

# Rotorua Lakes Council

Wastewater Strategy

May 2015

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# Issue and revision record

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# Contents

<b>Chapter</b>	<b>Title</b>	<b>Page</b>
	Executive Summary	i
<b>1</b>	<b>Introduction</b>	<b>1</b>
1.1	Project Drivers _____	1
<b>2</b>	<b>Design Criteria</b>	<b>2</b>
<b>3</b>	<b>Option Selection</b>	<b>5</b>
3.1.1	Phosphorus Removal _____	5
3.1.2	Filtration _____	7
3.1.3	Nitrogen Removal _____	8
3.2	Carbon Balance _____	10
<b>4</b>	<b>Process Selection</b>	<b>12</b>
4.1	Filtration _____	12
4.2	Primary Tank Bypass _____	12
4.3	Carbon Utilisation _____	13
4.4	Process Configuration _____	14
4.4.1	MLE Process _____	15
4.4.2	Four Stage Bardenpho _____	15
4.5	Ethanol Use _____	17
4.6	Solids Production _____	18
4.7	Membrane Details _____	19
<b>5</b>	<b>Costs</b>	<b>21</b>

# Executive Summary

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# 1 Introduction

Rotorua Lakes Council (RLC) is investigating options for the treatment and disposal of wastewater for Rotorua. This is driven by the existing land treatment system being decommissioned in 2019. In addition RLC has been investigating the use of wet air oxidation (TERAX) for the oxidation and destruction of primary and secondary solids from their wastewater treatment plant (WWTP).

The integration of TERAX into the treatment process has introduced risks associated with residual nitrogen and colour in the WWTP effluent. In addition there are some unknowns around the impact of phosphorus removal chemicals (such as Alum) on the TERAX system. These risks may affect the viability of some or all of the alternatives to land disposal.

This report presents an investigation of the most appropriate technology to meet the long term discharge consent requirements of the treatment plant (assumed to apply at the exit of the current or future treatment process), and how TERAX could be integrated into this solution. Note that the investigation is done on the basis of “best for plant” and does not assume that the TERAX process will be used by default.

## 1.1 Project Drivers

The driver for the treatment plant for effluent quality is the ability to meet likely future targets of 30tN/yr and 3tP/yr in the discharge from the WWTP. At current average annual flows of approximately 20ML/d, a total nitrogen concentration less than 4.1mgN/L and 0.4mgP/L on average are required. Under future flow conditions of 23.81ML/d these concentrations will reduce to an average of 3.5mgN/L and 0.35mgP/L.

At this time there are no drivers for biosolids quantities or dry solids content, albeit that minimum volumes leaving site are desirable. The ultimate fate of the biosolids is outside the scope of this report, however this is likely to require additional investigation if TERAX is not the best option for management of biosolids.

## 2 Design Criteria

The design criteria for used in this study have been derived from the following sources:

- TERAX business case – in particular the current use of ethanol, estimated future and current bio solids production rate, sludge disposal charges and polymer use for solids dewatering
- Sampling data for the period 29/4/12 to 21/4/15
- Wastewater characteristics (COD fractions etc) have been assumed to be the same as the TERAX business case and investigations – this information may need to be updated with the latest sampling results in the future

The raw and settled wastewater characteristics are summarised in tables 2.1 and 2.2 below:

**Table 2.1: Raw Wastewater Characteristics**

Parameter	Units	Average
Current Daily Flow	ML/d	19
Future Daily Flow	ML/d	23.81
Total COD	mg/L	450
Filtered COD	mg/L	119
Filtered Flocculated COD	mg/L	63
Total Kjeldahl Nitrogen	mgN/L	49
Ammonia N	mgN/L	32.5
Total Phosphorus	mgP/L	7
Total Suspended Solids	mg/L	280
Volatile Suspended Solids	mg/L	219

Source: TERAX business case

**Table 2.2 Settled Wastewater Characteristics**

Parameter	Units	Average
Current Daily Flow	ML/d	18.91
Future Daily Flow	ML/d	23.72
Total COD	mg/L	252
Filtered COD	mg/L	119
Filtered Flocculated COD	mg/L	63
Total Kjeldahl Nitrogen	mgN/L	42
Ammonia N	mgN/L	32.5
Total Phosphorus	mgP/L	5.6
Total Suspended Solids	mg/L	112
Volatile Suspended Solids	mg/L	102

Source: TERAX business case

Final effluent quality for the WWTP is recorded in three separate samples:

- MBR Permeate
- Bardenpho Effluent
- Combined

The data used in this study has been sourced from the separate samples for each process (MBR and Bardenpho) such that the performance of each process unit can be analysed separately.

