TWO IDENTICAL WATER TREATMENT PLANT PROCESS UPGRADES: TWO DIFFERENT SLUDGE MANAGEMENT SOLUTIONS?

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ABSTRACT

In 2009, Dunedin City Council upgraded two rural water treatment plants at opposite ends of the city's boundary. The primary driver of each upgrade was to improve treated water quality, with one plant also requiring an increase in capacity, however to gain efficiencies, they were procured jointly. Each plant utilised an identical membrane filtration process technology, installed by the same contractor but each project involved a different engineering consultant. Whilst the end products of treated water met the required parameters, each project also resulted in the production of an increased volume of sludge as a by-product from the treatment process, which stressed the existing traditional drying bed configurations.

This gave rise to two additional capital projects to address the treatment and disposal of the sludge. The original two consultants were engaged to investigate options and two different sludge management solutions have now been trialled at the two water treatment plants: one utilising reed beds and the other using geotextile dewatering bags, with the latter leading to construction of a full scale system. This paper examines the two approaches taken on the two projects, their similarities and differences.

KEYWORDS

Water treatment; Membrane filtration; Sludge management; Dewatering;

1 INTRODUCTION

In 2009 Dunedin City Council upgraded the West Taieri and Waikouaiti rural water treatment plants to improve treated water quality and capacity. Due to similar sizes of plant, timescales and river raw water sources, the two plant upgrades were procured jointly (despite using different design consultants) which resulted in similar treatment process solutions being implemented at each plant, this being membrane filtration. Prior to and during the upgrade process, it became clear that the new more efficient process would result in an increased production of sludge at both plants compared to previously, although this was not quantified at the time.

Once the new plants were operational, the additional volumes of sludge proved to be too much for the existing sludge management systems to deal with efficiently and the original consultants were re-engaged to investigate alternative methods of sludge management. One consultant recommended the use of dewatering geo-bags and the second consultant recommended the use of reed beds. This paper documents the process upgrades and the two different approaches which were employed to determine the optimum sludge management solution for each plant.

2 BACKGROUND

2.1 DUNEDIN CITY COUNCIL

Dunedin City Council (DCC) covers the largest area of any local authority in New Zealand and serves a population of around 120,000. It covers an area of 3,350 square kilometres and extends 40km up the coast north of Dunedin city, to 30km down the coast south of the city to the hinterlands 60km west of the city. Dunedin City is unique amongst larger New Zealand cities in that, outside of the main city, it contains vast tracts of rural land, mainly used for farming and forestry.

From a water supply perspective, this area is served by 12 water treatment plants (WTPs): two main and eight smaller WTPs located in and around the city itself and two, West Taieri WTP and Waikouaiti WTP, serving the rural communities outside the city.

2.2 WEST TAIERI RURAL WATER SCHEME

2.2.1 WEST TAIERI WTP

West Taieri WTP is situated approximately 40km south west of Dunedin. It is part of a rural water scheme which was originally built in the 1980s by the landowners themselves and currently serves approximately 420 people. The scheme is owned and operated by the DCC with the direction and involvement of the West Taieri Rural Water Scheme Committee. Together with 131km of reticulation pipework and three treated water pumping stations, it serves the predominantly farming area of the Taieri Plains but also includes Dunedin International Airport.

2.2.2 PREVIOUS WEST TAIERI WTP PROCESS

The raw water is sourced from the Waipori River. The Waipori river catchment comprises some grassland, lightly-farmed tussock country, forestry and native bush all of which result in a raw water quality which is variable with low turbidity, low alkalinity and of moderate colour. Flows in the lower Waipori River are almost entirely controlled by a dam used for a hydro-electric power scheme, and its operation contributes to some variability in the raw water quality on a daily or seasonal basis.

The normal seasonal range of the raw water is:

- Colour 10-35^{o} Hazen
- Turbidity 0.18-11.8 NTU

From the raw water intake, the water is pumped 900m up to an open dam type raw water reservoir situated above the WTP. The pump capacity is 3,150m^3/day, which is less than the current consented allowance of 3,542m^3/day. The raw water reservoir has a capacity of 10,300m^3 and provides storage of 8.5 days (at previous demand), settlement of sediment and buffering of the variable raw water quality at the intake (although raw water pumping ceases when the turbidity is high).

From the raw water reservoir, the raw water was dosed with aluminium sulphate to remove colour before passing through a flocculation chamber. Polyelectrolyte and soda ash were then dosed prior to the water entering a single Automatic Valve-less Gravity (AVG) sand filter to remove any particles. After the AVG, the filtered water was dosed with with soda ash for pH and alkalinity control, and then dosed with chlorine for disinfection before being transferred to treated water storage, comprising eight 23m^3 concrete tanks. This made a total storage capacity of 184m^3 which equated to 3.5 days at previous demand.

The process is shown schematically below in Figure 1:

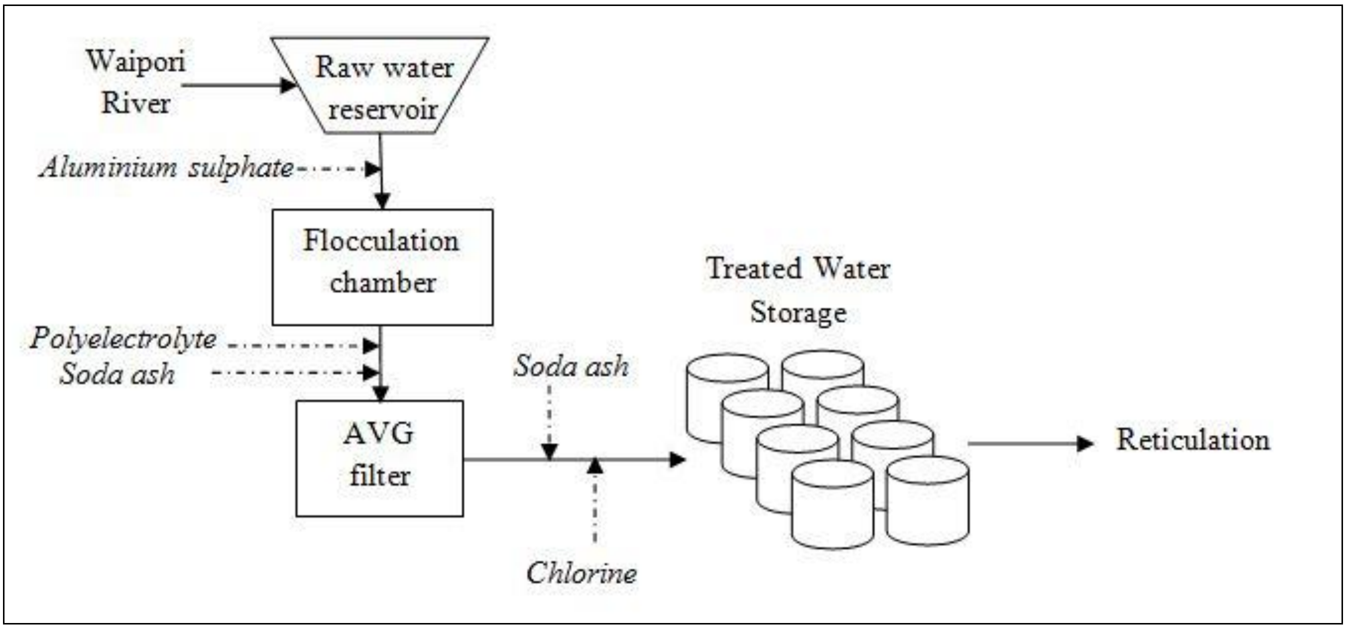

Figure 1: Schematic of Previous West Taieri WTP Process

The capacity of the previous West Taieri WTP was 1,200m^3/day.

Management of the sludge from the process is detailed later in this paper in section 5.1.1.

Photograph 1: Previous West Taieri WTP

2.2.3 ISSUES AND REASONS FOR WEST TAIERI WTP UPGRADE

DCC had commissioned a strategic review in 2004 to assess current capacity of the scheme and potential future development within the wider area which could impact upon it. This led to a recommendation that the WTP's capacity be upgraded in a staged manner to allow for immediate demand (at that time, there was waiting list for additional units totalling 157m^3/day) and future growth. In addition, it was recommended that the quality of treated water be improved to meet New Zealand Drinking Water Standards (NZDWS 2005).

The previous plant capacity was 1,200m^3/day and as noted above, this needed to be increased. An increase in WTP capacity to 1,700m^3/day was required initially, but with potential for this to be increased to 3,100m3/d at a later date to allow for the 50-year development scenario.

The previous WTP process had resulted in a Ministry of Health (MoH) provisional 'E' grading for West Taieri, this being ‘Unsatisfactory’. In order to obtain a 'C' grading for source and treatment as required by MoH for water supplies serving a population of West Taieri’s size, the plant would need to comply with NZDWS2005. Furthermore, monitoring of the intake water, a catchment risk categorization and the associated cryptosporidium log removal requirements led to a need for the WTP process to provide a default 4-log removal of protozoa, and the previous direct filtration process rated only 2.5 log credits.

Another drawback of the previous WTP process was that, with only one treatment process train, it had no redundancy. This meant that when routine maintenance on the AVG filter was required (1-2 times per year), consumers were supplied with chlorinated unfiltered water. This was exacerbated by the fact that treated water storage was minimal.

Additional recommendations of the strategic review required a new treated water reservoir with 1,200m^3 capacity in order to increase the storage from 3.5hours to 12 hours (again with scope for this to be further increased); and also that the reticulation network be upgraded to provide an increase in capacity to 3,500m^3/day by construction of 11.5km of mostly 150mm diameter pipework.

2.2.4 DESIGN OF SCHEME UPGRADE

Duffill Watts Group (since taken over by CPG, which has been renamed Spiire) were engaged by Dunedin City Council in 2007 to undertake the design, tender and contract administration of the West Taieri Rural Water Scheme Upgrade encompassing all aspects of the upgrade: the WTP, treated water storage and the reticulation network.

2.3 WAIKOUAITI WATER TREATMENT PLANT

2.3.1 BACKGROUND

Waikouaiti WTP is situated approximately 30km north of Dunedin. It serves approximately 1,100 people in the town of Waikouaiti, plus a further 600 in adjacent townships and rural communities, comprising residential, agricultural and commercial users. The area is served by 95km of reticulation pipework and three treated water pumping stations.

2.3.2 PREVIOUS WAIKOUAITI WTP PROCESS

The previous WTP was a coagulation/flocculation process directly onto pressure filters, and was originally commissioned in 1992.

The raw water is sourced from the main stem of Waikouaiti River. The Waikouaiti River comprises two main branches, the North and South branches which combine about 8km upstream of the river mouth to form the main stem of the river. The prevailing land use of the catchment is intensive pasture grazing, most of the original tussock and native forest having been converted to mix of high and low producing sward grasses. All of these factors result in a raw water quality which is variable and coloured.

The normal seasonal range of the raw water is:

- Colour 7.5-60^o Hazen
- Turbidity 0.3-43 NTU

Prior to 2006, the resource consent allowed a take from the river of 2,400 m^3/day. Water from the river is pumped by two river intake pumps to a raw water reservoir consisting of a 3,400m^3 circular tank.

From the reservoir, the raw water gravitated to water treatment pumps which pumped the raw water through the WTP. It was then dosed with polyaluminium chloride (PACl) before entering the first stage pressure filter, which removed the majority of the turbidity and colour. From here, it was dosed with a polyelectrolyte and transferred to the second stage pressure filter which flocculated out any impurities passing the first coagulation/filtration process. Both stages of pressure filters were multi-media filters with three layers of media. Chlorine was then added for disinfection before the treated water entered the treated water reservoir, also consisting of a 3,400m^3 circular tank.

