DE-SILTING THE HELENSVILLE RAW WATER DAM

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ABSTRACT

How do you de-silt a raw water supply dam while keeping the plant fully operational? The answer was not obvious as the traditional de-silting techniques posed significant risk to the continuity of the drinking water supply. In late January 2010 Downers, in conjunction with Monitoring Technologies Commercial Diving, used divers to utilise a siphon to de-silt 4,500 to 5,000m^3 from the primary raw water dam in Helensville. This approach was used not only because it was cost effective but also presented the minimum risk. There were no hydrocarbons on site, little sediment stir, no downtime to operations, and it had the lowest potential environmental impact. The whole process was completely recyclable with the filtered centrate returned to the dam, requiring no special consents and the resulting sludge is likely to be used by the local farmers. This paper outlines the method used and details the risk and environmental impact minimisation deployed by Downers during this sustainable project.

KEYWORDS

Raw Water Dam De-Silting, Taste and Odour Reduction, Sustainability, Divers, Dredging, Geo-Textile Filter Bags.

1 INTRODUCTION

How do you increase capacity of a raw water dam and reduce taste and odour compounds (T&O) whilst keeping a water treatment plant operational? This paper outlines the process by which this was done for one of the Mangakura Dams in Rodney District Council (RDC). The raw water supply overview will be described and what type of taste and odour compounds the supply had historically suffered and why the RDC needed to remove the sediment within the dam.

Previous analysis of de-silting the dam was undertaken in 2008 estimating the costs to be between $1,750,000 and $2,830,000. To determine which methodology was to be used a risk profile was carried out to minimise the environmental impact, keep the plant operational and avoid contamination of the raw water supply. The actual methodology used to de-silt the dam was novel and involved the use of divers to dredge the sediment out of the dam. The reasons why this approach was selected will be described and how the process met these criteria.

The quality of the water before and after the exercise is documented highlighting the effectiveness of the de-silting on the T&O compounds. The concluding benefits are outlined, including 100% recyclable waste and sustainability at significantly lower costs than those initially estimated. The environmental and operational benefits of the methodology will be described and how close co-operation with the stakeholders aided in the success of this project.

2 BACKGROUND:

2.1 MANGAKURA DAM RAW WATER SUPPLY OVERVIEW

There are five raw water dams at Mangakura that service the Helensville Water Treatment plant. The catchment of these dams is natural reserve with very little farm contamination. There is also a natural spring/stream called 'Sandhills' that contributes to the raw water at Mangakura Dams. Raw water can be pumped from either source or a combination of both to meet the demands of the town.

The raw water is pumped from Sandhills' intake 2-3 kms across Narby Farms where it is stored at three break tanks held at Mangakura Dam 1. The overflow from these tanks is taken up by Dam 1. Although there are five dams at Mangakura, only Dam 1 is generally used to service the treatment plant. Typically the treatment plant operates in the summer on a blend of water made up of 70% Sandhills and 30% Dam 1. During the winter usually only Dam 1 is utilised. The raw water is pumped to the plant at the flow required utilising three duty pumps via one rising main. For a geographical overview see photograph 1.

Photograph 1: *Overview of the Raw Water Supply.*

2.2 TASTE AND ODOUR (T&O) SOURCE

Over a number of preceding years T&O compounds (predominately geosmin and 2-methyl-isoborneal (MIB)) had been building up in raw water from Dam 1 with geosmin reaching a peak of 1,889 ug/l in March 2009. Considering the recognised taste threshold for geosim is approximately 9 ug/l, the elevated levels were placing a large process load on the water treatment plant and attention was turned to the raw water source.

The source of the T&O compounds in the raw water was not fully determined but it was suspected that it was associated with filamentous bacteria and/or algae. Although the role of gram-positive filamentous bacteria (predominately actinomycetes) in producing T&O compounds in raw waters is unclear[i] they have long been thought to contribute and increased actinimycete numbers[ii] have been coincident with T&O events[iii]. The ability of actinomycetes to produce T&O compounds is well understood[iv,v]. Actinomycetes are common in soils[vi] and have been found in bottom and suspended sediments in the aquatic environment[vii,viii].

It was believed that removing the silt from Dam 1 would have the dual effect of reducing the T&O compounds in the raw water and would also increase the storage available within the dam.