**Table 2.3 Bardenpho Effluent Characteristics**

Parameter	Units	Average	No of samples
Total COD	mg/L	44	149
Filtered COD	mg/L	16	46
Total Kjeldahl Nitrogen	mgN/L	2.61	95
Ammonia N	mgN/L	0.33	416
Total Phosphorus	mgP/L	3.42	150
Total Suspended Solids	mg/L	23	150
Volatile Suspended Solids	mg/L	19	150
Nitrate +Nitrite	mgN/L	2.04	354
Dissolved Reactive Phosphorus	mgP/L	2.81	150

Source: Site Data 29/5/12 to 21/5/15

The characteristics of the Bardenpho effluent show that this process is achieving very good consistent levels of nitrification and denitrification. Elevated suspended solids and the effect of these on total phosphorus and total nitrogen levels mean that the Bardenpho in its current configuration will not be able to meet the proposed future quality limits.

Table 2.3 MBR Permeate Characteristics

Parameter	Units	Average	No of Samples
Total COD	mg/L	17	257
Total Kjeldahl Nitrogen	mgN/L	1.34	236
Ammonia N	mgN/L	1.24	561
Total Suspended Solids	mg/L	0.7	143
Nitrate +Nitrite	mgN/L	2.43	258
Organic Nitrogen	mgN/L	0.93	255
Total Nitrogen	mgN/L	3.91	235
Dissolved Reactive Phosphorus	mgP/L	1.43	258

Source: Site Data 29/5/12 to 21/5/15

The characteristics of the MBR permeate show that this process is achieving very good consistent levels denitrification, virtually no suspended solids and some phosphorus removal. However the process appears to be unstable with respect to nitrification resulting in total nitrogen levels that are slightly higher than the future targets (3.91mgN/L vs 3.45mgN/L)

## 3 Option Selection

The selection of the best for plant treatment option has been based the revised effluent discharge criteria of 30tN/yr and 3tP/yr

Key questions considered are:

What are the best configurations and/or choice of process to reach the target nitrogen and phosphorus concentrations required in the plant final effluent:

### 3.1.1 Phosphorus Removal

Historic performance of the Bardenpho and more recently the MBR, has shown that good biological nitrogen and phosphorus removal can be achieved with the appropriate levels of carbon dosing. The removal of both nitrogen and phosphorus has not been consistently achieved at the same time.

While it is possible to meet the target concentrations for nitrogen and phosphorus via biological methods, there is competition between denitrification (nitrogen removal) and phosphorus removal for carbon (COD). Typically a COD/TKN ratio of greater than 15:1 is needed to achieve low levels of both nitrogen and phosphorus. The raw wastewater at Rotorua has a C/N ratio of about 11:1 so is not ideal. This restriction is not specific to the type of process. All biological processes rely on a favourable C:N ratio to achieve nitrogen and phosphorus removal so this limitation cannot be overcome by a different type of process.

To overcome the COD limitation additional carbon such as acetic acid could be added to achieve biological phosphorus removal. As this needs to be dosed to the process this would incur an additional OPEX cost. This cost needs to be compared to chemical dosing to determine the best option for the WWTP.

Table 3.1 and 3.2 compare the cost of alum versus acetic acid for phosphorus removal based on the performance of the current plant.