The process is shown schematically below in Figure 2:

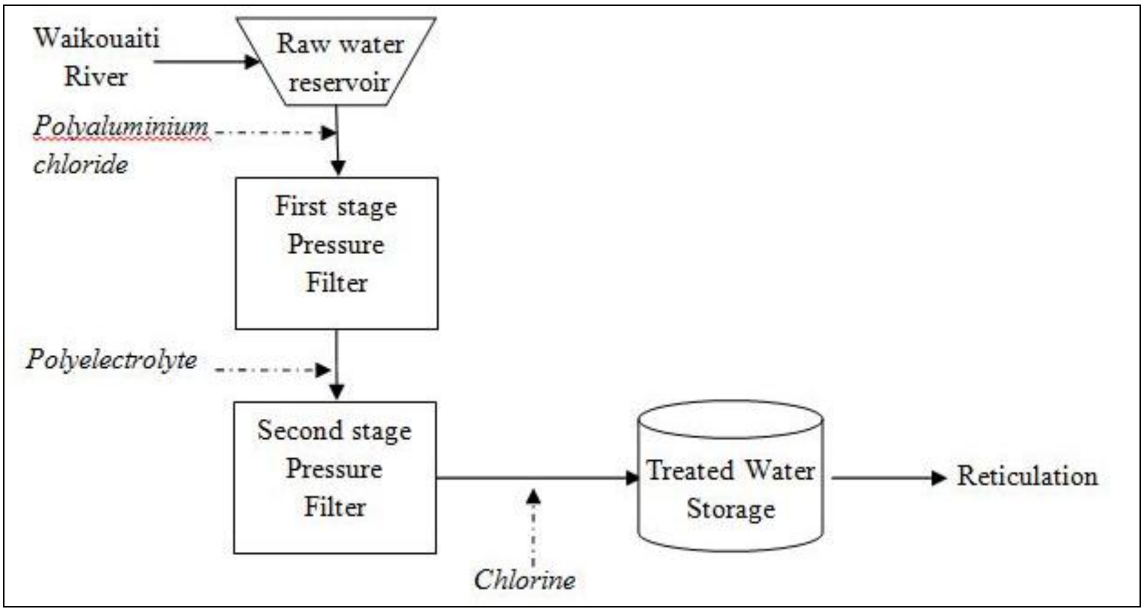

Figure 2: Schematic of Previous Waikouaiti WTP Process

The previous WTP had been designed for a maximum 3,200m^3/day, although the maximum achieved was 2,600m^3/d, with a typical average production of 1,240m^3/day.

Management of the sludge from the process is detailed later in the paper in section 5.1.2.

Photograph 2: Previous Waikouaiti WTP

2.3.3 ISSUES AND REASONS FOR WAIKOUAITI WTP UPGRADE

As noted previously, the Waikouaiti River led to the raw water source being of variable quality and this was particularly true during flashy river conditions. During such conditions, the previous pressure filter system suffered from filter break-through, which led to treated water of an unsatisfactory quality being supplied, necessitating frequent 'Boil Water' notices to consumers.

As mentioned above, the previous resource consent allowed a take from the river of 2,400 m^3/day., however the consent was renewed in 2006 to allow for 50-year demand projection for an allowance of 3,500 m^3/day, reducing to 1,900m^3/day if river levels are low. This meant the capacity of the WTP had to be increased also and it was required to be designed to meet a maximum capacity of 3,000m^3/day of chlorinated water to meet current demand. However, the potential for the plant capacity to be upgraded at some point in the future to provide 30% more treated water, also had to be incorporated in the design of the upgrade.

From a regulatory point of view, the previous MoH grading for Waikouaiti WTP was E, however the treatment process required an upgrade in order to meet DWSNZ 2005 and achieve a minimum of a 'B' grade for source and treatment. The upgraded WTP was also required to achieve a 4-log credit as defined by DWSNZ (2005). It had been thought that a 3-log credit would be sufficient, however a 12-month programme of cryptosporidium testing which resulted in a bad sample late in the year, meant that 4-log credit was required.

The Waikouaiti WTP upgrade formed part of a wider project to upgrade the Northern Water Schemes for the city. In addition to the WTP, 25km of new distribution pipeline was to be constructed to supply city water to rural communities of Waitati and Warrington, which had previously been supplied by individual WTPs which would be retired on completion of the scheme.

2.3.4 DESIGN OF SCHEME UPGRADE

MWH had a long standing engagement from Dunedin City Council to undertake the outline design, tender and contract administration of the Northern Water Scheme Upgrade encompassing both aspects of the upgrade: the WTP and new distribution pipeline.

3 JOINT PROCUREMENT OF WTP PROCESS UPGRADES

3.1 BACKGROUND

As the feasibility and outline design of both of the West Taieri and Waikouaiti WTPs were progressing, it became clear that there were a number of similarities between them. The sizes of plant upgrades (required output of treated water) were similar in scale with West Taieri requiring 1,700m^3/d and Waikouaiti requiring 3,000m^3/d. Both plants were fed by raw water sources which were rivers with a rural catchment and were therefore potentially suitable for the same treatment technology. Finally, the timescales for both the upgrades had begun to coincide. DCC decided that these similarities presented an opportunity for the two plant upgrades to be procured jointly. It was envisaged that this would enable any efficiencies and potential cost savings to be offered by the tenderers for joint award of both contracts, and avoid duplication of effort by all parties. This would also offer potential commonality of process, and hence operational, aspects.

Although the intention was to procure the two WTP upgrades jointly, they would remain commercially separate. Duffill Watts Group recommended that the West Taieri WTP upgrade be tendered in four parts, i.e. design and construction of process solution, and three further parts comprising construction of the new WTP building and associated civil works; inlet pipeline from raw water reservoir to WTP; and a power upgrade, all under NZS3910:2003 Conditions of Contract for Building and Civil Engineering Construction. In contrast, MWH recommended that the Waikouaiti WTP upgrade be tendered as a design and build package under 1999 FIDIC Conditions of Contract for Plant and Design and Build for Electrical and Mechanical Plant (commonly known as 'Yellow Book'), with two nominated sub-contractors regularly used by DCC.