2.3 SILT SURVEY AND INITIAL COST ESTIMATE

In the middle of 2008 RDC commissioned Pattle Delamore Partners Ltd to perform a "Silt Survey" of the Mangakura Dam (Dam 1)[ix] to determine the amount of silt deposit in the basin. This survey used a hand held GPS and a probe that was lowered into the dam to measure the top level and thickness of the silt in the dam.

From the survey an underwater contour of the silt layer was produced (see photograph 2) and based upon the silt survey it was determined that between 7,660 and 8,930 m^3 of sediment had built up in the dam. This volume represented approximately 10% of the total storage volume of the dam.

***Photograph 2:** Silt Contours in Dam 1*

The initial Engineers' estimate "*based upon previous work undertaken*" for the silt removal was between $1,750,000 and $2,830,000. This represented a significant cost and RDC approached Downer Water (the encumbered operations contractor) to assess if an alternative more economic solution to de-silting Dam 1 was possible.

3 DESILTING METHODOLOGY ANALYSIS

3.1 RISK PROFILE

When considering options for de-silting, a risk profile was drawn up following AS/NZS4360:2004 (for brevity we will not go into the full extent of the risk profiling). The key risks identified were:

1. Continuity of Raw Water Supply.
2. Contamination of Raw Water.
3. Environmental Contamination.

3.1.1 CONTINUITY OF RAW WATER

As the de-silting was to be performed during the summer months the plan was to use both the Sandhills and Mangakura raw water sources. This required the intake at Dam 1 to remain operational during the de-silting. The risk associated with the de-silting around the intake was sediment stirring resulting in poor quality raw water entering the plant. Sediment stirring had the potential to:

1. Release significant amounts of turbidity into the water column.
2. Release T&O compounds into the water column.
3. Release undesirable organics and dissolved gasses (H_2S etc) into the water column.

The Risk Mitigation taken to manage these events was to:

1. Isolate the intake structure with a floating boom filter cloth for the duration of the de-silting operation.
2. Implement a targeted monitoring programme at the pump station as an early warning as the time of flight of the raw water from the pump station to the treatment plant was approximately three hours.
3. Modify the operation at the treatment plant. This included:
    a. Increasing the powdered activated carbon does by approximately 50%.

b. Running the treated water reservoirs at elevated levels to allow the treatment plant to be shut while letting the sediment to settle again.
c. Increasing the intermediate chlorine dose.
d. Having a full contingency planning to cut over to the Sandhills supply if the Dam 1 raw water becomes undesirable.

3.1.2 CONTAMINATION OF THE RAW WATER

Contamination of the raw water in Dam 1 was also of high concern, in particular from hydrocarbons contamination. The recent RDC experience of the diesel spill upstream of the raw water intake to the Warkworth Water Treatment Plant meant that the project team was well versed in the lingering nature of hydrocarbons in the water course and for this reason ***ANY*** de-silting methodology was not to use any hydrocarbons that could potentially spill into the dam.

The site was to be fully demarcated across the crest of the dam with the upstream side (Lake Side) of the dam not to have any source of hydrocarbons. The downstream side (Dam Face Side) was permitted to use equipment that had hydrocarbons.

3.1.3 ENVIRONMENTAL PROTECTION

A methodology was to be implemented in such a way to:

1. Have minimal effect on the environment.
2. Minimise water wastage during de-silting.

This required the water fraction from the de-silting, where possible, to be returned to the dam.

3.2 METHODOLOGY INVESTIGATION

There were two components of the investigation into a suitable sediment removal from the dam. The first involved the mechanism for the removal of the sediment and the second related to the treatment of the sediment once removed from the dam.

3.2.1 SEDIMENT REMOVAL

Several methods for the de-silting of the dam were initially considered, but each of the conventional methods had fatal flaws from a risk perspective so were discounted. The options considered and the reasons for discounting were:

1. Empty the dam and mechanically dig out the sediment. This option (although very dangerous to the earth dam structure blowing out from pore water pressures) was discounted as it did not provide continuity of supply and the use of digging equipment within the dam could give rise to hydrocarbon contamination.

