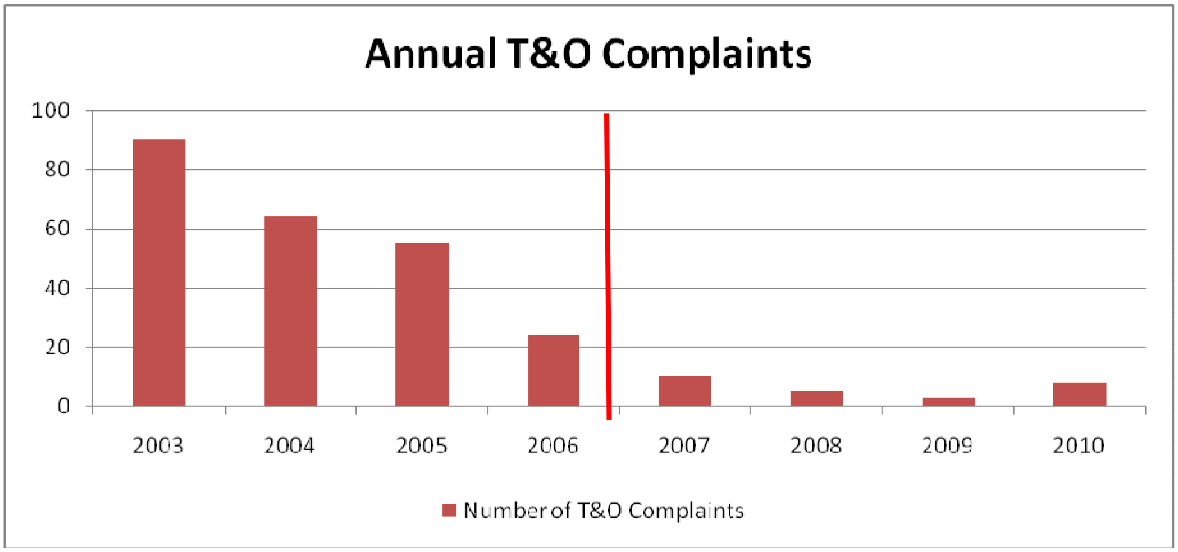
Elevated cell counts in the river intake water experienced in previous years, in particular 2003, resulted in significant taste and odour issues. During the summer of 2010/11, the treatment effectiveness was such that there was no discernable increase in the number of taste and odour complaints received, when compared to a normal summer.

2.2.4 END-USER TASTE AND ODOUR COMPLAINTS

HCC keep a register of the number of taste and odour complaints received in regards to the water supply. Figure 7 below shows the number of annual complaints received from 2003 until 2010. The vertical red line indicates the time at which the upgrade was completed.

The number of complaints is obviously influenced by events in the reticulation system as well as at the treatment plant output quality; however as can be seen the number of complaints has steadily declined since the completion of the upgrade.

Figure 7: Annual Customer Complaint Numbers for Taste and Odour of Water Supply



2.2.5 CUSTOMER SATISFACTION SURVEY

HCC undertake an annual customer satisfaction survey that asks for residents opinions on council services offered. It uses a weighted satisfaction score, called a CSI or Customer Satisfaction Index, to rate the various services. One of the items queried is satisfaction with the taste and odour of the potable water supply.

The CSI value is effectively a percentage of people who are satisfied with a particular service and thus a higher score indicates a higher degree of customer satisfaction.

The CSI values for taste and odour are shown in Table 2 and Figure 8 below. The vertical red line in Figure 8 again represents the point at which the upgrade was completed.

