TAURANGA WWTP'S - THE 10 YEAR JOURNEY OF ASSET OPTIMISATION

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ABSTRACT

In order to provide additional treatment capacity to meet projected population increases and improved treatment capability to meet new effluent discharge consent requirements, the Tauranga City Council (TCC) needed to implement a development programme for their two wastewater treatment plants namely Chapel Street and Te Maunga.

MWH carried out feasibility studies and prepared Design Statements for development programmes at the two Wastewater Treatment Plants (WWTPs) and project managed and designed over twenty project work packages over a period of 13 years, to implement the agreed development programme. The implementation works were staged to match increasing capacity demands and the coming into effect of new consent discharge conditions, to enable project implementation to fit within "live" plant operational constraints, to match funding availability, and to allow the progressive refinement of follow-on designs based on the commissioning outcomes from project packages which had been implemented at an earlier stage of the programme.

The paper traverses the journey from inception to completion and highlights some of the challenges and smart solutions implemented to provide redundancy and treatment security and defer capital investment by maximising the use and performance of existing assets at the two operational wastewater treatment plants.

KEYWORDS

Asset Optimization, Wastewater Treatment Plants, Energy Efficiency, Operational Security

1 INTRODUCTION

The Tauranga City Council (TCC) owns and operates two wastewater treatment plants (WWTPs) namely Chapel Street and Te Maunga. The treated wastewater from the Chapel Street WWTP is pumped to the Te Maunga Wetlands and the treated wastewater from the Te Maunga WWTP gravitates through a separate oxidation pond and wetland in series. The outflow from the two wetland systems is combined upstream of the outfall pump station from where it is pumped via a pipeline and diffuser arrangement into the ocean. Overall integrated treatment and disposal scheme is shown in Figure 6.

In 1999 MWH was engaged by TCC to conduct an Optimisation Study of the Chapel Street WWTP which identified several opportunities to increase the existing treatment capacity by maximising the use of the existing assets and by reducing or removing hydraulic bottlenecks. The WWTP is located within metropolitan Tauranga with very limited area available for extensions and one of the drivers was to maximise the use of the existing footprint and existing assets to defer major capital expenditure which would result from constructing new unit processes.

The proposed upgrade included a new fine bubble aeration system, increased hydraulic throughput and additional treatment capacity to satisfy future flows and loads. A staged approach was adopted in the implementation of the proposed upgrades.

In 2004 MWH was engaged by TCC to conduct a capacity review of the existing Te Maunga WWTP to improve and optimise performance and increase treatment capacity until the year 2051.

The proposed upgrades included a new fine bubble aeration system, converting the oxidation ditch to a plug flow bioreactor and a new clarifier which was implemented in 2006 and resulted in doubling the treatment capacity. The cost effective upgrade achieved improved and more consistent treatment outcomes and significant energy savings.

The process optimisation studies and capacity investigations at both WWTP's clearly showed that major capital works can be deferred or in some cases cancelled, whilst meeting the projected increased loads, by following an optimisation route of maximizing the use and performance of existing assets.

2 DESIGN CONSIDERATIONS

2.1 OPTIMISATION STRATEGY

The over-riding objective for the design of the WWTP's development was to optimise the use and performance of the existing assets and achieve the required treatment outcomes at minimal capital and operating cost.

The optimisation strategy which was implemented considered the follow key factors:

- Plant Item Effectiveness;
- System De-Bottlenecking;
- System Integration and Operational Security.

2.1.1 PLANT ITEM EFFECTIVENESS

The effectiveness of individual plant items was assessed against the required performance, reliability and other specified development outcomes. Options for improvement were considered, including modifications to the item itself or to its "support infrastructure" such as power supply or controls. An example was the 50% increase in treatment capacity of the Contact Stabilisation Tank (CST) at Chapel Street WWTP, as a result of upgraded diffusers and improved air distribution piping and aeration control. This improvement in effective treatment capacity within the existing process unit meant that the previously-planned construction of an additional CST was able to be shelved.

