EFFECTIVE LONG-CHANNEL, POND-BASED WASTEWATER TREATMENT AT OTOROHANGA

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ABSTRACT

The author has been involved with the Otorohanga wastewater treatment plant since 2010 and has been instrumental in changing it from a traditional oxidation pond to a long-channel, pond-based plant which performs well. In the process the author has learnt much about how the wastewater is treated progressively on its journey through the long channel, the keys to successful treatment and the importance of sludge management in ensuring sound treatment performance through the pond.

The paper follows on from the paper about the Otorohanga WWTP optimisation that was presented at the 2019 WaterNZ conference, brings in the role of Advanced Microbial Digestion (AMD) in long-term management of sludge and the effectiveness of after-pond coagulant dosing for reduction of Total Phosphorous and other parameters related to pond-based treatment. The plant in this configuration requires only minimal attendance by the plant operators and is very robust.

The paper is intended to share the author's learnings and to show how an old oxidation pond can be modified at reasonable capital cost to provide robust treatment performance outcomes and to avoid the much higher capital and operating costs and risks associated with moving to some alternative tank-based secondary treatment system.

KEYWORDS

Keywords: Pond-based treatment, After-pond TP reduction, In-pond sludge management, Advanced Microbial Digestion (AMD).

PRESENTER PROFILE

Following a 36-year career in local government engineering, Cliff Boyt "retired" in 2004 with the aim of setting up as a sole-practicing consultant operating in the disciplines of water supply and wastewater management, and project management. He has had an ongoing relationship with the Otorohanga wastewater treatment plant for the last 11 years.

INTRODUCTION & BACKGROUND

Little did I expect when I was contacted by a Waikato Regional Council officer in 2010 who suggested that I should offer to help Otorohanga District Council upgrade their oxidation pond and apply for a new resource consent, that they would continue to use my services for at least 11 years (and counting). Through that 11-year period Council has secured a suite of 25-year consents, transformed the old oxidation pond to generally perform to consent compliance and I have gained a sound understanding of progressive treatment of wastewater through a long-channel pond-based system. The long channel is 640 metres long by 50 metres wide by about 1.4 metres deep (average). I have personally learnt a lot about how an old oxidation pond system can be modified at reasonable cost to perform reliably to produce effluent of a quality that is expected in the current receiving environment.

When I first became involved with the Otorohanga oxidation pond in November 2010 it was in a sorry state. It was struggling to achieve compliance with the resource consent that was due to expire in 18 months' time and a section of the embankment had settled and allowed pond water to overflow into the adjacent drain during a wet period in the previous winter. The waveband around the pond had collapsed and the wetland cells were clogged with weeds. It was not a pretty sight for any visitor – and it is well understood that visitors smell with their eyes!!

The pond had been first constructed in the 1970s as were many of the then traditional oxidation pond systems throughout New Zealand. The pond has a surface area of about 36,000 m^2 (200 m x 180 m), is about 1.4m deep on average and provided around 60 days retention time when constructed. The pond was built on a flat former swampy area by minimal excavation and forming perimeter embankments above the general landform – it even seems that they simply cut and removed the manuka and left the stumps in place. Most Councils seem to have thought that an oxidation pond would just operate away for ever with minimum of maintenance and operator input, but by the 1990s cracks were starting to show. In the late 1990s Otorohanga Council purchased an area of adjacent land and wetland cells were constructed – two surface-flow cells followed by two subsurface-flow (gravel-bed) cells. A step-screen was also installed at the inlet to the oxidation pond. An aerial photo of the pond and wetland cells c2010 is shown in photo 1:

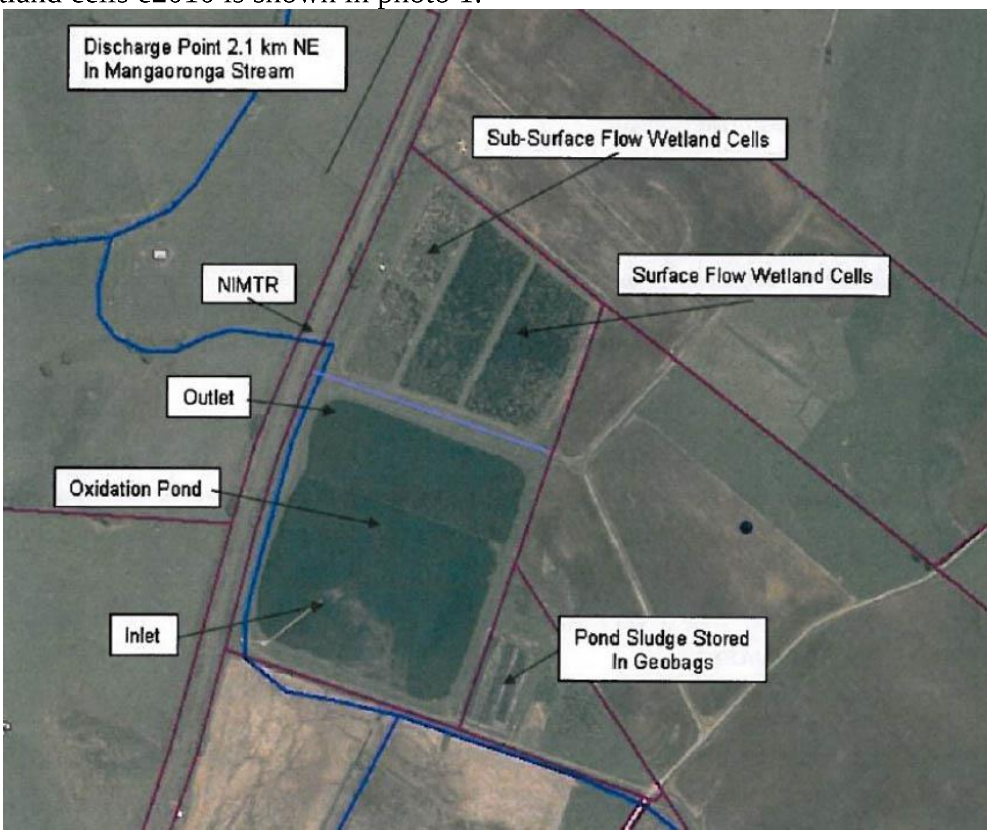


Photo 1: Pond and wetland cells prior to upgrading.