Table 3.1: Phosphorus Removal with Acetic Acid Dosing

Parameter	Units	Value	Source
Residual Phosphorus to remove	mgP/L	2.8	Sampling data table 2.3

Parameter	Units	Value	Source
Acetate Requirement	kg/kg	10	Henze et al
Mass P to remove (at current ADF)	kg/d	56	
Acetate Dose	kg/d	560	
Acetate Cost	\$/kg	\$2.92	Orica per IBC
Annual Dosing Cost	\$/yr	\$596,850	

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**Table 3.2: Phosphorus Removal with Alum Dosing**

Parameter	Units	Value	Source
Residual Phosphorus to remove	mgP/L	2.8	Sampling data table 2.3
Alum required	kgAlum/kgP	16	Calculation
Mass P to remove (at current ADF)	kg/d	56	
Alum Dose	L/d	1340	
Alum Cost	\$/L	\$0.6	Orica
Annual Dosing Cost	\$/yr	\$293,500	

Source: Insert source text here

The cost of acetic acid dosing is approximately double the cost of alum dosing for the same result (excluding the costs of sludge handling) and there does not appear to be a driver to enhance phosphorus removal via additional carbon dosing.

Given the cost advantage of alum and that the most reliable and controllable means for removing phosphorus is via chemicals (lime, alum or ferric) then a chemical dosing option for phosphorus removal is likely to be the preferred option for the WWTP. Dosing is not process specific and can be added to almost any biological process either in situ or as a separate tertiary stage.

*Conclusion: Use chemicals (i.e alum) to remove phosphorus*

### 3.1.2 Filtration

Sampling results for the Bardenpho (as shown in table 2.3) show that there are significant levels of suspended solids in the final effluent from this part of the treatment process. Loss of suspended solids causes several issues with the ability of the WWTP to meet the future nitrogen and phosphorus standards. These include:

- Secondary solids from all biological processes contain phosphorus due to this being an essential nutrient for growth. In a typical secondary process approximately 2% of the effluent volatile suspended solids are related to total phosphorus.
- With chemical dosing for phosphorus removal the phosphorus is bound to a chemical such as aluminium (when alum is dosed). Therefore the solids in the final effluent of a system dosed with alum will have higher percentages of phosphorus, in the order of 3-4%
- Secondary solids from all biological processes also contain nitrogen. This typically ranges from about 7% to 10% by mass.

The performance of the Bardenpho over the last three years has averaged 23mgTSS/L. This represents a phosphorus concentration of approximately 0.5mg/L or a mass discharge of 3.65 tonnes/yr alum dosing this could be as high as 6.7tP/yr. Removal of this residual phosphorus is essential to meeting the proposed limit of 0.3mgP/L.

In terms of nitrogen the discharge of 23mg/L of suspended solids represents between 1.6mgN/L and 2.3mgN/L. If the proposed average concentration of 3.5mgN/L is to be met then removal of these solids is essential.

If the Bardenpho were replaced with any other biological process where gravity settlement is used, the risk of solids loss and elevation of phosphorus and nitrogen concentrations remains. Filtration, either as part of the secondary process or as a tertiary process, is a reliable and relatively low OPEX means of virtually eliminating particulate phosphorus and nitrogen.

Removal of all the particulate nitrogen from the final effluent also means that the reduction of the other components of total nitrogen do not need to be as efficient to achieve the same result. This will reduce carbon consumption and more importantly allow more variation in the other nitrogen species.

As a unit process the highest levels of filtration can be achieved via a membrane (see tertiary options study) and it is likely that removing solids to essentially zero can only be achieved with membrane filtration

A membrane provides the most reliable means of filtering as all flows have to pass through a physical barrier to achieve treatment and there is no opportunity for short circuiting or variable pore sizes etc that can be an issue with other filtration devices.

*Conclusion: Filtration of the final effluent is essential to reduce or eliminate particulate phosphorus and nitrogen. Membrane filtration will give the highest level of solids removal due to very low pore size of the filter. Removing all particulate nitrogen will reduce the required removal efficiency of other nitrogen species such as nitrate and ammonia*

*If a membrane is used as final filtration stage in whatever configuration (MBR or tertiary) then this must give lowest particulate N as TSS is always essentially zero.*

### **3.1.3 Nitrogen Removal**

One of the key requirements of the WWTP is the ability to remove nitrogen. This can be done in a variety of ways either by fixed film systems (sand or media filters), suspended growth processes (activated sludge) or via newly developed processes such as AMMONOX.