2.1.2 SYSTEM DE-BOTTLENECKING

Opportunities to improve the overall effectiveness of connected system elements by removing the limitations or restrictions which existed between them were identified and assessed. These "bottlenecks" were often severely limiting the performance of the downstream elements.

Examples of "de-bottlenecking" which resulted in allowing the downstream elements to operate much more effectively include replacement of the flow distribution chamber and piping to the primary sedimentation tanks at Chapel Street WWTP and provision of new larger influent piping to the oxidation ditch at Te Maunga WWTP. These improvements enabled the downstream process units to operate at their maximum performance levels and helped defer the construction of additional process units to handle the expected plant loads.

2.1.3 SYSTEM INTEGRATION AND OPERATIONAL SECURITY

Options for improving the reliability and security of operation, and for maintaining operation in the event of process unit failure, were identified and evaluated so as to maximise the use of existing assets within each plant and between both plants. The objectives were to:

- Provide adequate operational redundancy;
- Reduce the risk of overall system outage and the potential for consent non-compliance; and
- Minimise the construction of major new standby process units (for example, bioreactors and clarifiers).

Examples of optimising the use of existing assets to provide adequate operational security include the investigative works on the Chapel Street CST (to reduce tank structural uncertainty to an acceptable level), provision of bypass system extensions at Chapel Street WWTP, and the addition of an emergency bypass connection between the Chapel Street effluent pipeline and the Te Maunga WWTP. These measures of making integrated use of existing assets avoided significant investment in additional standby capacity.

2.2 CHAPEL STREET WWTP

2.2.1 OPTIMISATION

The liquid process stream consists of pre-treatment (screenings and grit removal), primary sedimentation, diurnal flow balancing, high rate activated sludge process, secondary sedimentation and UV disinfection while the sludge stream consists of gravity thickening in the PST's, mesophilic anaerobic digestion and sludge dewatering.

The first stage of upgrade of Chapel Street WWTP was implemented in 2002 by replacing the existing coarse bubble aeration with fine bubble dissolved aeration (FBDA) system including an advanced dissolved oxygen control system and providing increased hydraulic capacity through the plant which resulted in power savings of about 20%. The optimisation study identified several opportunities to increase the existing treatment capacity of 16,300 m³/d to 25,000 m³/d in stages.

Additional upgrades were implemented from 2004 to 2012 to increase hydraulic and treatment capacity and reduce operating and maintenance costs which included:

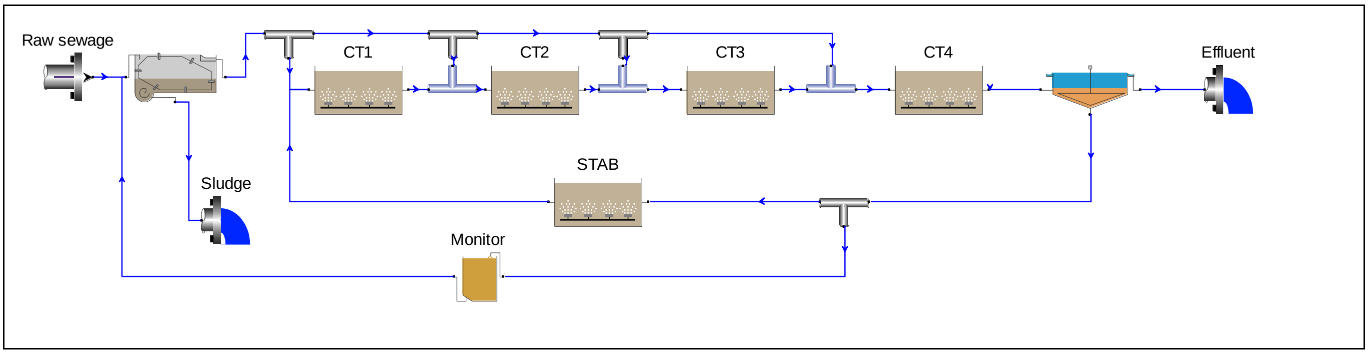
- Increased raw sewage pumping capacity for peak flows;
- Improved screenings capture of influent wastewater;
- Reduced hydraulic restrictions between inlet works and primary sedimentation tanks;
- Improved control of balancing tank operation;
- Increased final effluent pumping capacity;
- Installation of a new screenings facility;
- Construction of a bypass system;
- Installation of a new biogas cogeneration facility;
- Installation of a new waste activated sludge thickening facility;
- Installation of hydraulic mixing system in anaerobic digesters.