3.2 PROCUREMENT PROCESS

3.2.1 REGISTRATION OF INTEREST

A single Registration of Interest document was produced for both projects which enabled the pre-qualification of tenderers. The information required to be submitted at ROI stage included an indicative construction programme, a preferred technology proposal and indicative pricing.

The ROI process led to four tenderers being selected to tender for the individual upgrade contracts from eight ROI submissions. It also enabled conventional process technology to be ruled out as it was evident from the ROI submissions that membrane filtration technology was favoured by the industry and becoming very cost competitive. DCC already had a membrane filtration plant supplying 35-40% of the city's water. DCC were confident that this technology resulted in higher reliability of treated water quality and less operator input during adverse raw water conditions. Furthermore, such technology would give assurance of 4 log credit being obtained from DWA.

The four pre-qualified tenderers proposed to utilise the four major membrane brands namely: Memcor, Zenon, Pall and Kolon however the last two of these membrane suppliers had little or no track record in New Zealand at that time. The risk of utilising such new technology was managed by carrying out additional investigations into their use elsewhere, gaining certification of the log removal which was promised and implementing contractual guarantees (process performance guarantee, membrane supply guarantee and parent company guarantee). However, it was evident that accepting the Pall and Kolon membranes would lead to cost competitive tenders as there was the desire from the suppliers to get established in the market.

3.2.2 REQUEST FOR TENDERS

Two separate 'Request for Tender' documents were produced to reflect the contract requirements relevant to each plant; however it was ensured that the contract conditions were co-ordinated as far as practical. Matching tendering timetables ensured that tenders for both plants were issued and closed at the same time.

Tenderers were requested to submit a single envelope containing both their price and technical submission. Tender award would be on the basis of best value for DCC.

The tender evaluation of each contract was carried out initially separately by DCC and each consultant to check individual project requirements were met. This was followed by a collective evaluation using DCC, both consultants and project management consultant Octa Associates.

3.2.3 AWARD OF TENDERS

The successful tenderer for both plant upgrades was Filtration Technology Limited who proposed a membrane filtration solution for both WTPs utilising Kolon membranes. The contract value of the upgrade at West Taieri WTP was approximately $1.5M and that for Waikouaiti WTP was approximately $2.0M.

Throughout the ROI and tendering process, technical resources from both consultants were shared to ensure the robustness of the procurement process.

4 CONSTRUCTION OF WTP UPGRADES

4.1 WEST TAIERI WTP UPGRADE

4.1.1 UPGRADE REQUIREMENTS

The West Taieri WTP process upgrade was required to achieve the following:

- Produce 1,700m3/d treated water
- Include capacity for future upgrading to produce 3,100m^3/d
- Re-use of existing items of plant where suitable
- Integration into existing electrical and SCADA control system
- Backwash/waste treatment system to be upgraded as required by the new process
- Waste to comply with existing discharge consent
- Existing WTP to remain operational through construction of process upgrade.

4.1.2 PROCESS UPGRADE

The new WTP was constructed between August 2008 and June 2009, with the other elements of the scheme upgrade, i.e. the construction of the new treated water reservoir and reticulation upgrade, being constructed at a similar time.

The WTP upgrade comprised the following main elements:

- New WTP Process
- New intake pipeline between raw water reservoir and WTP
- New treatment plant building
- Upgrade power supply

As noted in section 3.2.3 above, Filtration Technology were contracted to design, supply and install the WTP Process upgrade, with other contractors being responsible for the other contracts.

The upgraded WTP process is shown schematically in figure 3:

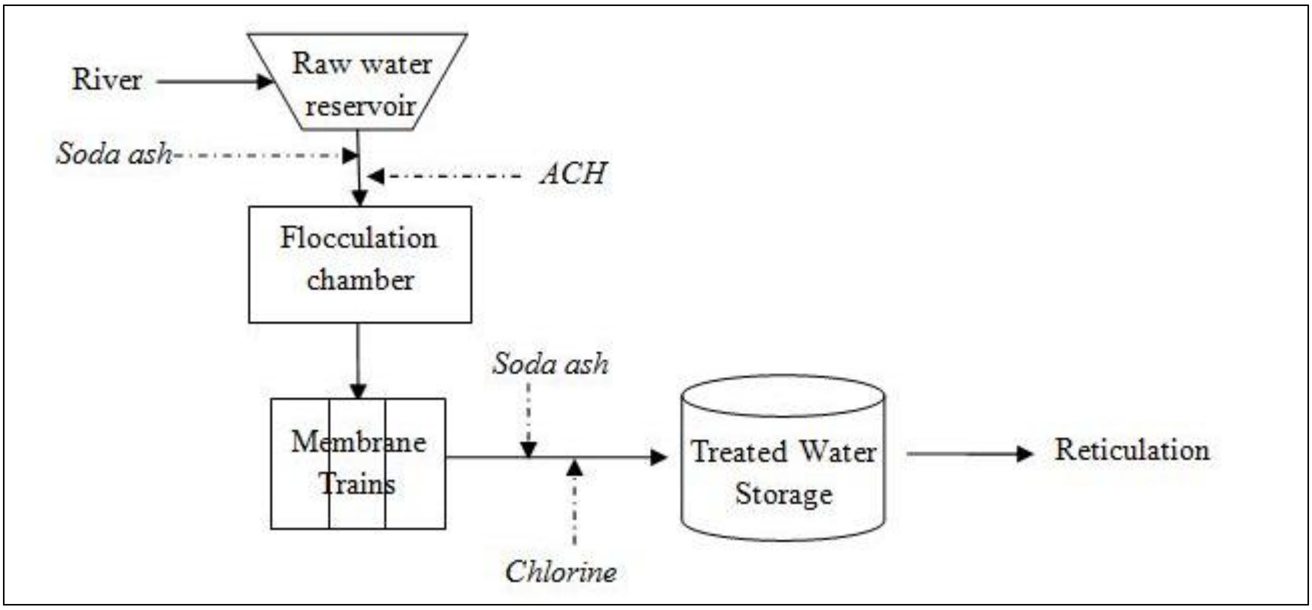

Figure 3: Schematic of Upgraded West Taieri WTP Process

Raw water is gravity fed from the raw water reservoir to a flocculation tank with mechanical mixer. Prior to entering the floc tank, it is dosed with soda ash to adjust raw water pH and also Aluminium choral hydrate (ACH) for coagulation. After the floc tank, it is pumped to a membrane system. Following the membrane filtration, the treated water is dosed with soda ash to adjust pH and chlorine gas for disinfection and pumped to the new treated water storage reservoir.