Given that the plant is configured as secondary activated sludge process and is removing nitrogen already, the key question is can this type of process (secondary activated sludge) remove enough nitrogen to meet the proposed consent limits or is another (tertiary) stage required?

#### **3.1.3.1 What efficiency of N removal is needed?**

The efficiency of the secondary process is an essential element to answering the above question. If sufficient removal efficiency can be obtained in a single stage (sludge) BNR then it is likely that the same type of process that is used at present can be modified to meet the new limits. If a single stage process cannot meet the required efficiency then irrespective of how the secondary process is configured a tertiary stage will be required.

The advantages of a tertiary stage are that if this were added to the current plant (or another type of single stage process) the combined



efficiency of each process stage can be used to meet the quality drivers.

For example if the secondary process is 80% efficient and a tertiary process 60% efficient then the overall efficiency is 92%. For very high efficiency levels it will be more reliable to use this effect of several stages in series.

The sampling data from site shows that the inlet total nitrogen to the WWTP is approximately 50mgN/L. Therefore to meet the new limit of 3.5mgN/L the required efficiency of the process overall is 3.5/50 or 93%.

Can this be reliably achieved in a secondary process?

### 3.1.3.2 Comparison to other Plants

The Water Research Foundation (WERF) has published several guides and investigations into low nutrient treatment plants and their reliability. For the purposes of this study, we have used the example plants contained in the WEF/WERF “Study Quantifying Nutrient Removal Technology Performance (2011)”. This study looks at 22 treatment plants that have the lowest nutrient standards in the US. It looks at the reliability of meeting different effluent qualities in terms of nitrogen and phosphorus and compares these using a range of statistical methods.

The plants most similar to Rotorua are summarised in table 3.3. Each plant is a single stage process (tertiary filters only), are of a similar scale and have similar nitrogen standards than those proposed for Rotorua.

**Table 3.3: Comparison of Nitrogen Removal Plants – Single stage N removal**

Plant	Configuration	Median TN (mg/L)	N Removal
Piscataway, MD (78,000m3/d)	Activated sludge and Tertiary Filters	3.00	86%
Eastern WRF, FL (64,000m3/d)	Bardenpho and tertiary Filters	3.64	90%
Parkway, MD (21,600m3/d)	4 Stage Bardenpho	3.40	88%
Rotorua WWTP (23,800m3/d)	?	3.50	93%

Source: WERF 2011

The data above illustrates that single stage plants can achieve similar standards to Rotorua, however it is important to note that these plants are not able to achieve these limits on more than a 50<sup>th</sup> percentile basis. This is important for the setting of limits for the plant as percentile concentrations greater than 50% are likely to mean that additional nitrogen removal stages are required to achieve lower average nitrogen standards.

*Conclusion: Single sludge BNR plants can achieve the standards required at Rotorua provided limits are set on median or mean concentrations. If greater levels of certainty are required (i.e. 90<sup>th</sup> or 95<sup>th</sup> percentiles) additional treatment stages will be essential.*

### 3.2 Carbon Balance

The key to removing nitrogen in a conventional nutrient removal process is the efficient use of organic carbon. Carbon is critical to the removal of nitrate nitrogen that is formed from the oxidation of ammonia. If sufficient carbon is not available to match nitrate generated in the process then incomplete nitrate removal will occur and consequently elevate final effluent nitrogen.

Currently the plant uses ethanol to supplement carbon and one of the primary drivers of considering TERAX was to recover carbon from primary and secondary sludge.

In the current process configuration primary settlement removes carbon (COD) associated with suspended solids. This COD is thickened and then dewatered and removed from site. In this configuration the COD removed in the primary settlement stage is not used for any other purpose in the treatment train. In larger plants, and historically at Rotorua, the primary sludge is mixed with secondary sludge and digested to make gas. This is no longer used at the plant and has not been part of the treatment train for a significant period of time.

The TERAX process has been developed to take primary sludge, ferment it and produce a carbon source for the WWTP. Residual solids are then oxidised in the TERAX “cooker” and the residual liquid (containing the carbon source) is returned to the WWTP.