2. Using traditional methods of pumping the sediment out of the dam. This was discounted due to the machinery required to remove the sediment. Although there was enough power on site for the use of electrical sludge pumps the cost of the procurement of the pumps and the initial setup cost ruled out this option. An alternative of using water driven hydraulic pump unit was also briefly considered but also discounted due to cost.

3. Flushing the dam using the existing scour valve. This was discounted as dam inspections had confirmed that the scour point was below the top sediment level and there was concern that the sediment could block the scour valve leaving an untenable operation condition. It was also believed that the scour point would only flush the area adjacent to the intake tower and would have very little effect on the sediment in the rest of the dam.

There was a further option of using divers to hand dredge the sediment. From all the options considered the use of divers was considered the only viable option as the dredging could be performed using a siphon meaning the all the risk factors could be mitigated. However the use of a dive team to perform the dredging brought another set of risks to the project and needed to be done in strict accordance with AS/NZS2299:2007.

After only a brief investigation it was very quickly determined that the traditional methods for de-silting working raw water dam were very limited and the only viable method was through the use of professional commercial divers that were familiar with dredging and water supply. At this stage Monitoring Technologies Commercial Dive Limited were brought on board to work through the methodology for the dredging operation, as this company had significant experience in all aspects of commercial diving associated with potable water supply and is the only commercial dive company in New Zealand suitably qualified for this type of work.

3.2.2 SEDIMENT HANDLING

Several options were considered for the sediment handling. From the beginning it was recognised that the sediment was going to be fluid and only contain in the region of 1-1.5% solids. A system needed to be developed where the solids were captured and centrate was of a suitable quality to be returned to the environment.

Several options were considered for the capture of the sediment. These include the deployment of a centrifuge, chemical dosing and the use of geo-textile filter bags. The centrifuge option was discounted from the need of a large buffer storage facility for the feed water. Chemical dosing was also discounted due to the possible presence of chemical residuals (alum and or polyelectrolyte) in the centrate, therefore geo-textile filter bags were selected as the preferred medium.

Once geo-textile filter bags were settled upon as the methodology for capturing the sediment, a method to return the centrate to the dam needed to be devised. The project team decided to add a final filtration step of hay bales at the discharge to the centrate to the dam. This was done for two reasons: firstly the hay bales would capture a large proportion of the sediment that passed through the geo-textile bags and, secondly, would act as a flow dissipater which reduced the scour potential of the water going back into the dam.

4 DE-SILTING SETUP

The methodologies called for divers to hand dredge the sediment from the Dam. To satisfy the requirements of the prevailing commercial diving standards (AS/NZS:2299:2007) it was necessary to have a minimum dive team size of three (one supervisor, one diver and one standby diver). As dredging was being used it was necessary to have the dicers on surface supply and reliable hardwired communications.

The fist component of the site setup was to isolate the intake by running a floating screen filter cloth around the intake point. This was achieved by using a spider lashing and warratahs to pin the bottom of the filter cloth to the bed of the dam. As the job progressed, the filter cloth was sucked in towards the intake screen. It is recommended that at least a 5m setback is used between the filter cloth and the intake for a project of this duration. Should a longer dredging operation be considered then a greater setback or two sets of floating filter cloth (so one set can be changed with a clean set) should be used.

The dredging and centrate return schematics are shown in Figure 1. The dredging was achieved with a siphon over the crest of the dam. A quick siphon break was used at the apex of the dam to allow the Dive Supervisor to break the siphon should the diver require it. The siphon break point was also used for priming of the dredge. Once the water had flowed through the geo-textile bags it was then allowed to flow to a closed culvert. A high lift diesel driven pump then sucked centrate out of the culvert and pumped it up over the crest of the dam. The centrate was then directed into a hay bale bund and then into the dam via raupo reeds.

The sediment was an anerobic sludge, black in colour with the centrate being a light grey colour. During the operation the discharge point in the dam was monitored for high concentrations of the grey centrate entering the dam. No sign of the centrate was noticed in the dam.

Two geo-textile filter bags were used as this allowed one bag to be filled in a single day of operation. The next day the bags would be swapped over and the first bag was allowed to rest. During the filling operation the geo-textile bags grew to approximately 1,800 mm high by the end of the day and would shrink down to approximately 700 to 1,200 mm high after a day of rest.