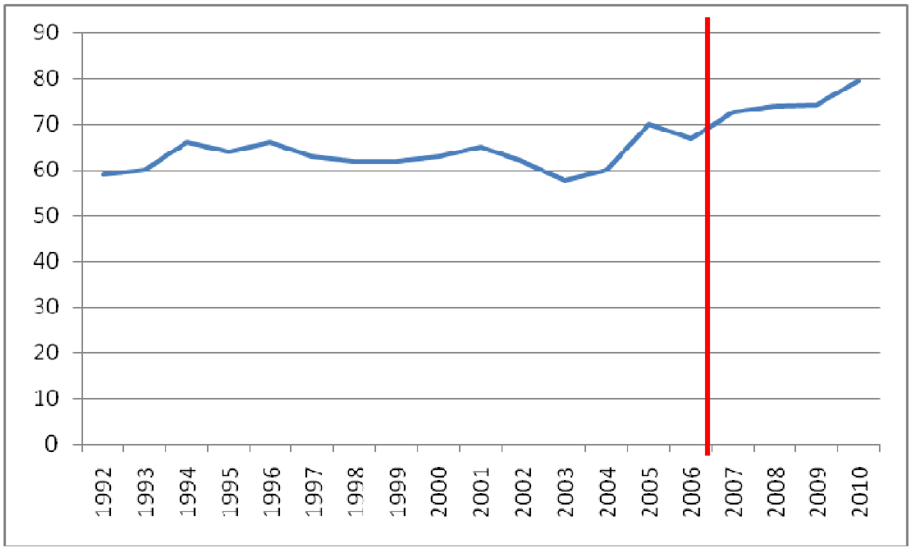
It should be noted that in the Executive Summary Report for the 2004 survey the following comment was made "*The taste of water was the lowest score in 2003, but remains 4th lowest in 2004 with 60.1*". The executive summary only comments on a very limited number of factors each year so this is indicative of the level of concern that people had over taste and odour in the potable water supply.

The plant upgrade was publically announced in 2005 and completed in 2007. It is interesting to note that the level of satisfaction rose significantly in 2006 and 2007, even prior to the plant upgrade being completed. This suggests that there may have been a psychological aspect to the answers given by end-users. Despite this, it is clear that since the plant upgrade has been completed there has been an increasing level of customer satisfaction with the taste and odour of the potable water supply. The 2010 CSI of 79 rates this parameter as "excellent" according to the grading system used by the research company.

Table 2: CSI Results for Taste and Odour

Year	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10
CSI	59	60	66	64	66	63	62	62	63	65	62	58	60	70	67	73	74	74	79

Figure 8: Customer Satisfaction Index for Taste and Odour of Water Supply



2.3 CARBON FILTER DISCUSSIONS

2.3.1 GRANULAR VS BIOLOGICAL ACTIVATED CARBON

There has been a large amount of discussion within industry in recent times in regards to what the difference is between a GAC and a biological activated carbon (BAC) system.

GAC filters were first used to take advantage of the fact that activated carbon achieves a large surface area in comparison to filter bed volume due to the large number of porous active surface sites on the carbon. These active sites react with any impurities in the water and the impurities became attached to the GAC particle. Originally plants were designed to treat the water until these pores were close to saturation. The filters were then backwashed to clear these sites and the process started again. The carbon was periodically "reactivated" by re heating the carbon or replaced with new activated carbon.

Over time it was noted that there could also be a build-up of bacterial growth on the surface of the carbon, and that this biological layer could assist with the treatment of the water. This is especially effective when used with pre-ozonation.

There are a number of advantages to running the plant in a more "BAC mode". These include less frequent backwashing required, by definition, and that the carbon requires reactivating or replacement less often. The filters serve a dual purpose of filtration and bacterial treatment. The bacterial treatment is achieved in a mode very similar to that achieved by fixed film reactors. The small amount of biosolids produced is removed during the backwash procedure.

It is widely accepted that in the majority of modern applications GAC filters are run in a BAC mode. While there are no hard and fast rules in regards to what constitutes GAC and what constitutes BAC it is widely accepted that if there is pre-ozonation and an Empty Bed Contact Time (EBCT) of at least 7.5 minutes there will be some degree of BAC treatment. Without pre-ozonation, as is the case at the Hamilton WTP, a 10 minutes EBCT is more widely considered to be the minimum amount of time required for BAC treatment to be established.