The plant is fully automated and visited daily by operational staff. Telemetry and SCADA systems enable information to be gathered and the plant to be operated remotely if required.

4.1.3 WTP & MEMBRANE OPERATION

The Kolon membranes are 0.1-0.003 micron which means the process is defined as ultra-filtration. There are three membrane trains, with each train having two membrane modules. Each module consists of 20 cassettes, in a row of 10 stacked 2 high, and each cassette has a surface area of $20m^2$ hence the total membrane surface area is $3,200m^2$. The trains operate together to produce $1,700m^3/d$. During periods of low demand, the trains can be rested on a rotational basis.

The membranes are back-pulsed, which is a short duration backwash, and relaxed every 13 minutes that a train is in operation. A maintenance clean is carried out daily which comprises an extended backwash and relax with super-chlorinated water, followed by a drain down. Wastewater from both these backwash processes is sent to the settling pond.

A recovery clean or ‘clean-in-place’ is undertaken every 6months when the membranes are soaked in-situ for 6 hours in sodium hypochlorite followed by 6 hour hour soak in citric acid. Wastewater from this process is sent to a neutralisation tank where is it neutralised before discharging to the settling pond.

The plant is fully automated and visited daily by operational staff. Telemetry and SCADA systems enable information to be gathered and the plant to be operated remotely if required.

4.1.4 COMMISSIONING

The West Taieri WTP upgrade was commissioned in June 2009, capable of a maximum treated water production of $1,700m^3/day$.

Provision for further upgrade of the WTP’s capacity had been achieved by leaving space in the WTP building for further membrane trains to be added in future.

In terms of water quality, 4 log membrane credits had been achieved through the use of Kolon membranes. This new membrane technology had been successfully introduced to New Zealand and produced a high quality, reliable treated water.

At the time of writing, DCC had yet to apply to MoH for an official DWSNZ grading for West Taieri WTP, however it should be capable of receiving an 'A' grading.

4.2 WAIKOUAITI WTP UPGRADE

4.2.1 UPGRADE REQUIREMENTS

The Waikouaiti WTP upgrade was required to achieve the following:

- Produce 3,000m3/d treated water
- Include capacity for future upgrading to produce further 50%
- Re-use of existing reservoirs, ponds, WTP building and chlorine system where suitable
- Integration into existing electrical and SCADA control system
- Backwash/waste treatment system to be upgraded as required by the new process
- No increase to existing discharge consent of 120m^3/d at a maximum rate of 30l/s.

The existing WTP could be taken offline during construction of process upgrade. In this situation, chlorinated raw water could be supplied to consumers, along with a 'Boil Water' notice. It should be noted that MoH approval was sought in advance of this potential course of action required.

4.2.2 PROCESS & MEMBRANE OPERATION

The new WTP was constructed between October 2008 and January 2009, with the other elements of the scheme upgrade, i.e. the distribution network, being constructed at a similar time.

As noted in section 3.2.3 above, Filtration Technology were contracted to design and build the WTP process upgrade.

After the raw water reservoir, the upgraded WTP process at Waikouaiti is largely identical to that at West Taieri as described in section 4.1.2 above. The only difference is that due to the additional flow requirements compared to West Taieri WTP, the Waikouaiti WTP has an additional membrane train, making a total of four trains.

The membrane operation including back-pulses, maintenance and recovery cleans is identical to that at West Taieri WTP. Wastewater from the membrane process is sent to a tube settler tank before discharging to the settling lagoons.

Also similar to West Taieri WTP, the plant is fully automated and visited daily by operational staff. Telemetry and SCADA systems enable information to be gathered and the plant to be operated remotely if required.

4.2.3 COMMISSIONING

The Waikouaiti WTP upgrade was commissioned in February 2009, capable of a maximum treated water production of 3,000m^3/day.

Like West Taieri WTP, provision for further upgrade of the WTP's capacity had been achieved by leaving space in the WTP building for further membrane trains to be added in future.

Also like West Taieri WTP, in terms of water quality, 4 log membrane credit had been achieved.

MoH granted an official DWSNZ grading of the Waikouaiti WTP of ‘A’ in December 2012.

Photograph 3: Waikouaiti WTP membrane trains

4.3 SUCCESS OF THE WTP PROCESS UPGRADES

DCC consider that the main success of both WTP upgrades was the elimination of the variable quality of treated water being sent to the distribution system which had previously resulted from the variable raw water quality. Since the successful commissioning of the plants, the consumers have enjoyed a far more consistent quality treated water at their taps.

For both WTPs, while the cost of treating the water has risen, it has actually been a lesser increase than had been originally expected. DCC operational staff are continuing to streamline the processes, and it is hoped that this will continue to reduce costs without compromising quality.

Achieving ‘A’ grading for Waikouaiti WTP and being expected to achieve the same for West Taieri WTP exceeded the original expectations for both WTP upgrades.

5 SLUDGE MANAGEMENT

5.1 ISSUES

5.1.1 WEST TAIERI WTP

Under the previous WTP process, backwashes from the AVG were discharged to a backwash settling pond where suspended solids settled out and the supernatant liquid was siphoned off to discharge to a nearby gully between backwash cycles. DCC holds a permit for this discharge which limits it to 320m3/d.

This settling pond was drained and the sludge transferred by pump to two adjacent shallow drying pits every 4-6 months typically. In the drying pits, the sludge was allowed to dry via evaporation and any supernatant was siphoned back off to backwash pond. However, the drying process was not very efficient and the moisture content of the semi-dry sludge remained high. Sawdust was mixed with the sludge to facilitate removal and transportation of it. It was removed on a biannual basis and transported to the local landfill 34km away, incurring both transportation and disposal costs of approximately $13,000 per year.