In order to assess the potential capacity of the biological process, the contact stabilisation process was calibrated and verified using the BioWin® activated sludge simulator, the details of which are shown in Figure 1 below. The calibrated model was then used to determine the potential ultimate capacity of the biological process and the associated oxygen demand. Based on the evaluation the maximum treatment capacity of the overall treatment plant was set at 25,000 m³/d. This flow coincides with the maximum capacity of the blowers together with a more efficient aeration diffuser system.

In assessing the potential biological treatment capacity of the contact stabilisation process (high rate activated sludge process) it was also necessary to evaluate all other unit processes to determine their individual hydraulic and organic and solids capacities to ensure that there is no mismatch and that the complete plant is capable of treating the proposed capacity at minimal cost.

The evaluation also revealed that it was not possible to extend the existing aeration system due to space limitations in the tanks to install more diffusers and the requirement for additional blower capacity.

Figure 1: Process flow diagram of the Chapel Street WWTP



The aerial view of the Chapel Street plant layout is provided below in Photo 1 to demonstrate the restricted nature of the site and the proximity to commercial development on the adjoining predominantly eastern boundaries.

Photo 1: Aerial view of the Chapel Street WWTP[1]

Photo 2: New pipework to feed the primary settling tanks

Increased hydraulic capacity by removing plant bottle-necks

[1] *Aerial view courtesy of Google Maps*

2.2.2 BY-PASS SYSTEM

The By-Pass system at the Chapel Street WWTP provides the facility to by-pass peak wet weather flows in excess of 750 L/s and an extreme wet weather flow in the order of 1,000 L/s whilst still meeting the conditions of the Resource Consent.

The objectives of the bypass system were:

- To provide the capability to bypass flows exceeding the capacity of plant process units (i.e. storm events in excess of approximately 750 L/s);
- Provide the capability to divert flow around particular treatment units for maintenance purposes (planned or emergency). Bypass the secondary clarifiers and Contact Stabilisation tank (CST) can be achieved via a new Flow balancing tank (FBT) plug valve;
- To provide treatment security with Te Maunga WWTP by connecting the transfer Main from Chapel Street WWTP to the Te Maunga WWTP inflow pipe especially during planned maintenance of the CST at Chapel Street WWTP;
- Provide separation of secondary treated and bypassed untreated flows to ensure only secondary treated, disinfected effluent is discharged to the harbour during extreme events in accordance with the resource consent;
- Make maximum use of existing facilities and minimise construction;
- To allow active bypass around the UV system for flows up to 700 L/s;
- To allow primary treated wastewater up to 700 L/s to be pumped to the Te Maunga WWTP for secondary treatment should weather and subsequent secondary treatment not be available at Chapel Street due to the CST being offline

The Resource Consent allows, under extreme wet weather conditions, for secondary treated disinfected wastewater to be discharged directly to the harbour. This was achieved by diverting the peak wet weather flows from the Flow Balancing Tank past the CST and clarifiers, and connecting the Chapel Street Plant effluent using the rising main to the Te Maunga Wetlands.