The TERAX process, in its current form, is only of value to the WWTP if this primary solids stream can be transformed into a carbon source.

Given that without TERAX the primary solids present no value (in fact a significant cost) to the WWTP, there is no driver to continue removing primary sludge. It is recommended that to minimise OPEX and make the best use of the available carbon that the primary sedimentation system is removed from the process configuration.

In terms of considering the use of TERAX at the WWTP, this is only a valid option in its current form if carbon recovery for nitrogen removal is required (to minimise or eliminate ethanol use) and to reduce the tonnage of bio solids leaving site. If primary solids are not removed in the WWTP then one of the key drivers for TERAX is removed.

## 4 Process Selection

The option selection analysis discussed above has identified the following:

- From a reliability and OPEX perspective dosing with chemicals such as alum is the best means of phosphorus removal at this WWTP
- Filtering of the final effluent is essential to remove particulate nitrogen and phosphorus
- Nitrogen removal targets of 3.5mgN/L as median or mean can be achieved by a single stage process and tertiary nitrogen removal (denitrification) is not required to meet the proposed limits
- To make maximum use of the available carbon in the wastewater primary sedimentation could be by passed

Given the above there are several options that can be considered as the best option of the WWTP. If a single stage process can achieve the limits proposed then making the best use of the existing assets on site such as the existing Bardenpho reactor are likely to represent the lowest capital cost.

### 4.1 Filtration

The unit process of filtration can be added as a separate stage after the existing final clarifiers of the Bardenpho or as a process that is integral to the secondary process such as an MBR. As discussed above the ideal filtration stage from a quality perspective is a membrane filter as this has the lowest pore size compared to most tertiary systems such as sandfilters, disc filters etc.

### 4.2 Primary Tank Bypass

Bypass of the primary sedimentation system at the plant will increase the carbon applied to the Bardenpho and should decrease or eliminate the need for ethanol dosing. Table 4.1 and Table 4.2 below compare the nitrogen reduction potential of the primary settled and raw wastewater respectively. The calculations have been based on 100% of the flow being treated in the Bardenpho (as currently configured). This is done for illustrating the use of carbon only and assumes no ethanol dosing.

Table 4.1: Denitrification Potential of Primary Settled Wastewater

Parameter	Units	Value	Notes
Total COD	mgCOD/L	252	Site data
Process Sludge Age	days	12	Site Data
Anoxic Fraction	%	33	Existing unaerated fraction
Nitrogen removal potential	mgN/L	12	calculated
Ethanol Saving	L/d	0	Baseline

Source: Insert source text here

Table 4.2: Denitrification Potential of Raw Wastewater

Parameter	Units	Value	Notes
Total COD	mgCOD/L	450	Site data
Process Sludge Age	days	12	Site Data
Anoxic Fraction	%	33	Existing unaerated fraction
Nitrogen removal potential	mgN/L	22	calculated
Ethanol Saving	L/d	700	At 20ML/d

The tables above show that in its current configuration the Bardenpho can remove approximately 10 mgN/L more nitrogen with bypass of the primary sedimentation tanks. At 20ML/d this represents a saving of approximately 700L/d of ethanol or \$320,000/yr at \$1.27/L.

### 4.3 Carbon Utilisation

As discussed in section 4.1 the use of primary sludge as a carbon source could reduce (not eliminate) the use of ethanol for denitrification and provide a significant OPEX saving. However the major disadvantage of bypassing primary treatment is an increase in the mass of solids entering the secondary process.

If the secondary volume of the plant is taken as fixed (i.e. assuming reuse of the Bardenpho reactor) then the concentration of solids within the process will increase as a result of bypassing primary solids. This

is estimated to in the order of 1.2g/L taking the estimated MLSS from 2.8g/L to approximately 4g/L.

As discussed above the Bardenpho clarifiers are currently performing relatively poorly in terms of solids removal with an average of approximately 23mg/L under current flows. In the future with increased flow, this performance could deteriorate further. Moreover if more solids are added to the process from primary bypass then it is highly likely that the clarifiers will be overloaded.