The upgrade of the plant in 2009 resulted in an increased volume of sludge production resulting from both the new process (a finer filtration than previously) and the increased capacity. Furthermore, the new process used a different coagulant in ACH. These factors combined to produce a finer sludge which was more difficult to dry.

The settling pond no longer worked as previously and this resulted in the drying pits needing to be emptied every 2-3months. The sludge was wetter and had to be removed using vacuum 'sucker' trucks and transported to landfill, and the higher water content increased the volume for disposal. All of these resulted in a much increased cost of sludge management of $37,500 per year.

Photograph 4: Previous backwash/settling pond and drying pits at West Taieri WTP

5.1.2 WAIKOUAITI WTP

Under the previous WTP process, water from the raw water storage reservoir was used for backwashing the filters. The backwash water was then discharged to one of four lagoons on site, where it was settled prior to discharge of the supernatant to an adjacent watercourse. DCC holds a permit for this discharge of $120m^3/d$ at a maximum rate of 30l/s.

The lagoons were emptied by using a sucker truck and the contents taken to Tahuna Wastewater Treatment Plant (WwTP), 30km away in Dunedin city. Due to the number and volume of lagoons available, this operation was carried out on an annual basis, at an approximate cost of $50,000.

As part of the new membrane process upgrade, a tube settler was installed. This added an additional front-end stage to treatment of wastewater from the process. Wastewater is fed into the tube settler initially and from here, the sludge is discharged to one of four lagoons on site, in the same way as previously. However, consistent with the findings at West Taieri WTP, the new sludge was wetter and there was a greater volume of it, requiring an increased frequency of disposal. The cost of this increased waste management was $73,000 in 2010-2011.

Photograph 5: Typical settling lagoon at Waikouaiti WTP

6 NEW SLUDGE MANAGEMENT STRATEGIES

6.1 CONSULTANT APPOINTMENT

Following their involvement in the process upgrade at West Taieri WTP, CPG consultants were again employed in December 2009 to review options for more efficient dewatering and methods to excavate and remove the sludge from site.

Similarly, based on MWH's involvement in the process upgrade at Waikouaiti WTP, MWH were commissioned in November 2009 to assist with the development of a long term sludge management strategy for the plant.

6.2 WEST TAIERI WTP

6.2.1 WEST TAIERI OPTIONS CONSIDERED

CPG undertook investigations in the chemical composition of and estimated likely volumes for the sludge now being produced at the WTP.

CPG had calculated that the total dry solids produced per year was 4,700kg/year and depending on the solids content, this would result in a sludge production of ranging between 30-119,000kg/year based on 16-4% dry solids respectively. Laboratory testing showed that the sludge from the existing drying pits had a solids content of around 4%.

Current and alternative methods to remove and dispose of the sludge from the WTP were reviewed, as were various options to dewater the sludge thereby increasing the solids content of it. An assessment was made of the following options:

- Status Quo – the sludge is left to dry on site in the drying ponds and they would continue to be removed and transported to landfill

- Discharge to Forest – the sludge would be directly removed from backwash pond by sucker truck and then discharged to land in a nearby forest

- Improve Drying Pits – the surface area of the drying pits would be increased to improve their effectiveness. Sludge would still be removed and transported to landfill.

- Dewatering geobags – geotextile bags would be filled with polymer-dosed sludge and leachate would drain from the bags. The dewatered sludge would still be removed and transported to landfill.

- Mechanical dewatering e.g.

    - Belt presses – sludge is sandwiched between two porous belts and passed over and under rollers of various diameters. As the roller diameter decreases, pressure is increasingly exerted on the sludge, squeezing out the water.

    - Centrifuges – a process which uses the force developed by fast rotation of a cylindrical bowl to separate solids from liquids.

A Net Present Value (NPV) analysis was carried out on the above options considering investigation, capital and operational costs. This showed that the capital costs of improving the drying pits and mechanical dewatering equipment (whether as a permanent installation or portable system) would involve significant capital costs. The lowest NPV and most cost effective option for on-going sludge management at West Taieri was found to be dewatering geobags and it was determined that these should be therefore investigated further.

6.2.2 PRINCIPLE OF GEOBAGS

The principle behind geobags is as follows: polymer-dosed sludge is pumped into a high-strength permeable material. Excess water drains from the bag through the small pores in the bag material, resulting in dewatering and volume reduction of the contained material. This volume reduction allows for repeated filling of the bag. The excess water or leachate drains back the WTP.

After the final cycle of filling and dewatering, the retained material can continue to consolidate by evaporation as the residual water vapour escapes through the fabric. The bag can then be cut open and the solids excavated and transported for disposal.

The advantages of a geobag system are that it would be a gravity dewatering system, with no moving parts. The system resulted in lower capital and operational costs because the solids content of the sludge would be higher than previously, hence less volume would require disposal.

6.2.3 PILOT TRIALS

Having determined that the use geobags was the preferred option, CPG carried out pilot trials on site at West Taieri WTP to confirm their effectiveness in August 2010.

A sample of sludge was collected from the backwash pond and a polymer was added and mixed to improve flocculation of the sludge (the polymer having been previously selected following laboratory tests to determine the optimum type). The dosed sludge was poured into a test rig consisting of a scaled down geobag 500mm x 500mm which filled with approximately 40litres of sludge. The frame and geobag was left uncovered and any rain which fell on and entered the bag was assumed to imitate the real life situation.

The bag was monitored daily to check the volume of water draining from it and the height of the bag. At the start, mid-point and end of the test, sludge samples were removed and laboratory tested for total solids (TS). The results from the trial showed:

Day 1 – 4% total solids (TS)

Day 2 – 49% of total volume of the bag had drained away (most of this occurred in the first 25 minutes of the test)

Day 3 – very little water draining out of water

Day 7 – drainage had completely stopped.