The following summarises the upgrade works that have been carried out since 2010:

Stage	Year	Actions
1	2012	Partial de-sludging, install curtains to form long channel & prevent short-circuiting, raise and strengthen embankments, revise outlet weir to optimise flow buffering, revise inlet arrangement, modify surface-flow wetlands outlet control, modify subsurface-flow wetlands by cutting channels through gravel and modifying inlet and outlet. Photo 2
1A	2012	Secure new resource consents for WWTP related activities.
1B	2014	Install mid-pond bottom-deployed aeration system to deal with high NH_3-N from increased septage discharges. • There was some discussion about the best place to locate the aeration, but mid-pond proved to be about right. Photo 3 • *I acknowledge the input of Gilles Altner (Global Environmental Engineering Ltd) in design of the aeration..*
2	2015-18	Surface-flow wetland cells renovated by removing vegetation, de-sludging and replanting. • Did not improve the treatment performance.
3	2017/18	Sludge survey in pond carried out – showed significant volume of wet sludge in pond, particularly downstream from mid-pond aeration zone. • Partial de-sludging of pond in winter of 2018, particularly downstream of aeration zone.
4	2019	Trial of after-pond coagulant dosing system installed using decommissioned surface-flow wetland cell as settlement basin. Dosing adjusted manually. • Secured Iwi support for this modification.
5	2019	Preparation of Biosolids Management Plan.
6	2020	Introduction of Parklink AMD dosing in denitrification zone downstream from aeration zone. • Reviewed after first year and found to be successful.
7	2020	Review of coagulation trial showed it to be successful. • Upgraded to include automation by flow-rating of chemical dosing.
8	2021	Partial dredging of sludge accumulation in inlet zone, followed by AMD dosing in this zone.

Photo 2 – Modified gravel bed wetland cell

Photo 3 – Showing mid-pond aeration zone.

PROGRESSIVE TREATMENT MONITORING

Once the first upgrade had been commissioned, we put in place a proposal to carry out progressive treatment monitoring twice each year. We set up a plan where samples were to be collected at 6 places through the plant in September and March. The places where samples were to be collected are shown on photo 4 and were:

1. The influent – just downstream from the inlet screen.
2. Mid-pond – A sample collected about 2 metres from the embankment opposite the end of the second curtain.
3. Upstream of the outlet filter curtain.
4. The pond effluent as it discharges from the pond – i.e. The effluent that enters the wetlands (now TP Reduction system).
5. After the outlet from the surface-flow wetland cells (now settlement basins).
6. After the subsurface-flow (gravel-bed) wetland cell – i.e. the WWTP discharge.

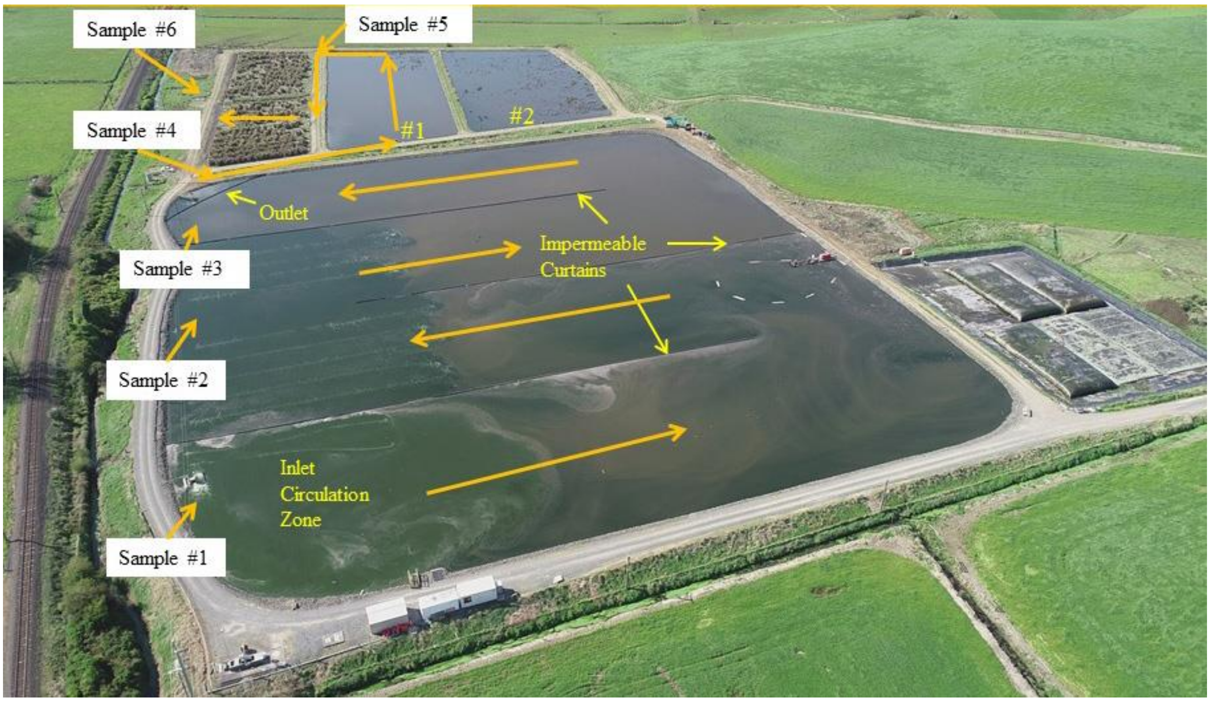


Photo 4 – Progressive treatment sampling points

These samples were analysed for all parameters as required for monitoring for compliance with the resource consents – i.e., BOD_5, SS, NH_3-N, Total-N, Total-P & *E. coli.* The results for each monitoring year were recorded and graphed – both sets of results on the same graphs.