A photo essay of the project setup is shown in photographs 3 to 7 below.

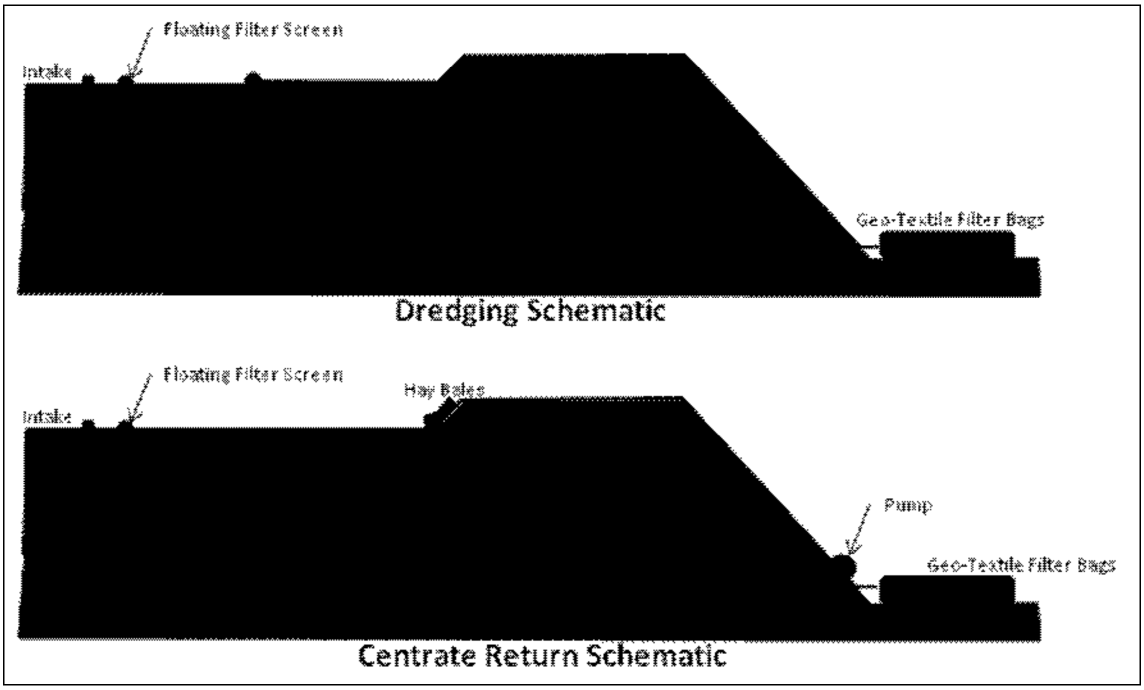

Figure 1: *General Arrangement of Dredging Operation.*

Photograph 3: *Siphon Priming System.*

Photograph 4: *Diver on Surface Supply Entering the Water*

Photograph 5: *Floating Filter Cloth around Intake.*

Photograph 6: *Computer Monitoring of Divers in Zero Visibility*

Photograph 7: *Diver on Surface Supply Swimming to Dredge Face.*

5 PROJECT OUTCOMES

The success of this project was measured on a number of levels and each key outcome is discussed below.

5.1 CONTINUITY OF SUPPLY:

Throughout the entire de-silting operation the treatment plant only needed to be shut down on two occasions. The first was the installation of a floating filter boom around the intake and the second when the divers were inside the floating boom around the intake removing the silt. The total shutdown period for the ten day operation was six hours.

The raw water was monitored throughout the de-silting operation and an increase from approximately 12-15 NTU to 15-20 NTU was noted at the plant. This was considered insignificant to the water treatment plant operations and the plant operated normally (see figure 2).

Approximately half way through the diver operation it was decided to flush the rising main from the Mangakura pump station to the plant. This was done as a periodic flush was scheduled and also as a precaution "*just in case*" large debris had entered the rising main which could subsequently be mobilised. The flushing caused a turbidity spike at the plant that peaked at 188 NTU but during this time the raw water was flushed to waste and did not cause any operational issues.

Figure 2: *Raw water Turbidity during De-silting*

After the de-silting operation, slightly elevated raw water turbidities were noted at the plant for a further ten day period, then the raw water settled down to the levels we would expect from this supply.