EBCT is a measurement of the average amount of time that a particular water molecule will have in contact with the filter bed, if the bed was empty. It provides a measurement of the amount of treatment that the water receives from the filter. It is calculated by dividing the flowrate of water through the filter by the volume of the GAC in the filter.

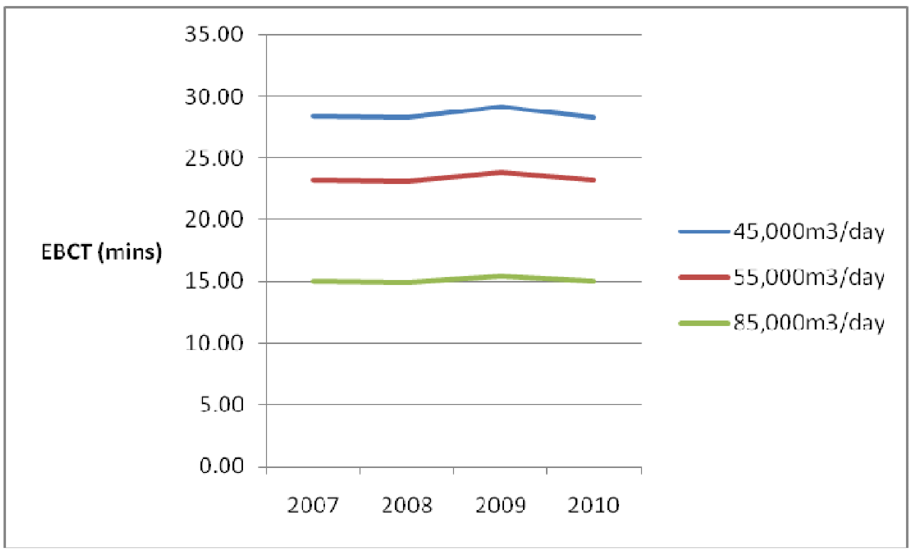
There are varying depths across the filters with Filter 1(the lowest volume) having typically 10% less GAC volume than Filter 4 (the highest volume). This difference has been consistent since 2007 however, so it is assumed that this difference is a result of the original filter loading process, rather than as a result of an operational process.

HCC measures the volume of GAC in each filter annually in December. The measurements are averaged across the six filter beds and an average EBCT is calculated for the filters. The result of these calculations is illustrated in Figure 9 below.

As stated above for effective BAC treatment without preozonation an EBCT of 10 minutes is recommended. As can be seen, even at a flowrate of 85,000m^3/d an EBCT of approximately 15 minutes is maintained.

The 2009 readings appear to be an anomaly. Obviously the volume of the filters cannot increase unless GAC is added. HCC have not replaced any GAC since the initial GAC installation. As no GAC has been added the higher readings probably represent an error in the filter bed volume measurements. Given that each filter bed is 10.6 m by 6.0 m and that the bed depth is calculated by measuring from the top of the filter bed walls down to the surface of the GAC and averaging across the entire bed there is large margin for error.