Our objective for these progressive treatment monitoring samples was to gain an understanding of the treatment performance as the wastewater progressively flows along the long-channel and through the after-pond processes.

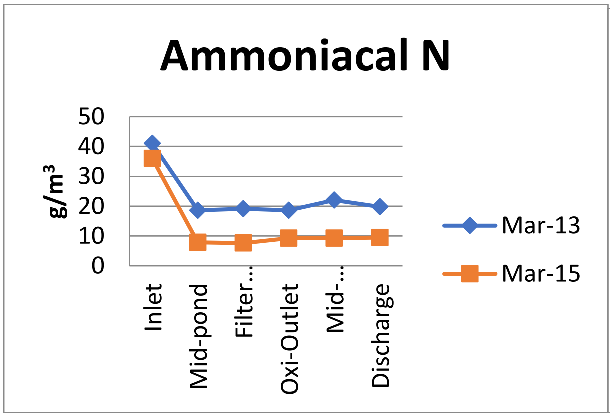
We now have 10 years of records of these progressive monitoring results, and they have provided a guide to:

- What is working acceptably and what is not working well.
- What modifications may be needed, and the results of those modifications.

The results have led to key modifications, including:

- Installing the mid-pond bottom-deployed aeration system to promote nitrification thereby reducing Ammoniacal-N.
- The need for periodic de-sludging of the pond.
- The need for renovating the surface-flow wetland cells and then noting that they were not contributing much to the treatment.
    - Iwi supported the move to retire these cells and use them as settlement basins.
- The need for post-pond coagulant dosing (alum) and using the ex-wetland cells as settlement basins for TP reduction.

The graphs below show Amm-N and TN progressive results from before and after the installation of mid-pond aeration in 2014:



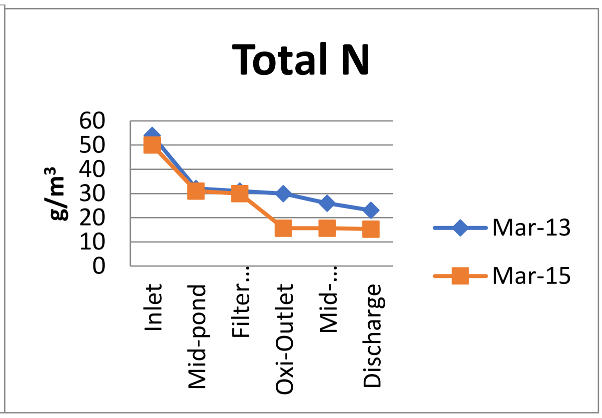


Figure 1a – Amm-N through the WWTP sampling locations

Figure 1b – Total-N through the WWTP sampling locations

These graphs show how the mid-pond aeration improved the Ammoniacal-N concentration from around 20 g/m^3 in 2013 to below 8 g/m^3 in 2015. Similar improvements in Total-N results through the denitrification zone are shown. It must be noted that the progressive monitoring has samples being collected all on the one day, whereas the actual flow time from inlet to mid-pond would normally be at least 20 days.

LONG-CHANNEL TREATMENT AND POST-POND COAGULATION

Progressive monitoring has shown that different zones through the long-channel and after-pond address reduction in different parameters. This progression is shown on Photo 5 showing the upgraded WWTP:

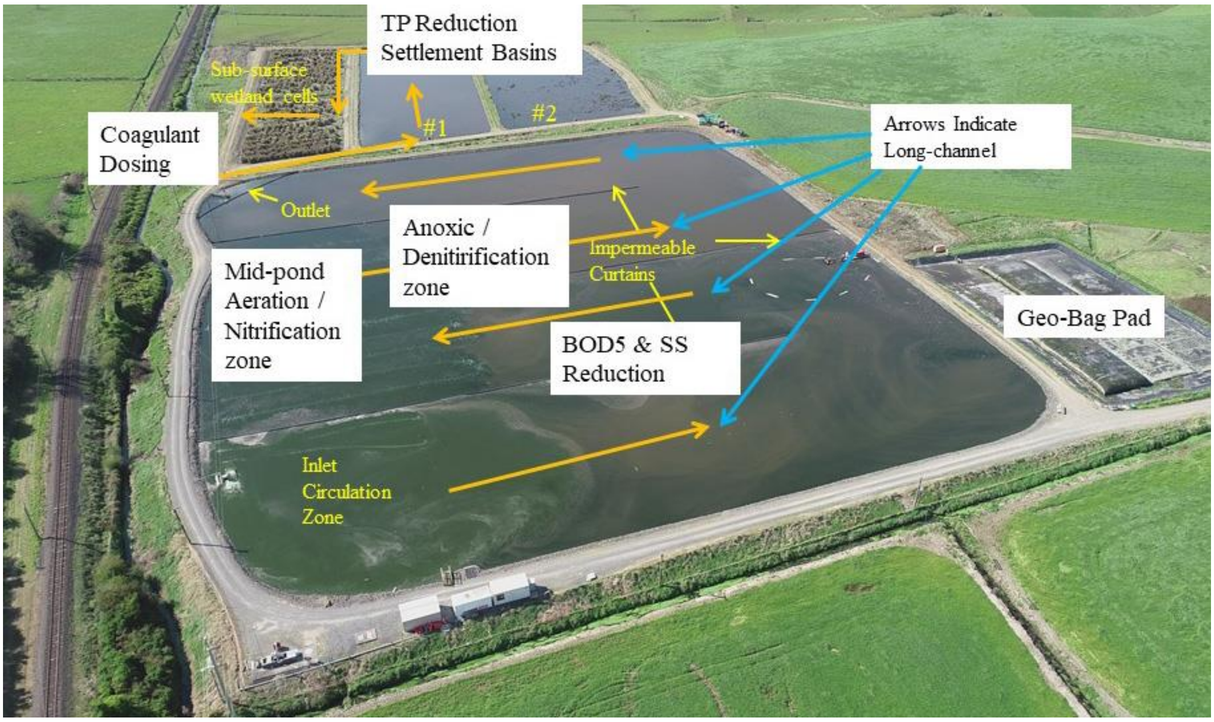


Photo 5 – Progressive Treatment Zones

The following describes the separate progressive treatment zones:

Inlet Zone - Suspended Solids & BOD_5

The retention time in the inlet zone ranges from about 28 days in dry summer periods (with little sludge accumulation) to as short as about 9 days during wet weather conditions (with significant sludge accumulation) – at average flows, the retention time is about 16 days.

- The circulatory flow driven by the S & N Brush Aerator keeps the solids component of the inflowing wastewater in suspension initially and helps to keep the influent "sweet". The solids then settle to the floor in the zone immediately downstream from this circulation area in an area of quiescent flow.
- The BOD_5 component of the influent has a strong demand for oxygen which takes priority over the nitrification phase. The relatively long retention time allows the BOD_5 demand to be largely satisfied before any introduced aeration.
- The micro-organisms that consume the BOD_5 are maintained in suspension and multiply as they are transported down the long channel until their food source is depleted, at which stage they die off and settle to the floor, thereby adding to the accumulating sludge load.

Mid-Pond Aeration Zone

The retention time through the mid-pond aeration zone ranges from about 14 days in dry summer periods (with little sludge accumulation) to as short as about 5 days during very wet weather conditions. At average flow, the retention time is about 7 days.

- The aeration through this zone promotes the growth of nitrifying bacteria (*Nitrosomonas*) which convert NH_3-N to Nitrites and then Nitrates.

- Further through the aeration zone the micro-organisms that carry out this conversion run short of their food source, so they also die off and settle to the pond floor, thereby adding to the accumulating sludge load.

Denitrification Zone

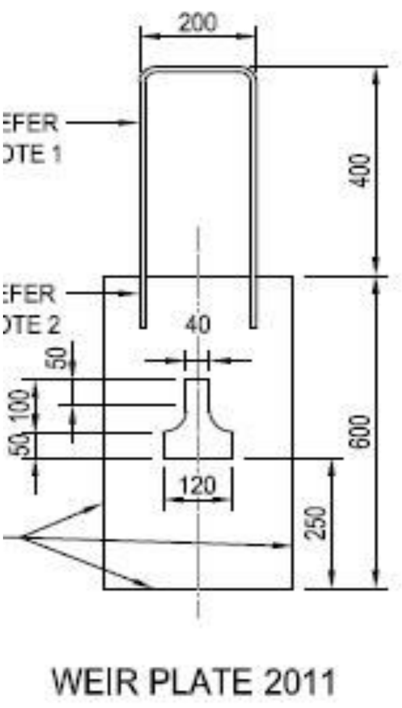
The denitrification zone provides retention times similar to those which occur in the inlet zone.

- This zone provides an anoxic layer between about 200mm below the pond surface and the top of the sludge layer. The anoxic conditions promote the growth of denitrifying bacteria (*Nitrobacter*) which break down nitrates .
- Further through the denitrification zone the bacteria run out of their food source, die off and settle to the pond floor, thereby further adding to the accumulating sludge load.
- At the outlet from the pond, we can generally find that the effluent is compliant (median and/or average as applicable) with the requirements of the resource consent except for Total Phosphorous (TP).

Pond Outlet Flow Control

The control of discharge from the pond was modified as part of the 2011/12 upgrade by installation of a "keyhole" weir plate – designed by Gilles Altner (see figure 2 below).

The weir operates to have the pond water level at about 70 mm above the sill of the weir at low summer flow rates - with a discharge of about 600 m^3/day. As the inflow rate increases the pond water level rises and increases the in-pond water volume to buffer hydraulic retention times. The keyhole orifice becomes "flooded" (i.e., submerged) at an outlet flow of about 1,450 m^3/day and the weir gate overflows at about 2,300 m^3/day. The pond highest discharge flow rate is about 2,700 m^3/day at which point effluent is overtopping the top of the weir plate by about 15 mm. The pond water depth can range through about 295 mm.



This controlled water level rise provides about 11,000 m^3 capacity in the pond, thereby providing buffering of peak daily inflows to the pond. The highest inflow rate in a wet weather period is around 3,700 m^3/day and there is also the volume of rain falling directly onto the pond surface. The discharge from the pond in that wet period seldom exceeds 2,500 m^3/day. This demonstrates the effectiveness of the flow buffering capacity provided in the pond when combined with the flow throttling of the keyhole weir plate. On any day, the discharge rate varies very little.

Figure 2 – Pond outlet flow control weir. The outlet is an inverted keyhole shaped orifice in the centre of the plate. At extreme high flows, effluent can flow over the top of the plate.

After-Pond Treatment

The resource consent sets summer and winter average daily mass-load limits for TP. These mass-load limits largely translate to the need to target a maximum concentration throughout the year of about 2.5 g/m^3. Options for reducing the TP concentration through wetlands and through a "melter slag" filter had been tried but failed to deliver adequate results. It was then decided that an after-pond coagulation dosing system, using aluminium sulphate (alum) and polymer, and the settlement basin would provide an economic solution. This was trialled and proved to be successful.

The effluent is dosed with liquid alum and a contact time of 5 to 10 minutes is provided for floc formation. Polymer is injected as the effluent enters the settlement basin to stiffen and increase the density of the floc.