Day 14 – 12% TS and no change to volume

Day 30 - 12% TS and no change to volume

CPG considered that total solids of 12-16% could be achieved with longer settling and given a full-scale operation.

As a result of the pilot trial the estimated capital cost of a full-scale geobag system were revised and increased, however, the revised NPV analysis still resulted in this system being the most cost effective option. DCC accepted CPG’s recommendation that a full scale system be designed and installed.

6.2.4 DESIGN OF FULL SCALE SYSTEM

Design of a full scale geobag system was undertaken by CPG and the project was procured in two contracts: the civils work and the chemical dosing system. Both contracts were tendered competitively in April/May 2011, with Fulton Hogan Ltd. being awarded the civils contract and Chemical Feed Solutions Ltd. being awarded the chemical dosing contract.

6.2.5 CONSTRUCTION OF THE FULL SCALE SYSTEM

Work on site began in June 2011 and the completed geobags system was commissioned in November 2011. The civils work comprised:

- Installation of submersible pump and intake structure in backwash ponds
- Reshaping of backwash pond
- Conversion of redundant AVG filter into a mixing tank (removal of existing filter chamber and pipework and reshaping of floor, installation of submersible mixer)
- Construction of a new shed to house dosing equipment
- Backfilling of existing drying pit to enable construction of platform to support geobags and allow them to drain by gravity into backwash pit, including retaining wall
- Associated pipework

Chemical Feed Solutions then supplied and installed the polymer-dosing equipment. The polymer used is an emulsion polymer called Crystalfloc DW12 which is supplied in 20litre containers and it is diluted in two stages to achieve a solution of 0.1-0.2%.

The capital cost of the new sludge management system was approximately $220,000 which was about 15% of the value of the plant process upgrade.

The system is shown schematically in figure 4:

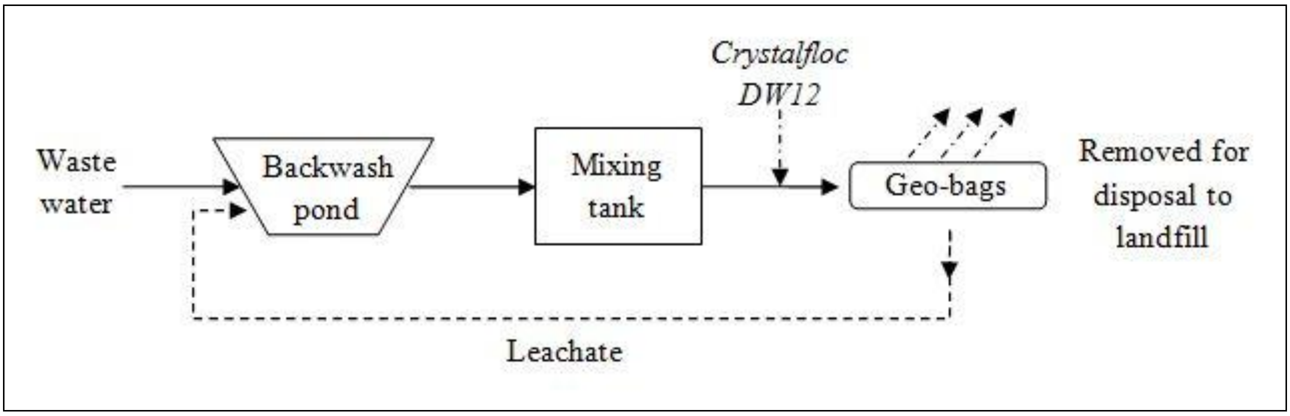

Figure 4: Schematic of West Taieri WTP Geobag System

6.2.6 OPERATION

Use of the new system began in November 2011 and the geobags were progressively filled over the next 10 months.

During this time, polymer dose rates were optimized to provide the best consistency of sludge between transferred into the geobags.

After 10 months, the bags were allowed a final 14-day period to dry off before they were removed from site. Results of dewatered sludge were analysed and showed a TS content of between 9.5-10% (compared to target TS of 12-16%). This resulted in less volume requiring disposal to landfill and an estimated annual cost of removal/disposal of $14,000.

In addition to the savings in disposal costs, there had been an additional benefit of saving in time/cost of operational staff. Previously they had had to handle pumps and hoses to transfer the sludge from settling pond to backwash pond, with this operation taking up to 8-10 hours. The new process only required them to operate switches and open valves, taking a much reduced time of 2-3 hours.

Photograph 6: Geobag System at West Taieri WTP

6.2.7 RESOURCE CONSENT IMPLICATIONS

The new sludge management system required no change to the existing discharge consent. The leachate from the geobags drains into the backwash pit, from where the supernatant is still discharged to the nearby gully as previously. The addition of the polymer to the sludge would however result in a small amount of it occurring in the leachate. However the concentration of polymer in the leachate would be low as it is designed to react with the sludge. Furthermore any polymer in the leachate would be diluted with water from the backwash pond and would be likely to bind with remaining sludge in the backwash pond. These factors were advised to the Otago Regional Council who confirmed than no variation was required to the existing discharge permit.

6.3 WAIKOUAITI WTP

6.3.1 WAIKOUAITI OPTIONS CONSIDERED

MWH undertook the first stage of the project in November 2009 which included an estimate of the annual sludge production, a preliminary review of the potential treatment and disposal options, and recommendations on further investigations. Stage 2 comprised review of the data from these investigations to determine which treatment and disposal routes were still available given the contaminant concentration. A whole life cycle cost assessment was carried out of those remaining options.

MWH reported that analysis of sludge from the sludge lagoon showed dry solids concentration of 2.4% and an annual quantity of sludge produced of 8,991kg total dry solids/year.

Current and alternative methods to remove and dispose of the sludge from the WTP were reviewed, as were various options to dewater the sludge thereby increasing the solids content of it. An assessment was made of the following options:

- Status Quo – the sludge is left to settle in lagoons on site and then disposed of to Tahuna WwTP

- Application of sludge to land - the sludge would be directly removed from lagoons by vacuum truck and then discharged to adjacent land or in a nearby forest

- Dewatering and disposal to landfill or cleanfill

- Mechanical dewatering by plate presses –sludge is placed between vertical plates and a hydraulic cylinder is used to compress the sludge, dewatering it and forming a cake. The cakes are then disposed of to landfill, cleanfill or forest.