In terms of option selection this has the following implications:

- Bypass of primary sedimentation is not feasible without increasing clarifier capacity – ground conditions onsite are known to be poor introducing construction risk if new clarifiers are built
- Filtration is considered essential to remove as much particulate phosphorus and nitrogen as possible so this would need to be added to the process in addition to clarifiers if the primary tanks were bypassed.
- If primary solids are removed then the plant will rely more heavily on external carbon and this is likely to be a higher operational cost than making best use of the COD in the wastewater.
- TERAX can be used to add carbon back to the process if primary solids are removed, however this has the same risk profile as the options currently being considered and does not mitigate any of the identified risks associated with TERAX.

If filtration is a given in the process, tertiary denitrification is not essential, best use is made of the current Bardenpho reactor and primary sedimentation is bypassed, then the most likely option is to replace the final clarifiers of the Bardenpho and retrofit these with membranes.

An MBR can operate at a much higher mixed liquor concentration than a clarifier based process an increase in solids loading on the Bardenpho reactor is not an issue, provided maximum solids loading limits of the membranes are not exceeded.

#### **4.4 Process Configuration**

Based on the characteristics of the raw wastewater (assuming primary bypass) the nitrogen removal potential of the plant can be calculated as above (see table 4.2). In addition to the carbon availability a critical factor for determining nitrogen removal potential is the process

configuration. There are “standard” process configurations for nitrogen removal there are described below.

#### 4.4.1 MLE Process

The MLE process consists of a single anoxic zone followed by an aerobic zone and solids liquid separation (see figure 4.1). Recycles are taken from the aerobic zone to the anoxic zone and from the clarifier or membrane underflow

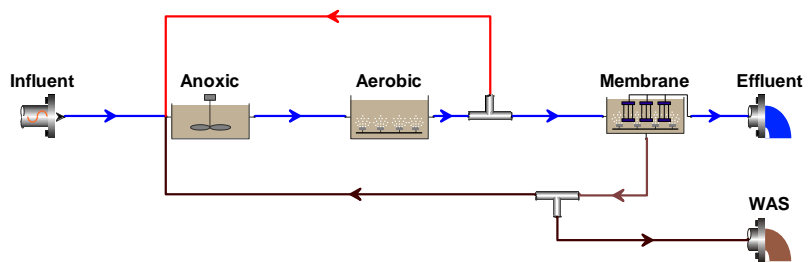


Figure 4.1: MLE Process (with Membrane)

#### 4.4.2 Four Stage Bardenpho

Four stage Bardenpho - this configuration consists of a series of four reactors in an anoxic, aerobic, anoxic aerobic series. This configuration is very similar to the 5 stage Bardenpho configuration at the WWTP, with the first anaerobic zone removed (see figure 4.2)

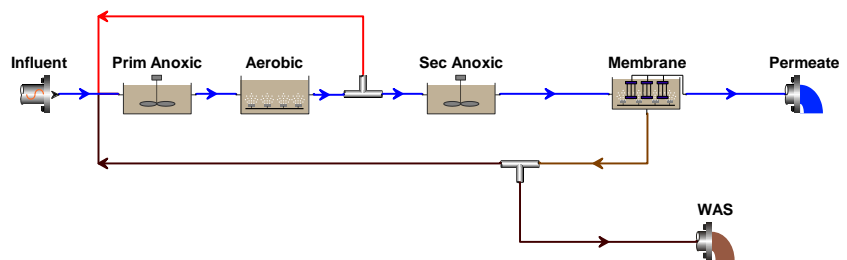
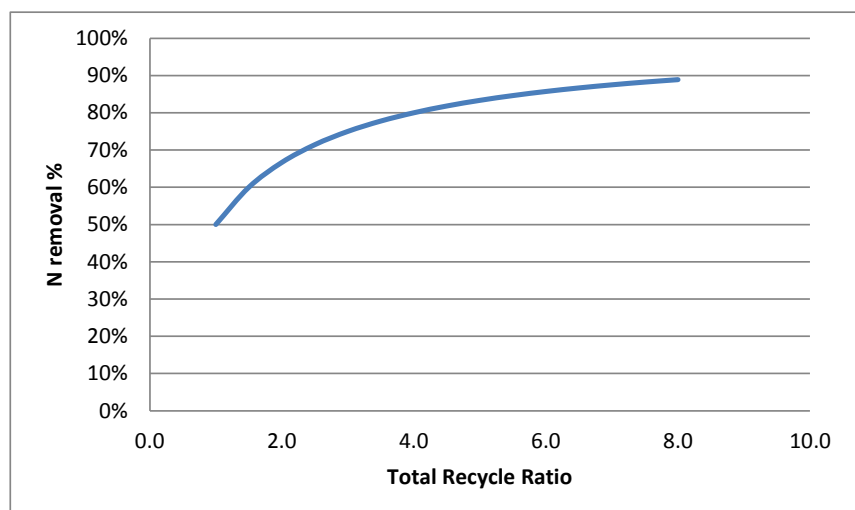