The two old surface-flow wetland cells have been converted to serve as settlement basins (alternating duty every 4 years). The basin used in the trial proved to be effective with no evidence of floc breaking down and resuspending. Retention time in the basin is between 3 and 5 days.

We find that the alum dose needs to be about 60 g/m^3 in summer and about 30 g/m^3 in winter. The polymer dose is about 0.5 g/m^3. The operators will be making slight adjustments to these dose rates over time to endeavour to find optimum summer and winter settings that will meet the target TP concentrations (and therefore consent daily mass-loads) at an economic dose rate.

A side-benefit from the alum coagulant dosing is that any carry-over of algae from the pond during high-summer is incorporated with the floc formed by coagulation, thereby reducing the suspended solids in the discharge during those periods.

E. coli Reduction

As the wastewater progresses along the pond's long channel its optical transmissivity (clarity) improves progressively. This allows natural UV to penetrate the wastewater to an increasing degree through the treatment system. The effluent clarity through the settlement basin and then the subsurface-flow gravel-bed cells provides polishing, and we find that the *E. coli* concentration in the discharge can often be close to 100 cfu/100 ml. This is achieved by natural UV disinfection and die-off resulting from long retention in the system.

The gravel-bed cells, with numerous shallow channels through the beds which are growing native *Carex* plants provides "cultural treatment". A key outcome of this is that Iwi can view the "clear" effluent just before it is pumped to the receiving waters and discharged.

RESOURCE CONSENT LIMITS

The limits for the various parameters that are set in the resource consent are listed in the table below. These limits came into operation in December 2017, after a 5-year interim period to improve the pond treatment. We have demonstrated that the current format of the pond-based treatment can comply with these limits so long as the pond continues to be maintained effectively.

Parameter	Median / Average	90%ile
$_{c}BOD_5$	25 g/m^3	60 g/m^3
Suspended Solids	30 g/m^3	95 g/m^3
Ammoniacal-N	12 g/m^3	20 g/m^3
TN – average Summer	16 kg/day	
TN – average Winter	30 kg/day	
TP – average Summer	3 kg/day	
TP – average Winter	5 kg/day	
E.coli – Summer	500 cfu/100ml	1,500 cfu/100ml
E.coli – Winter	2,500 cfu/100ml	No condition

Table 1 – Resource consent limits

Note: It has been ascertained that a TP concentration of 2.5 g/m^3 will consistently provide to meet the mass-load limit, both summer and winter. It has been set as the target for regular monitoring.

ACCUMULATION OF SLUDGE / BIOSOLIDS IN THE POND

Note: Through my process and operational involvement with this WWTP I have developed a clear appreciation of the difference between "sludge" and "biosolids". The screened influent to the pond incorporates a range of inorganic solids and some heavy metals as well as a significant proportion of organic material, both in solid and dissolved form.

- *Most of the influent solid material is settled out in the upstream end of the inlet zone – this material includes both organic and inorganic material. I interpret this material as sludge.*
- *Through the downstream part of the inlet zone and the nitrification and denitrification zones the material that settles to the floor is primarily organic material that comprises dying-off microorganisms who have run out of food. I interpret this material as biosolids.*
- *If there is a significant accumulation of sludge in the inlet zone there will be some transport of that material down current into and through the nitrification (aeration) zone and this tends to contaminate the biosolids in those zones. I therefore interpret this "mixed" material as being sludge.*
- *I use "sludge" as the collective term.*
- *In the following sections I have endeavoured to apply these definitions.*

We have been able to analyse the sludge / biosolids accumulation rate from our records of sludge surveys and of dredging since 2011. We have also been able to gauge the in-pond generation of biomass and the effect that sludge / biosolids has on treatment performance.

Our calculations suggest that about 2,750 m^3 of "wet" sludge accumulates on the floor each year – this from a population of about 3,000 with little commercial and industrial wastewater. The annual sludge volume is roughly made up of:

- About 2,100 m^3 of suspended solids per year enters the pond after passing through the inlet screen.
- About 250 m^3/year is generated by micro-organisms that consume BOD_5 and then die off as their food source runs out – i.e., upstream of the aeration zone.

- About 150 m^3/year is generated through the aeration zone by nitrifying bacteria which convert NH_3-N to Nitrates and then die off as their food source (NH_3-N) runs out.
- About 250 m^3/year is generated through the denitrification zone by bacteria who then die off as their food source (nitrates) runs out.

An advantage of the long-channel treatment system is that organic and inorganic solids, and any heavy metals components in the influent tend to settle in the inlet zone. The organic biosolids from die-off of micro-organisms tend to drop out, beginning in the downstream end of the inlet zone and through and after the aeration zone. These organic materials are true biosolids and they can be treated differently from the sludge from suspended solids which mainly accumulate just beyond the inlet circulation area, so long as we can keep them separated.

IMPORTANCE OF MANAGING SLUDGE ACCUMULATION IN THE POND

Every 1 m^3 of accumulated sludge in the pond results in an equivalent loss of available wastewater treatment volume. However not all of this "lost volume" has negative consequence for treatment. It appears that the optimum sludge depth through the pond should be between 150 mm and 250 mm – this serves a purpose of maintaining anoxic conditions in the lower water levels and this is particularly important through the denitrification zone. It also serves as a seedbed for the microorganisms that treat the wastewater. The Otorohanga pond has an area of about 36,000 m^2 so the volume of accumulated sludge should preferably be managed to between 4,500 m^3 and 7,500 m^3. With an annual sludge volume accumulation of about 2,750 m^3 it appears that we would have to dredge the whole pond every 2 years to maintain the sludge depth close to these preferred limits. That probably represents a recurring cost of about $175,000 each 2 years, plus the cost of storing and then disposing of the sludge.