This diversion ensures that only disinfected secondary treated wastewater is discharged into the harbour. The bypass control was programmed to divert flows at specific setpoints to protect secondary treatment processes under these conditions. The bypass strategy also allowed the CST to be taken out of service for maintenance without compromising the ocean outfall water quality.

2.3 TE MAUNGA WWTP

2.3.1 BACKGROUND

The Te Maunga WWTP provides wastewater treatment for the domestic, commercial and industrial communities from the Mount Maunganui and Papamoa catchments. The industrial COD load to the plant is about 13 % of the total incoming load. Whilst the industrial component is not large, the composition and the variable nature of the trade wastes posed several operational issues and have historically been attributed as the cause of the instability and variable performance of the treatment process. The main issue with the plant related to periodic loss of nitrification and poor settleability of the sludge due to high levels of filamentous bacteria in the biomass.

The facilities at Te Maunga WWTP prior to the upgrade comprised; an inlet works with 3 mm step screens and vortex degritter, a lift pump station, completely mixed activated sludge treatment within an oxidation ditch type system, secondary clarification in a circular clarifier and waste activated sludge is stabilised in a lagoon. Final effluent from the WWTP flows through an oxidation pond followed by a wetland before combining with the flow from the Chapel Street WWTP for final disposal in the ocean.

The original bioreactor consisted of a single oxidation ditch configuration rated at 9,000m^3/d with fine bubble aeration and slow speed vertical shaft mixers to maintain an internal recycle rate of 100 to 200 times average daily flow (ADF) to achieve nitrification and denitrification.

2.3.2 BIOREACTOR CONVERSION

Although the existing reactor channel can be considered a plug type system, the high internal recycle resulted in a system that is completely mixed. Notwithstanding the geometry of the oxidation ditch (continuous channel without partitions) it was considered appropriate to provide partitions in the existing ditch so that the anoxic zones become separate reactors and also provide controlled internal recirculation for overall process stability.

The proposed modifications to the oxidation ditch had to consider the continued operation of the 'single train' oxidation ditch during the construction period to ensure that a good quality effluent was maintained. TCC allowed short term (few hours) shut downs for tie-ins and other construction related works.

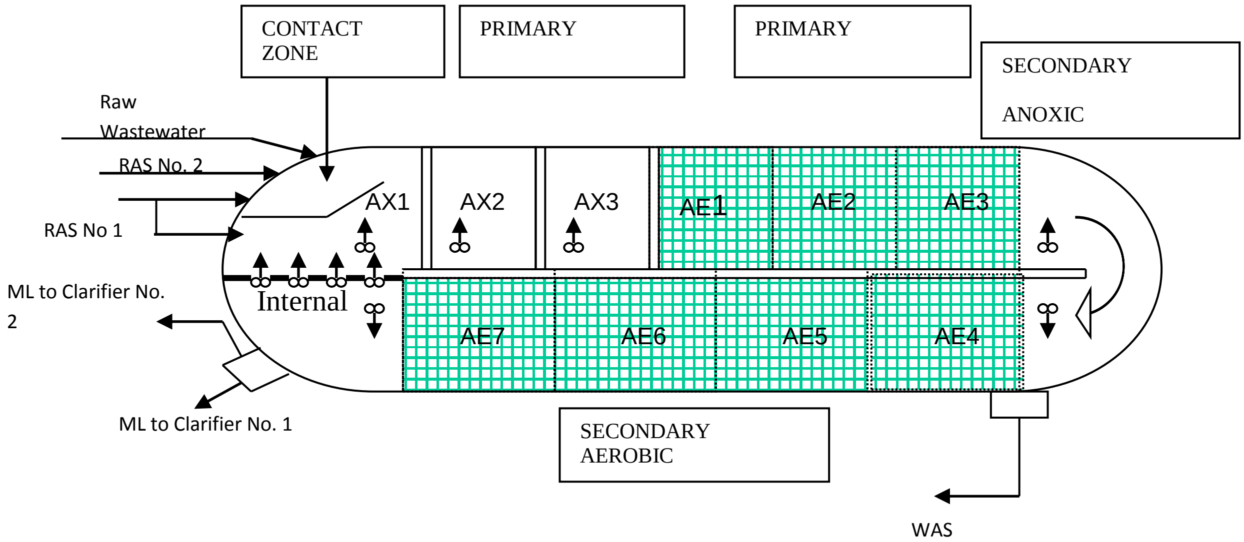
The first anoxic zone of the BNR process is now preceded by an unaerated selector (previously aerated) to increase the food to mass ratio to create environmental conditions that promote the growth of floc forming bacteria.

