THE DARK SIDE OF DRINKING WATER – MANAGING RESIDUAL STREAMS

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ABSTRACT

The landscape of freshwater in New Zealand is changing with the introduction of Te Mana o Te Wai into to our regulatory frameworks, and the National Environmental Standards for Freshwater driving improvement to the freshwater quality in New Zealand.

This is bringing an increased focus on the availability and efficient use of water, and requirements for improved water quality for any discharges to freshwater bodies or the surrounding environment. This is driving water suppliers to look for:

- greater efficiency through recycling of waste streams to reduce discharges from water treatment plants, and
- improved water quality of discharge streams for the betterment of the environment

Upgrades from cartridge filtration and ultra-violet disinfection to processes using membrane filtration are becoming more common in New Zealand due to changing source water quality, particularly during heavy rainfall events. This process change introduces liquid residuals streams from backwashing and chemical cleaning of the membranes, which require management as part of the plant upgrades.

This paper summarises the typical residuals process streams used across New Zealand ranging from basic tank or pond settling systems to zero liquid discharge facilities with dewatering of solids.

As the amount of water recycled back into the process increases, the complexity of the process and operation increases. For each waste treatment option, this paper discusses:

- challenges in meeting drinking water regulatory compliance with rules around the recycle of water through the process,
- the increased operational requirements, and associated risk profiles,
- the overall plant operation including how plant start-up and shutdown are managed and challenges with recovering from an abnormal event or process failure,
- specific process constraints.

This paper also discusses challenges experienced through consenting of discharges with the lack of a national standard resulting in inconsistent approaches and standards throughout the country.

KEYWORDS

Drinking water, Water treatment, Discharges, Freshwater, Waste streams

INTRODUCTION

The landscape of freshwater in New Zealand/Aotearoa is changing with the introduction of Te Mana o Te Wai into to our regulatory frameworks, and the National Environmental Standards for Freshwater driving improvement to the freshwater quality in Aotearoa.

This is bringing an increased focus on the availability and efficient use of water, and requirements for improved water quality for any discharges to the freshwater bodies or the surrounding environment. This is driving drinking water suppliers to look for:

- greater efficiency through recycling of waste streams to reduce discharges from water treatment plants, and
- improved water quality of discharge streams for the betterment of the environment

Upgrades from cartridge filtration and ultra-violet disinfection to processes using membrane filtration are becoming more common in Aotearoa due to changing source water quality, particularly during heavy rainfall events. This process change introduces liquid waste streams from backwashing and chemical cleaning of the membranes, which require management as part of the plant upgrades.

Managing waste streams requires consideration of multiple factors, including land availability, available discharges (quantity and quality), cost, and operational risk. This paper discusses some of these challenges and considerations.

TYPICAL WASTE STREAMS

Drinking water treatment processes involve the removal of solids through differing process(es). Figure 1 below shows the most common waste streams from a conventional water treatment plant (WTP).

Figure 1: Typical treatment process

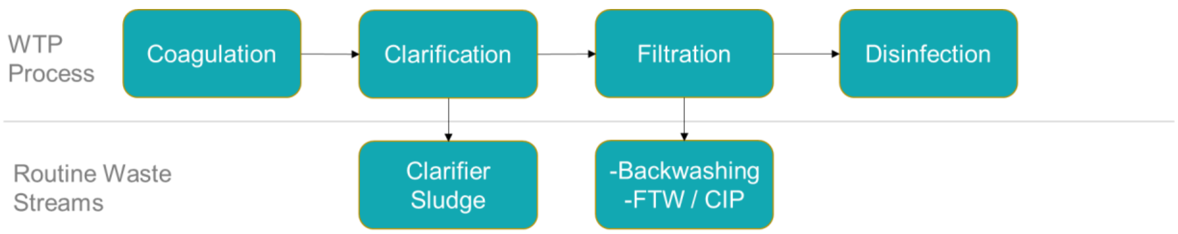


Table 1 below summarises the waste stream discharges from typical WTP processes.

Table 1: Typical WTP process discharges

Discharge path	Typical use and frequency	Typical volumes (as a % of process unit feed)	Typical solids ranges (g/m^3)
Clarifier Sludge	Removal of settled solids with a 30 second to 2	1 to 4% depending on raw water quality	4,000 to 10,000 g/m^3

	minute drain every 5 to 60 minutes depending on water quality.		
Filter backwashing – rapid media filtration	Every 8 to 48 hours per filter, to remove captured solids	<1%	20 to 400 g/m³
Filter backwashing – membrane	Every 15 to 60 minutes per membrane train	4 to 10% depending on feed water quality (can go higher in poor quality feed for short durations)	200 to 400 g/m³
Filter to waste – rapid media only	After each backwash	<1%	Less than 5 g/m³
Membrane Clean in place (CIP)	Periodic chemical (acid or chlorine based) clean as required to maintain membrane health	<1%	Targets dissolved solids, typically low.