Many local authorities have allowed sludge accumulation in their ponds to reach critical levels so that they are now faced with large deferred-maintenance costs to reduce the sludge volume to the preferred depths – often several millions of dollars. Disposing of the sludge is also an issue. Some ponds have "turned sour" over recent summers requiring special attention at great cost – these conditions are related to having excess sludge accumulation in the pond, the decay of which depletes the ponds dissolved oxygen levels. Ponds with large sludge accumulations are susceptible to a botulism incident with many waterbirds dying in the pond during warm summer days.

Managing Sludge Accumulation in the Pond

Council seemed to be "chasing their tail" in trying to get the sludge accumulation down to within the preferred range – the following graph shows sludge volumes from 2005 to 2021 and the effect of dredging exercises.

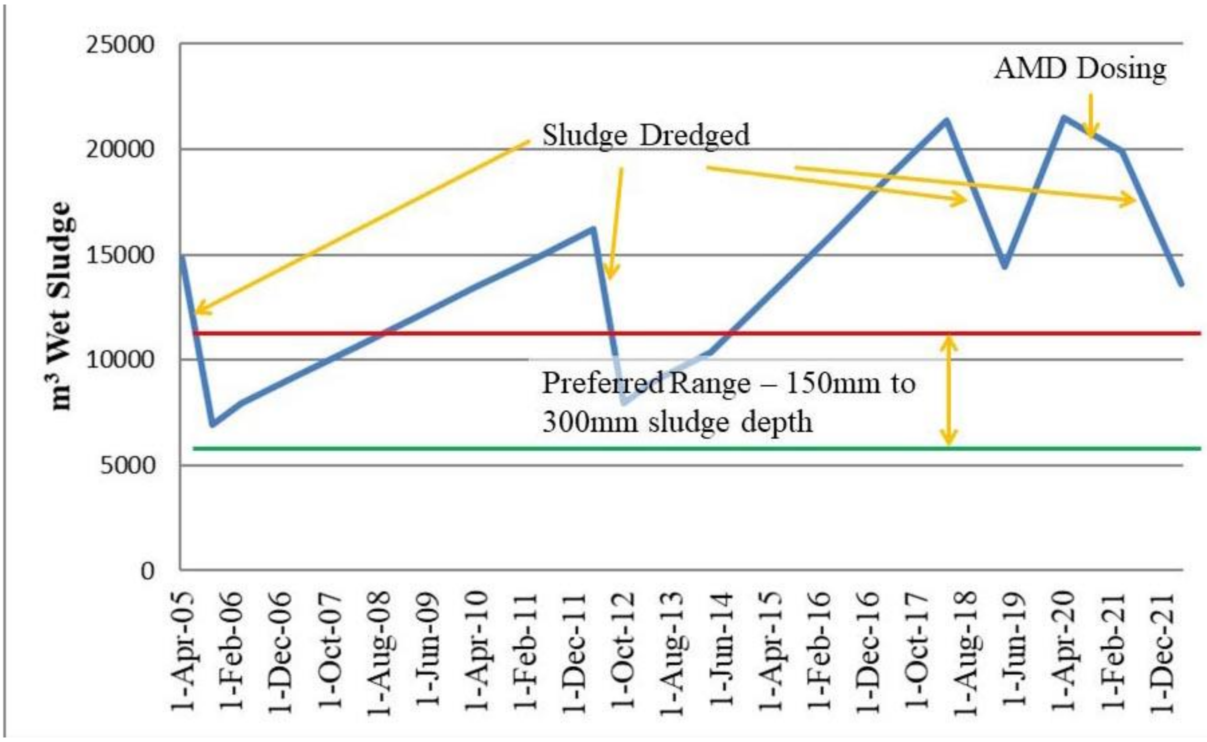


Figure 3 – Pond sludge volume 2005 to 2021

DOSING THE POND WITH ADVANCED MICROBIAL DIGESTION (AMD)

In 2019 a Biosolids Management Plan was developed for the Otorohanga WWTP. It had at least two objectives:

1. To provide a plan for managing the sludge that accumulated in the pond, plus that originating from the after-pond coagulant dosing system.
2. As sound background information for the documentation and assessment of environmental effects (AEE) that were to be prepared for the application for replacement resource consents for discharge of sludge to land that expire in November 2021.

A trigger for developing the Biosolids Management Plan was the need for forward planning and budgeting for the measures that would be needed to reduce the average depth of accumulated in-pond sludge to within the preferred range and then to maintain it within that range in the future. The Plan recommended that Council should trial a programme where AMD dosing was carried out in the denitrification zone, supported by occasional dredging, particularly of mixed sludge in the inlet zone.

AMD dosing was introduced in the denitrification zone only (downstream from the aeration zone) in February 2020 with an objective of improving denitrification. The first 11 months of AMD dosing showed a reduction of about 4,100 m^3 of wet sludge overall, which includes about 2,500 m^3 of sludge that entered the pond with the influent or was generated by in-pond micro-organism activity. At the commencement of the AMD trial there was a significant accumulation of sludge immediately downstream from the inlet circulation area (untreated) and this accumulation increased through the trial period.

Councill staff considered the AMD trial to have been a success and programmed to carry out dredging of sludge in the inlet zone, followed by the introduction of AMD dosing in the inlet zone after a settling down period. It is expected that AMD dosing in both the inlet and denitrification zones will bring the average in-pond sludge depth down to within the preferred range by the 2024/25 year and that maintenance AMD dosing will suffice from then on.

AMD can only have effect on the organic component of the sludge so it is anticipated that the volume of sludge will continue to accumulate in the inlet zone, albeit at a much-reduced rate than without AMD dosing. It is expected that a dredging exercise may be required in the inlet zone maybe every 10 to 15 years. Sludge surveys every 2 years will tell the story.

Sludge contour diagrams from February 2020 and January 2021 are shown Figure 4.

February 2020 January 2021

Figure 4 – Pond sludge depth contours prior to and after AMD dosing in the denitrification (top) zone.