Figure 4.2: Four Stage Bardenpho with Membrane

The advantage of the four stage Bardenpho over an MLE is nitrogen removal efficiency. Figure 4.3 below shows the relationship between

the nitrogen removal efficiency and recycle ratio for an MLE process. As shown on the figure this configuration is limited to about 90% nitrogen removal with a recycle rate of up to 8 times the influent flow. Even at this very high recycle rate this configuration will not be able to remove enough nitrogen to meet the standard required for the Rotorua WWTP. With a four stage Bardenpho the limitations associated with one anoxic zone are removed and removal efficiencies of >90% are possible.

Figure 4.3: Nitrogen Removal Efficiency of Two Stage Process



In addition to the process configuration the unaerated fraction of the process with respect to the aerated fraction determines its nitrogen removal potential. As a rule of thumb a maximum anoxic mass fraction of 50-55% can be used before nitrification becomes unstable. With a maximum anoxic fraction of 55% the denitrification potential of the process is increased therefore minimising the use of ethanol. Table 4.2 shows the denitrification potential of a four stage bardenpho at a mass fraction of 55%. This represents the maximum nitrate removal that can be achieved with the raw wastewater without carbon addition.



Table 4.2: Denitrification Potential of Raw Wastewater at 55% Mass Fraction

Parameter	Units	Value	Notes
Total COD	mgCOD/L	450	Site data
Process Sludge Age	days	12	Site Data
Anoxic Fraction	%	55	Existing unaerated fraction
Temperature (min)	C	20	calculated
Nitrogen removal potential	mgN/L	33	At 20ML/d

*Four Stage Bardenpho is the most Efficient Configuration to meet the required Nitrogen Standards with an anoxic fraction of 55%.*

#### 4.5 Ethanol Use

With an anoxic mass fraction of 55% the WWTP, configured as four stage Bardenpho, has the potential to remove approximately 33mgN/L without carbon addition. Table 4.3 summarises the required nitrogen concentrations required to meet the proposed consent limits. Based on these nitrogen standards there is a significant shortfall in the amount of nitrogen that can be removed without additional carbon. It is estimated at future flows of 23.8ML/d that approximately 600L/d of ethanol is required. This compares with an estimated ethanol consumption of 1900L/d projected for the current plant configuration (source: TERAX business case)

Table 4.3: Average Effluent Nitrogen Concentrations – Future Flows

Parameter	Units	Value	Notes
Effluent Ammonia	mgN/L	0.5	Based on Mean of combined current effluent
Soluble organic Nitrogen	mgN/L	1.25	Mean of MBR Organic N
Particulate Nitrogen	mgN/L	0	Assumed
Nitrate/Nitrite Required	mgN/L	1.75	Required to Meet limits
Nitrate/Nitrite with no carbon dosing	mgN/L	6.2	Calculated
Ethanol Dose	L/d	600	Calculated

Source: Insert source text here

*Conclusion: Ethanol dosing is required to meet future standards. In the proposed plant configuration this is estimated to be 600L/d*

#### 4.6 Solids Production

Solids production in the plant currently arises from two sources namely primary and secondary sludges. Waste activated sludge is thickened in a DAF and combined with primary sludge and dewatered (belt press). The resulting cake solids concentration from the existing belt presses is approximately 17%. Table 4.4 and 4.5 summarise the solids production for the current process configuration and for the suggested process configuration at current flows of 20ML/d.