Figure 9: Average EBCT across the filters at various flow throughputs

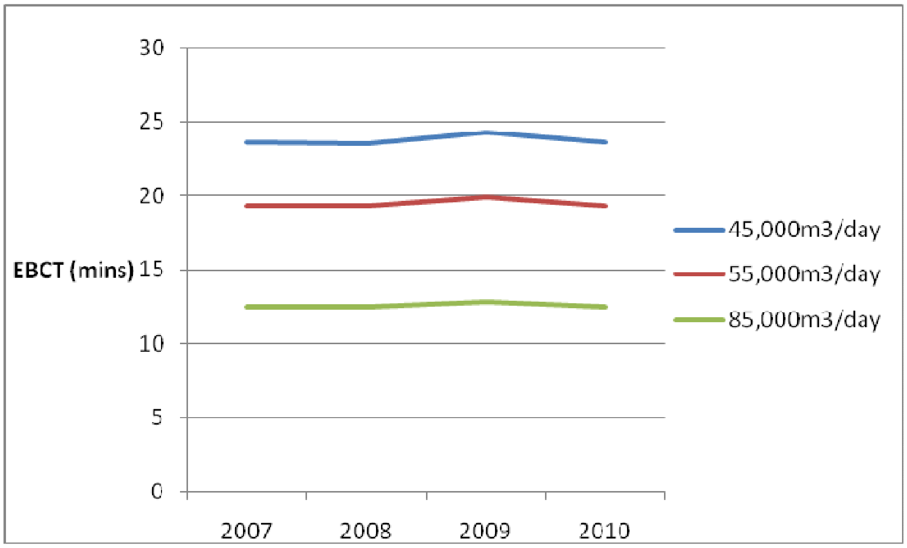


An overall trend of a slowly decreasing GAC bed volume, and hence reducing EBCT, over the lifetime of the facility is what would be expected to be observed. It is as yet unlear if this is the overall trend seen here as the currently recorded change in volume is only in the order of -1% per annum. The expected reduction in volume is due to the natural breakdown of the GAC granules and unintentional carryover of GAC in the backwash process.

When operating normally the filters are operated so that there is only one filter out of service for backwashing or cleaning at any one time. For a truly indicative EBCT the calculations need to be rerun assuming that the maximum flow is passing through 5 filters only. This is indicated in Figure 10 below.

As can be seen, even with one filter out of service and a flowrate of 85,000m^3/d, an EBCT of over 10 minutes is maintained. It can be concluded from this that the plant is achieving a degree of BAC treatment. Further investigations are being undertaken to establish the biological status of the activated carbon currently in the Hamilton GAC filters and to establish when the media will require replacement.

Figure 10: Average EBCT across the filters at various flow throughputs with one filter out of service



3 CONCLUSIONS

The following conclusions can be made from the analysis and discussions undertaken in this paper:

- The upgrade project itself was a successful project that achieved the goals it set to achieve.
- There were a number of learnings gained throughout the upgrade that are discussed in this paper. These range from learnings regarding the selection of lead contractors, through to the technical aspects such as design of ventilation for UV control units.
- The plant has a history of issues related to algal toxins and taste and odour from algae. There have been 4 complete summer periods since the upgrade was completed. There have been 3 minor algal events and one more significant event that would previously have resulted in customers issues prior to the upgrade.
- The 2010-2011 summer event was the most significant event experienced yet, but was successfully managed by the Hamilton treatment process, the level of customer satisfaction in regards to taste and odour of the potable water supply has increased steadily since the plant upgrade, and now scores in the "excellent" range for customer satisfaction.
- The plant is operating with an EBCT of well over the 10 minutes that it was designed for, even allowing for one filter to be out of service for cleaning or maintenance.
- With the above EBCT the plant is essentially operating in a BAC mode, and this will assist with prolonging the life of the GAC.

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REFERENCES

Carne S, (2003), 'H*amilton City Council Water Treatment Station Strategic Upgrade Options*

Report'; GHD Limited, Palmerston North, New Zealand

Hansen J., Porter M., (2006) '*Hamilton Water treatment Station – Optimisation of Filtration Process using PCDM* Technology', 69th Annual Water Engineers and Operators Conference, Bendigo, Australia

International Research Consultants Ltd (2004), '*Hamilton City Council Residents Survey, 2004, Executive Summary Report'*

International Research Consultants Ltd (2005), '*Hamilton City Council Residents Survey, 2005, Summary Report'*

International Research Consultants Ltd (2006), '*Hamilton City Council Residents Survey, 2006, Executive Summary Report'*

International Research Consultants Ltd (2007), '*Hamilton City Council Residents Survey, January 2007 to December 2007, Summary Report'*

International Research Consultants Ltd (2008), '*Hamilton City Council Residents Survey, January 2008 to December 2008, Summary Report'*

International Research Consultants Ltd (2009), '*Hamilton City Council Residents Survey Report, January 2009 to December 2009'*

International Research Consultants Ltd (2010), '*Hamilton City Council Residents Survey Report, July 2009 to June 2010'*