- Geotextile bags – using the same principle as those at West Taieri WTP, with disposal of dewatered sludge to landfill or forest.

- Reed beds – the sludge is discharged into a bed where reeds are growing and the reeds dewater the sludge which is then disposed of to forest.

MWH used a cost model to assess and determine the NPV of the above options. It showed that the current system of settling the sludge in lagoons followed by removal and disposal to Tahuna WWTP was not the least cost option, plus it was very sensitive to cost of haulage. Dewatering using reed beds was assessed to be the lowest cost option, provided that the dewatered sludge could be disposed of to land. The total NPV of the geotextile bags and plate press dewatering options were similar to that of the current system.

It was therefore recommended that the feasibility of reed beds should be further investigated to determine appropriate species of reeds, loading rates and efficiency of dewatering.

6.3.2 PRINCIPLE OF REED BEDS

Reed beds are specially-designed ponds with underdrains covered by a sand and gravel mixture which are constructed and filled with common reed plants. Sludge is then pumped into the reed beds which then perform three basic functions: (1) dewatering the sludge, (2) transforming it into mineral and humus like components, and (3) storage of the sludge for a number of years.

Dewatering is achieved via three methods: through evaporation (as in a normal sludge drying bed operation); transpiration through the plants root stem, and leaf structure; and filtration through the bed's sand and gravel layers and the plant's root system. Leachate is channelled back to the treatment plant through an underdrain.

At the end of the dewatering process, the dewatered sludge, the underlying drainage layer and the reeds themselves are dug out and taken away for disposal.

Reed beds are essentially a passive system, with dewatering occurring without the use of chemicals (unlike geobags) and having a low energy requirement, only requiring the sludge to be pumped into the reed bed.

Reed beds are better known for dewatering of sewage sludge than water treatment sludge and research has shown reeds beds to be effective in dewatering ferric sludge to between 30-40% dry solids, given the right conditions. However at the time of MWH’s investigations, there was little information regarding the suitability of reed beds for dewatering ACH-based sludge, as produced at Waikouaiti WTP.

6.3.3 PILOT TRIALS

From March 2011 to April 2013, a pilot trial comprising three reed beds was undertaken at Waikouaiti WTP. The first year involved the growing of the reeds from small plants to fully grown at a reduced sludge loading. In the second year, the sludge loading was gradually increased, until over the summer of 2012 the beds operated at the maximum applied load of the trial period. In early 2013, the sludge loading was stopped and the beds were left to dry out until April 2013 when the trial finished.

The trial beds were sited in an area to enable the sludge to feed by gravity from the tube settler to the reed beds and the filtrate from the beds to gravitate to one of the lagoons. This avoided the need for any pumped flows. After entering the reed beds, the water flowed vertically down through the bed through an underdrain system. The beds effectively acted as a filter to remove sediment and other solids from the water whilst dewatering the sludge as it accumulated. The leachate was collected and fed to the existing lagoons.

The three reed beds each had an area of $4m^2$ and this was based on a design loading rate of 30kg dry solids/m^2/year, based on trials carried out for the Hanningfield WTP in the UK. The trial beds were sufficient to treat 360kg dry solids per annum, which compares to an estimated annual sludge production from Waikouaiti WTP of 8,991kg dry solids.

The species of reed commonly used in reed beds in Europe is *phragmites australis* but this cannot be used for reed beds in New Zealand because it is classified as an 'unwanted organism' under the Biosecurity Act 1993. As an unwanted organism, it is illegal to knowingly release or spread, display or sell, breed, propagate or otherwise distribute this species. Three potential alternative native plant species were chosen for the trial from those suggested by a plant nursery, one of whose specialisms was in effluent treatment. These had to be tolerant of permanent submergence, robust and evergreen in order to resist winter. Each type of reed was trialled in its own bed.

The beds were dosed with sludge over a week on a monthly basis, i.e. one week dosed, 3 weeks not and five different dosing regimes (length of and frequency of dosing) were trialled. Regular sampling of the sludge feed, the filtrate and the dewatered sludge was undertaken throughout the trial.

Photograph 7: Reed Bed Trial at Waikouaiti WTP

The results of the pilot trial were as follows:

- a suitable reed species had been identified
- a dry solids of 20% was achieved during normal sludge loading regime, this increased to 60% after a 6-8 week drying period
- the dry solids content was considerably better than could be achieved with a geobag or centrifuge and at a much lower NPV.
- a change to the discharge consent may be required to allow a higher aluminium concentration in the filtrate.

Based on the above, MWH recommended a full scale trial be undertaken by converting one of the settling lagoons into a reed bed.

6.3.4 NEXT STEPS

At the time of writing, DCC is assessing the results of the pilot trials and MWH's recommendation. Consequently, at this stage it is not possible to confirm which solution will be implemented at Waikouaiti WTP.

7 CONCLUSIONS

DCC benefitted from the upgrade of both West Taieri and Waikouaiti WTPs utilising the same membrane filtration process. The benefits included cost saving at the construction stage and common technology and operation.

Whilst the additional sludge produced by the upgraded plants was identified as a risk at the time of the process upgrades, it was not fully considered. However it was only since the new WTPs had been in operation for a number of months that the issue was able to be quantified and potential solutions investigated.

Geobags have proved to be an effective sludge management solution at West Taieri WTP and enabled operational cost savings. This solution was particularly suited to West Taieri WTP as space was very limited within the existing WTP site. A reed bed scenario would not have worked without purchasing more land, adding to the capital cost. In addition, Waikouaiti WTP has a tube settler which will help concentrate the sludge going to the pond.

The next steps for improved sludge management at Waikouaiti WTP are still under consideration. Use of reed beds has yet to be proven at full scale for WTP sludge in New Zealand and DCC consider that a number of risks remain which have yet to be clarified.

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