Photo 3: Aerial view of the Te Maunga WWTP

The scope of works for the conversion of the ditch to a plug flow bioreactor comprised:

- Removal of one existing oxidation ditch mixer;
- Construction of submerged baffle walls to create separate anoxic zones;
- Construction of a full height partition wall;
- Installation of propeller pumps in the partition wall to provide controlled internal recirculation;
- Installation of submersible mixers in the anoxic zones;
- Provision of a baffle wall in the first anoxic zone to create a contact zone;
- Replacement of existing ceramic diffusers with membrane type diffusers;
- Provision of additional aeration capacity and upgrading of the control system.

Figure 2: Schematic layout of bioreactor



2.3.3 CONTROL SYSTEM

The advanced aeration control system was designed to control the amount of air to maintain a constant level of oxygen concentration in the seven aeration zones.

The aeration system consists of three control loops for control of blower air, dissolved oxygen and blower pressure. The RAS pumps are variable speed driven and the rate of return flow is set as a percentage (70%) of the incoming raw wastewater flow which is operator adjustable. The control system for the RAS pumps has also been provided with a minimum setpoint to ensure that settled mixed liquor from the clarifier is recycled at a specified rate under all incoming flow conditions.

The internal recycle pumps have been selected to provide a minimum internal recycle rate four times the average daily incoming flow. The selection of the number of pumps depends on the actual daily incoming flow.

The optimization of the performance of the existing oxidation ditch meant that increased load could be treated without the significant cost of an additional process unit.

3 OPERATIONAL EXPERIENCE

3.1 CHAPEL STREET WWTP

The installation of the automatic aeration control system has achieved process stability and the DO concentration remains constant around the setpoint.

Significant energy savings have been achieved by controlling the amount of air according to the oxygen demand and maintaining a constant level of oxygen concentration in the contact zones.

The plant has been operating with the new diffuser and improved dissolved oxygen control system since October 2002 and the average power saving on the blower system is in the order of 48 kW/h. The overall site power usage has dropped by 10 % and can be attributed largely to the more efficient aeration system. The power saving on the aeration system is about 30 %.

The installation of the new screens equipment, which consisted of band screens with 5-mm opening screen face, has made big changes to the plant operational activities:

- The pre-treatment tank were previously cleaned out every 12 months, this is now scheduled for every 24 months cleaning;

- The aerated grit pump clogged regularly, now hasn't required cleanout or inspection for the last six months;
- Regular cleaning of screenings from the primary settling tanks is no longer required;
- Reduction of rag accumulation in pumps in general and the anaerobic digesters has occurred, requiring less disruption to treatment processes and less labour inputs.

The blowers were repaired and maintained a number of years ago and there have been no further problems experienced with the blower operation. The change from coarse to fine bubble diffused aeration improved aeration control a great deal. The observed benefit was that the treated wastewater quality was much more consistent.

The treated wastewater pumped from Chapel Street WWTP is no longer disinfected with the UV disinfection system as the effluent is pumped to the Te Maunga wetlands as shown in Figure 6 below. This results in a significant electrical power saving as well as the annual lamp replacement cost, as the 2005 annual power costs were about $44,000 with annual lamp maintenance costs of $58,000 amounting to an annual $102,000 total operating cost, or approximately $120,000 annual savings in present day terms.