AMD was dosed into the last two legs of the long channel (at the top of the contour diagrams) monthly. The lighter shading in that zone in the January 2021 plan indicates that there is generally less sludge than in February 2020. The areas outlined in red indicate where there had been an increase in sludge depth – the area of increase in the aeration zone is probably from sludge being transported down-current from the inlet zone.

The biosolids management plan proposes that sludge surveys across the whole pond be carried out every 2 years.

ALUM SLUDGE FROM COAGULATION SYSTEM

From survey data it appears that the settlement basin #1 has an expected life of about 4 years before we need to swap to settlement basin #2. The basin has an area of about 7,000 m^2 and it can have a sludge accumulation of about 200 mm depth average – a volume of about 1,400 m^3.

In August 2020, after the alum and polymer coagulant dosing system had been operating for 15 months the average sludge depth was about 106 mm. Therefore, the basin had a remaining capacity of about 700 m^3. Sludge surveys in October 2019 and August 2020 suggest that the volume of sludge accumulation in the 10 ½ months was about 194 m^3, which represents about 222 m^3 in a full year. At that rate we estimate that the basin will be over 90% full by May 2023 – after a 4-year life.

After basin #1 has been taken off-line it will be drained and then kept dry through the following summer (2023/24) to allow sun-drying of the accumulated sludge. In autumn 2024 the basin will be de-sludged and the material moved to an on-site sediment trap where it will be held for at least 2 years to mature and dry. By the end of the summer of 2027 the residual material will be removed and disposed of at a landfill – it is considered unsuitable for application to land as the sludge will still have a gelatinous texture due to the alum. It is estimated that the residual volume of the material to be disposed of at landfill will be less than 200 m^3.

THE IMPORTANCE OF HAVING A BIOSOLIDS MANAGEMENT PLAN

The experience gained from 11 years involvement in the Otorohanga WWTP and information from the twice-yearly progressive treatment monitoring demonstrated to me that management of sludge depths in the pond is critical to achieving good, reliable treatment of the wastewater to give confidence that resource consent conditions can be met consistently. It also became apparent that we needed to know what we were going to do with the sludge that had been removed from the pond. This led to the preparation of our first comprehensive Biosolids Management Plan in 2019.

The 2019 Biosolids Management Plan dealt with sludge / biosolids generation in the pond and through the after-pond coagulant dosing system. It also covered storage and disposal of the sludge that is removed from these processes.

Currently the dredged sludge ex-pond is stored in geo-tubes on a lined and drained Geobag pad for 5 years to mature and to dry, before discharge onto a triangle of land within the designated treatment plant property. Spread, dried sludge is mixed into the topsoil to encourage grass growth. The pasture grass is maintained by cut & carry for two years after deposit and then by regular grazing by dry-stock cattle. The replacement resource consent for sludge disposal was issued in 2021 and provides for the above management strategy.

Sludge from the coagulant dosing system will be stored in a lined sediment trap for 3 to 4 years before being transported to a landfill.

The 2019 version of the Biosolids Management Plan recommended, among other things, that Council should introduce a trial of AMD dosing in the zone downstream from the aeration zone with objectives to see how effective it is and to improve the denitrification. The 2019 Plan considered options for AMD being successful versus an ongoing regime of regular dredging. It recognised that the significant accumulation of sludge in the inlet zone would probably require to be dredged to bring it down to manageable levels before introducing AMD into that zone.

The Biosolids Management Plan has been reviewed and updated in 2021 to recognise the success of AMD dosing in the pond and the success of after-pond coagulant dosing. The revised Plan estimates that the cost of managing sludge in the pond will settle to around

$37,000 / year, plus a dredging exercise every (say) 12 to 15 years at a cost of about $120,000 (i.e., equivalent to $8,000 to $10,000 / year).

Given the recognition of the importance of keeping sludge accumulation in the pond at low levels and the cost of regular dredging it is important that the owner of every treatment pond should have a Biosolids Management Plan for each such plant and that they update the Plan at least every two years, preferably following a survey of sludge depths across the whole pond. The Biosolids Management Plan should be incorporated inti the overall Operation & Management Plan for the plant.

THE IMPORTANCE OF MEASURING TREATMENT PERFORMANCE

"You cannot manage what you do not measure"!! This well-known quote applies to wastewater treatment just as much as to management!!

We introduced twice-yearly progressive monitoring of the wastewater as it passes through the pond after the 2011/12 upgrade project and have continued it through to the present and hopefully Council will continue it in the future. The results from these measurements, especially the graphed results, are a good guide to how the progressive treatment through the pond is working. Careful study of the results over several years and a sound knowledge of activities in the pond over those years gives an indication of what factors are critical to the treatment performance. It is also through these progressive monitoring results and the graphing thereof that I came to understand the progressive treatment by zone – i.e., BOD_5 and SS in the inlet zone, NH_3-N in the aeration zone, TN in the denitrification zone, TP in the after-pond coagulation system and *E. coli* progressively through the whole treatment chain, improving as the water clarity improves. My understanding of the progressive treatment has been devolved from a process and operational background, and not from a text-book approach.

When we commissioned the upgrade works in 2012, we recommended that Council should carry out a sludge survey every 2 years. However, that did not happen. After 2012 the next sludge survey was in March 2017 and that showed large accumulations of sludge in the inlet and in the denitrification zones. Looking back at the progressive treatment graphs we could then explain why the treatment performance had deteriorated through that period.

Our results show how important it is to measure what is happening in a pond system twice-yearly and to carry out sludge surveys every two years – a sound methodology and consistency are key to being able to measure trends in sludge depths. Other key measurements include daily inflow to and outflow from the pond and final discharge daily volumes, as well as the monitoring required to show compliance with the resource consent conditions.

Having the information from these measurements will prove to be invaluable when and if you need to carry out upgrade works in the future. The regular sludge survey results will provide a clear guide as to when action is required to reduce sludge volume in the pond by dredging.