5.2 ENVIRONMENT PROTECTION:

The de-silting operation was performed under "*maintenance*" provisions of the Dam consent. As the system was closed loop (i.e. no discharge from site), no discharge monitoring was necessary. There were no noticed effects on the environment. During the dredging the discharge point into the dam was monitored and not noticeable effect on the lake adjacent to the centrate discharge point was recorded.

5.3 SEDIMENT REMOVAL:

It was estimated that a total of 4,500-5,000 m^3 of 1-1.5% sediment was removed from the Dam over the 10 day period. During the sediment removal the divers reported pockets of sediment up to 1.8m deep. When removing the sediment the divers worked in a series of arcs and could easily differentiate between sediment and the dam lining. The area dredged by the divers is shown in photograph 8.

Photograph 8: *Area De-Silted*

The divers also noted that there were a number of dead tree structures in the base of the dam. If remote controlled dredging using mechanical means was used these structures would have caused entanglement issues and potentially slowed the job progress down. With suitably qualified and experienced divers it was straight forward to dredge around these obstacles.

Also during the dive a rock wall was encountered. This rock wall was believed to be part of the enabling works that were constructed to divert the stream flow during the construction of the original dam. There was significant silt built up around this wall which slowed the operation down as the divers were required to dredge between the rocks taking care not to dislodge the structure (this could have caused an entrapment issue).

During the operation the geo-textile filter bags inflated to a height in region of 1.8m. Once left to dewater for six months the geo-textile filter bags have settled to an average height of 400m. As the sediment is now very firm it is estimated that the water content is in the region of 20-30% solids, and this represents a total of approximately 80 m^3 of dry solids. The original estimate for the total amount of sediment in the dam was 89-135 m^3 of dry solids within the dam (assuming 8,930 m^3 of sediment at 1 – 1.5% solids). It is now believed that the initial survey had difficulty determining the top and bottom layers of the sediment and as such underestimated the total amount within the dam.

Photograph 9: *Geo-Textile Filter Bags being filed.*

Photograph 10: *Geo-textile filter bags after 6 months of dewatering.*

5.4 REDUCTION IN T&O COMPOUNDS:

The RDC has had a structured programme of recording geosmin in Dam 1 from early 2008 to present. The measurements are more frequent during the summer months and measure background geosmin concentrations during the winter months. Prior to the de-silting significant summer peaks of geosmin were measured during the 2008 and 2009 summers, however after the de-silting only background levels of geosmin were recorded through the summer of 2010 (see figure 3). Although it has only been six months since this project has been undertaken the results of analysis of geosmin measurements indicate a significant reduction in geosmin levels. The success of the reduction of T&O compounds will only be proven after another summer of measurements.

Figure 3: *Geosmin Concentrations Measurements*

5.5 PROJECT COST:

As stated above the initial Engineers' estimate for the project was $1,750,000 and $2,830,000. The total cost for diver dredging of the sediment complete with setup and operational cost was $153,562 (approximately 9% the lower end of the Engineers' estimate) and a total of 4,500-5,000 m3 of sediment was removed, approximately 60% of the initial sediment estimates.

6 CONCLUSIONS:

Overall this project was extremely successful. As with any project of this type several lessons were learnt along the way which will result in a more efficient methodology for similar projects. The key project success factors and lessons were:

1. Dredging of potable water supply dams cannot be approached in a similar way to dredging of wastewater ponds.

2. Any methodology used for the dredging of potable water supply dams cannot use equipment that can be a source of contamination of the raw water.

3. Using divers to hand dredge the dam is viable and cost effective.

4. It is possible to use a closed loop system to reduce water loss during the dredging without affecting the raw water quality entering the water treatment plant. And continuity of raw water can be maintained during dredging.

5. The dam does not need to be emptied to remove the sediment.

6. The choice of subcontractors for this type of project is a critical success factor. The dive team must be experienced in this particular type of operation and also needs to have specialist skills in protection of

raw water for drinking water supplies. A poor choice for the dive contractor has the potential to undermine the success of the operation.

7. Reducing the sediment in the bottom of the dam will increase storage capacity as well as reduce the amount of T&O compounds in the raw water.

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