The UV system is only operated when treated wastewater is likely to be discharged to the harbour. The change in flow path as a result of the final effluent pump upgrade together with the installation of the new by-pass pipe lines has allowed an improved and lower environmental impact on the harbour, while reducing the operating costs for disinfection of the order stated above.

The bypass system was tested up to 900L/s during the 23 July 2012 wet weather event and the setpoints checked and adjusted to suit the new bypass pipework arrangement. The bypass strategy has allowed the UV system to be shut down unless required during an extreme wet weather event (as discussed above). Only two events have initiated a discharge of treated wastewater to the harbour.

The co-generation of anaerobic digester methane using combined heat and power generation has realized a daily production of around 3,300kWH, which equates to 150kW of installed motor capacity which is about the same power requirement of the blowers. The cogen plant operates well using primary sludge with limited Thickened Waste Activated Sludge (TWAS). A portion of the TWAS is transported to the Te Maunga WWTP and treated with the raw wastewater in the bioreactor to avoid the operational control problems and ensure that power generation is maximised at the Chapel Street WWTP. In time, when funds are available, separate treatment of TWAS can be considered to further reduce the volatile solids in the anaerobic digesters to increase gas production.

3.2 TE MAUNGA WWTP

Since the upgrade, the performance of the plant has improved significantly in terms of nitrogen removal and settleability of the biomass.

The total nitrogen in the treated wastewater is consistently less than 10 mg/L and the settleability measured as SVI (sludge volume index) is less than 150 m*l*/g, whereas prior to the upgrade the SVI was higher than 250m*l*/g.

The treatment plant capacity was previously limited by the clarifier capacity due to the poor settling biomass but with the improved settleability and an additional clarifier, considerably more clarification capacity has been created. The biological treatment plant capacity has been doubled by the upgrade.

The additional diffusers and upgrading of the DO control system and new blowers with VSD control resulted in a reduction in daily airflow requirements, more stable and reliable operation and reduced maintenance and power consumption.

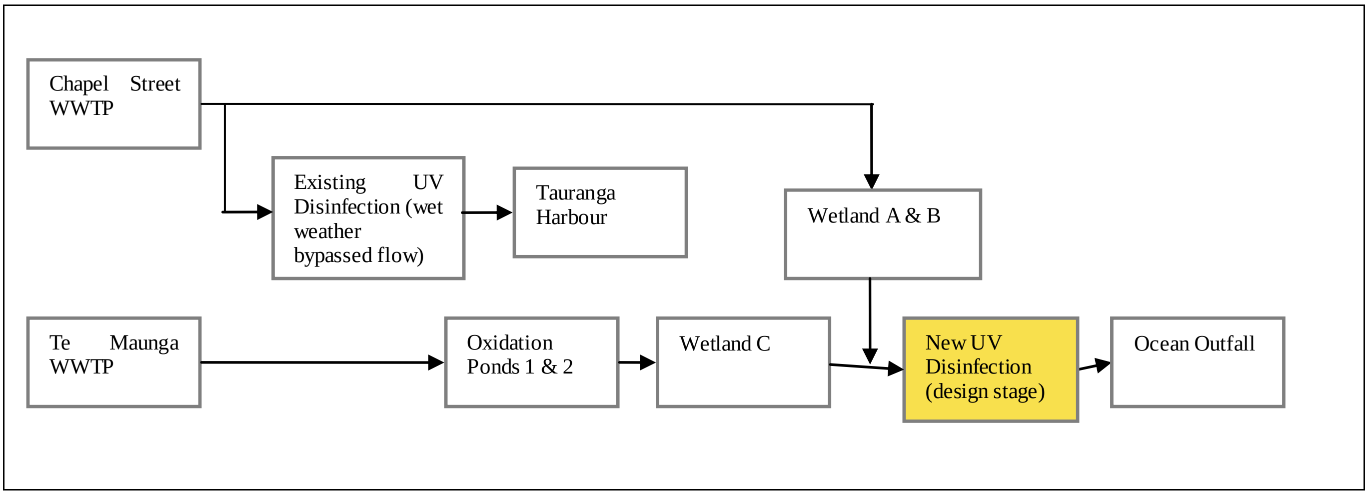
Te Maunga inlet works was also upgraded with fine screens with a similar improvement to the general plant operation. The plant is remotely operated from Chapel Street and with improved screenings capture rate, problems with clogging of the clarifier inlet well have been avoided and planned changes to the clarifier inlet well has been shelved. The Te Maunga WWTP has had no changes made to sludge wasting rates or aeration control for the last year and operates as an unmanned plant providing a big reduction in labour input costs.