For the purposes of comparison we have assumed that the current dewatering system would be replaced with duty standby centrifuges operating for a maximum of 6 hours per day and would increase cake solids to approximately 18%DS

Table 4.4: Sludge Production rates

Parameter	Units	Value	Heading Right
Primary Solids Mass	kg/d	3190	Data
Waste Activated Sludge Mass	kg/d	2280	Data
Total solids to Dewater	kg/d	5470	
Cake Dry Solids %	%	17	Data
Cake Volume for Disposal	m <sup>3</sup> /d	32	Data

Source: Insert source text here

Table 4.5: Sludge Production Rates - Proposed Configuration

Parameter	Units	Value	Heading Right
Waste Activated Sludge Mass	kg/d	3430	Data
Alum Sludge	kg/d	320	Tertiary Options Study
Total Solids to Dewater	kg/d	3750	
Cake Dry Solids	%	18	Assumed Centrifuge

Parameter	Units	Value	Heading Right
Cake Volume for Disposal	m <sup>3</sup> /d	21	Data

*Conclusion: Solids production is projected to be approximately 21m<sup>3</sup>/d including for solids associated with alum dosing. This compares to approximately 32m<sup>3</sup>/d under the current configuration.*

#### 4.7 Membrane Details

For the purposes of this study we have based the sizing and costs of the membrane system on GE ZeeWeed 500D membranes. These are the same product that was used for the side stream MBR currently used onsite.

The membrane capacity has been based upon treating 100% of the peak wet weather flow. This is reported as 850L/s in the Tertiary Options study and previous capacity study reports.

The membrane system has been sized to fit in a separate structure outside of the existing tanks and clarifiers such that the system can be built off line. We have not at this stage considered the fitting out of the existing clarifiers as we are unsure how this would be done while keeping the plant live. It is worth considering how this might be achieved if MBR is considered the preferred option as this represents significant costs savings to use existing structures.

The membrane selection details are summarised in table 4.5. The table is based on the following assumptions:

- Average through put of side stream MBR of 7ML/d
- Peak day flow to plant 40ML/d
- Peak day flow to side stream MBR 7ML/d
- Peak hour flow of side steam plant 470m<sup>3</sup>/hr
- Peak instantaneous flow to plant 850L/s
- Peak flow duration <1hr
- Standard GE Zeeweed 500D Membranes
- Minimum temperature of 18C

Table 4.5: Insert Table Title here

Flow Condition	Flowrate to new MBR	Flux Rate (L/m <sup>2</sup> /hr)	No of Cassettes
Average Day (future less side stream MBR)	17ML/d	24.7	16
Peak Day	33ML/d	37.5	28
Peak Hour	850L/s	43.5	36

Source: Insert source text here

We have assumed that the membranes will be arranged in four “trains” similar to the side stream plant. Based on the above table each train would have 9 cassettes making a total of 36. To allow the side stream plant to be offline for maintenance we have allowed a total of 10 cassettes per train arranged in a four trains, each having a peak instantaneous flow capacity of 200L/s. This gives a flow capacity of 800L/s with 4 trains online and 600L/s at n-1. If the instantaneous capacity of the side stream plant is considered (8 cassettes) the total flow capacity of the plant would be 960L/s.

*Four trains of 10 cassettes have been used to cost the plant*

## 5 Costs

Table 5.1: CAPEX Costs Estimate

Item	Estimate incl contingency
Preliminary and General	\$3,585,400
Screening	\$1,999,000
Connection of Membrane tank to Bardenpho	\$585,000
Membrane tank, RAS tank channels	\$4,743,000
Membranes, penstocks drain pumps and valves	\$7,176,000
RAS pumps and pipework	\$578,000
Permeate System	\$1,290,000
Blower and control building	\$1,600,000
Blowers	\$975,000
Utilities	\$877,000
Solids Dewatering	\$965,000
Electrical	\$2,700,000
Roading and general Site works	\$573,000
Alum Dosing	\$400,000
<b>Total Works Costs</b>	<b>\$28,046,400</b>

Source: Insert source text here