CAPITAL COSTS OF THESE IMPROVEMENTS

An option for Council back in 2011 may have been to abandon the oxidation pond and build a new tank-based secondary treatment system – a direction that some Councils have adopted when their oxidation pond systems fail to comply with consent requirements. In some cases that may be a suitable solution, but I recommend that, depending on future resource consent conditions and population growth trends, upgrading the current pond along the lines that we have taken at Otorohanga will probably provide a more economic option, both in terms of capital and operating costs and can provide similar outcomes. This also recognises the significant investment the Council already has in the land and infrastructure in the oxidation pond-based treatment system.

In the case of the Otorohanga WWTP the capital costs from 2011 to 2021 amount to about $1.3 million which is made up of:

- Curtains and other upgrade work in 2011/12 — $1.12 million
- Bottom-deployed aeration works in 2014 — $ 87,000
- Coagulation dosing system in 2019 and 2020 — $ 74,000

Sludge dredging in 2012, 2018, and in 2021 cost a total of about $600,000 and other maintenance costs over the same time, such as renovating surface-flow wetland cells cost around $120,000. These are deferred maintenance costs, not capital costs.

I estimate that a replacement tank-based secondary treatment plant on the same site would probably cost between $3 million and $5 million and I recognise that the operating and maintenance cost would be significantly higher than for the pond-based system.

CONSTANT DISCHARGE RATE TO THE RECEIVING ENVIRONMENT

The outflow from the treatment pond is almost constant on any single day, increasing slowly under wet weather conditions and then reducing more slowly after the wet weather has ended. This pattern is mirrored by the outflow from the settlement basins and gravel-bed cells. However, the discharge pumps are fixed-speed units so the discharge to the receiving water is intermittent with the flow rate when pumping being about 3 times the average pond outlet rate, followed by zero discharge for about 2/3rds of the time.

There would be a real advantage to the impact on the receiving water if the pumps were supplied from variable speed drive units so that the discharge rate can be constant through any day. When a higher discharge is required it will be due to there being a wet weather period, at which time the receiving river will also have an increased flow rate.

ADVANTAGES OF RETAINING A POND-BASED TREATMENT SYSTEM

The Otorohanga WWTP is now a long-channel pond-based treatment plant, but it retains many of the key advantages of the old oxidation pond plant, including:

- The daily and seasonal flow variations are buffered by the ability to store peak influent volumes in the pond and thereby flatten out the daily discharge rate variations.
    - The outlet flow control weir improves the buffering capacity of the pond.
    - The discharge from the pond is virtually constant through any one day, increasing slowly during wet weather periods and then decreasing slowly after the wet weather has stopped.
    - A tank-based treatment system must be designed to handle the peak influent volume, which means redundant capacity most of the time.
- Any toxic or shock load is dissipated as the wastewater flows along the channel so it has no more than minor impact on the treatment effectiveness, whereas it could "wipe out" a tank-based treatment process.
- The whole system generally runs itself with little need for operator involvement. At Otorohanga the operator only needs to visit the plant for a short look-around twice each week.
    - A tank-based system requires regular operator involvement, at least every day.
- The electrical energy requirement is very low – just the inlet screen and screw press, a brush aerator, a blower for the mid-pond aeration system, a small pump at the inlet and pumps for the discharge. Otherwise just instrumentation loads.
    - All other energy input into the treatment is natural, driven by sunlight and wind.
- The only chemical inputs are liquid alum and polymer for after-pond TP reduction.

Opportunities for dealing with increased loading include:

- Extending the mid-pond aeration system, probably to the upstream end,
- Installing fixed-growth media (e.g.. AquaMats) between the aeration pipes in the aeration zone.
- Raising the embankments to increase the treatment volume.
- Extending one of the legs of the (serpentine) long treatment channel and the curtain in that leg.

CONCLUSIONS

Otorohanga no longer has a traditional oxidation pond treatment system – it has a long-channel, pond-based system. The outcome gives confidence that the discharge can consistently comply with the conditions in the resource consent. With the contempt in which oxidation ponds are now being held in some quarters of our New Zealand municipal three-waters sector, this long-channel modification offers an economic option that other oxidation pond owners should consider.

When we set out on this journey eleven years ago, we did not fully understand that our pond improvements would lead us to what we now have – Council's foresight in keeping me involved through the eleven-year period has allowed for these measurements and incremental improvements to lead them to the current outcome. We had some Iwi and representatives from one of the leading consultancies visit the plant recently and they were impressed with the appearance of the plant and with the clarity of the effluent – that was very satisfying.

We now understand what parameters are treated in each zone of the long-channel and after-pond and we have also realised how management of sludge depths is critical to reliable performance.

We have found that AMD dosing offers a reliable and economic option for sludge reduction and management, but that dredging of sludge will still be required in the inlet zone in the future, albeit at longer time intervals.

The long-channel pond-based system has a low energy requirement and requires operator visits only twice each week with little intervention.

ACKNOWLEDGEMENTS

I acknowledge the Otorohanga District Council team who have shown faith in my ability by keeping me involved in their WWTP continuously for 11 years – I think it has been mutually beneficial. I especially acknowledge the support that has been provided to me along this journey by Otorohanga District Council's Mark Lewis, Roger Brady, their predecessors, and the operators – we have been on this journey together.

I acknowledge the involvement of Gilles Altner of Global Environmental Engineering Ltd for his design of the initial upgrading works and for the enlightenment of introducing bottom-deployed aeration in mid-pond a couple of years later.

I also acknowledge Regan Senior of Parklink Ltd for assistance regarding AMD dosing, and James Sukias of NIWA and Jim Bradley of Stantec Ltd who both encouraged me to write this paper and who both reviewed the draft version and offered suggested improvements.

Cliff Boyt – July 2021