3.3 INTEGRATION OF BOTH PLANTS

The disinfection pathway to handle the flow conditions that occur is flexible and makes use of natural disinfection processes to achieve the pathogen reduction required by the consent without making sole use of a UV system.

The strategy used to integrate the two plants and achieve this outcome is shown schematically in Figure 6 below.

Figure 3: Treatment Plant Integration



The additional benefit of the bypass strategy has been to allow the CST at Chapel Street WWTP to be isolated for planned maintenance and emergency events. In September 2012, the CST was prepared for maintenance and the primary settled wastewater was diverted to Te Maunga for full treatment. The CST was out of service for at least three weeks during the drain down, inspection and minor metalwork repair and strengthening that was required.

The plant performed as expected and Te Maunga WWTP operated at near upgraded design capacity levels, receiving 9,000 m^3/d of normal flows with an additional flow of 16,000m^3/d settled wastewater from Chapel Street WWTP. The organic load was about 90% of the upgraded Te Maunga WWTP design load and treated the water to the required consent quality without the need for additional oxygen. A temporary Vitox system was configured to be used under these conditions, but during this period the existing aeration system coped with the increased loads. If the load exceeds the plant capacity, then Vitox will add additional oxygen to achieve full treatment for a limited duration.

By employing the bypass upgrades, the consent conditions have not been breached during the extreme wet weather events or when a process unit has been taken off-line. This is a significant achievement with minimal investment in additional capital, but rather improved use of existing assets at both plants in a reconfigured fully integrated manner.

4 CONCLUSIONS

The successful plant optimization upgrades at the Chapel Street and Te Maunga WWTPs demonstrates that there are opportunities at existing facilities to improve energy efficiency and optimise treatment and hydraulic capacities by maximising the use and performance of existing assets and thus reducing capital, operating and maintenance costs.

In summary the specific benefits achieved at the Chapel Street WWTP are:

- A 10 % overall site power saving which equates to a 30 % power saving on the aeration system;
- Lower utilisation of blowers hence longer life expectancy of equipment;
- Increased overall treatment capacity due to more efficient diffusers and automatic DO control;
- Process stability and uninterrupted operation of the plant;
- Increased hydraulic capacity by providing by-pass facilities;

- Increased screenings capture;
- Provision of treatment security;
- Integration with Te Maunga WWTP;
- Reduced labour and maintenance input.

In summary the specific benefits achieved at the Te Maunga WWTP are:

- A 20 % overall site power saving which equates to at least 30 % power saving on the aeration system as reflected in lower airflow requirements;
- Lower utilisation of blowers hence longer life expectancy;
- Doubling the treatment capacity at significant lower capital cost when compared to the construction of a second bioreactor and clarifier;
- Improved effluent quality in terms of ammonia and nitrates with a total nitrogen concentration of less than 10 mg/L;
- Improved settleability (SVI < 150 ml/g) of the biomass which creates additional settling capacity in the clarifiers which will match the bioreactor capacity and thus avoid the need for a third clarifier;
- The commissioning of a second bioreactor has been deferred until 2019;
- The provision of oxygen injection to increase treatment capacity;
- Reduced labour and maintenance input.

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