REGULATORY REQUIREMENTS

The Drinking Water Quality Assurance Rules (25 July 2022, QA Rules) have specific rules for the recycle of waste streams, with a high-level summary below:

- All recycle streams must be returned to the inlet of the plant (or upstream of the membranes where membrane filtration is used).
- Recycle must be less than 10% of the instantaneous raw water flow.
- Turbidity monitoring is required to demonstrate that the recycle water has received effective solids/liquid separation.
- If a recycle flow of greater than 10% is required, separate treatment of the recycled stream is required to inactivate or kill protozoa and bacteria before the waste stream is returned to the inlet of the plant.
- Filter to waste is not considered within the 10% limit for a recycle stream
- Where there is no filtration (sedimentation only), water cannot be recycled. Recycle is not stipulated for UV or Ozone processes, however these do not typically have a waste stream if used as only treatment process.

Generally, recycle of filter backwash and clarifier sludge is achievable providing that the instantaneous rate of 10% of the raw water flow is not exceeded. Where 10% of this instantaneous rate may be exceeded, separate treatment is required to inactivate protozoa and bacteria prior to any recycle. Our interpretation of this is that a secondary treatment process is required

DISCHARGE PATHS

The following discharge paths for waste streams are available:

- To sewer
- To land
- To a water body.

These are described below.

DISCHARGE TO SEWER

Where there is a nearby wastewater network, discharge of solids to sewer, then treatment at a wastewater treatment plant can be considered. This removes the need for any specific discharges and consenting requirements from a water treatment plant – but passes on the problem downstream.

Discharges of more concentrated solids from a water treatment plant can have some benefit for a wastewater plant, with the typical introduction of an aluminum-based sludge from the coagulant process able to bind some phosphorous from wastewater.

Discharge of the waste stream from a WTP to sewer means that all solids are managed through a wastewater treatment plant, meaning that any solids dewatering, or removal is not required from a WTP.

DISCHARGE TO LAND

Typically preferred of discharges to water from a mana whenua perspective; waste streams from a WTP can be discharged to irrigation or ground soakage. These discharges can have a positive benefit with surrounding land users where a conjunctive use may be possible.

DISCHARGE TO A WATER BODY

A common discharge point for waste streams is into a nearby waterway (often downstream or away from the water source). Discharges to a water body typically require a more detailed assessment of environmental effects (AEE) with a requirement to demonstrate the ecotoxicity of the discharges and the effect on the downstream water body.

Limits of water quality and flow typically require strong justification

CONSENTING ENVIRONMENT

Based on the Authors' experiences, we have noticed some inconstancies and repetition of analysis within similar discharges. These are summarised below:

- **Aluminium**: we have completed similar analyses and discussions with various consenting authorities relating to the ecotoxicity of aluminium. We have also noticed an inconsistent approach in the required measurement method of aluminium across regions, with a variety of total, acid soluble or soluble aluminium measurements required.
- **Chlorine**: discharge requirements for chlorine are generally more consistent; however we have seen limits in consents between 0.2 and 1.0 mg/L. Although chlorine can be ecotoxic at lower concentrations, we consider a 0.2 mg/L limit appropriate due to the typical colorimetric method of testing, with accuracy of readings decreasing below this level.
- **pH:** there is consistency in this area with typical limits being between a pH of 6 and 9.
- **Suspended solids:** there is consistency in this area with typical limits being between 25 and 50 mg/L. We note that these limits are higher than typical wastewater discharges, however suspended solids may be considered as a surrogate for other contaminants so do not consider this as unreasonable.

There is a strong need for consistency in the management of discharges with nationally accepted standards as a starting point to consider typical contaminant discharges from WTPs; to include limits and required measurements for each parameter. Providing this as a starting point could significantly reduce the complexity and cost of obtaining future discharge consents.

WASTE MANAGEMENT OPTIONS

Waste management options can be coarsely considered by the treatment and recycle of the following individual or groups of processes (Table 2), with a typical priority on the high volume, low solids waste streams:

Table 2: Typical WTP process discharge treatment options

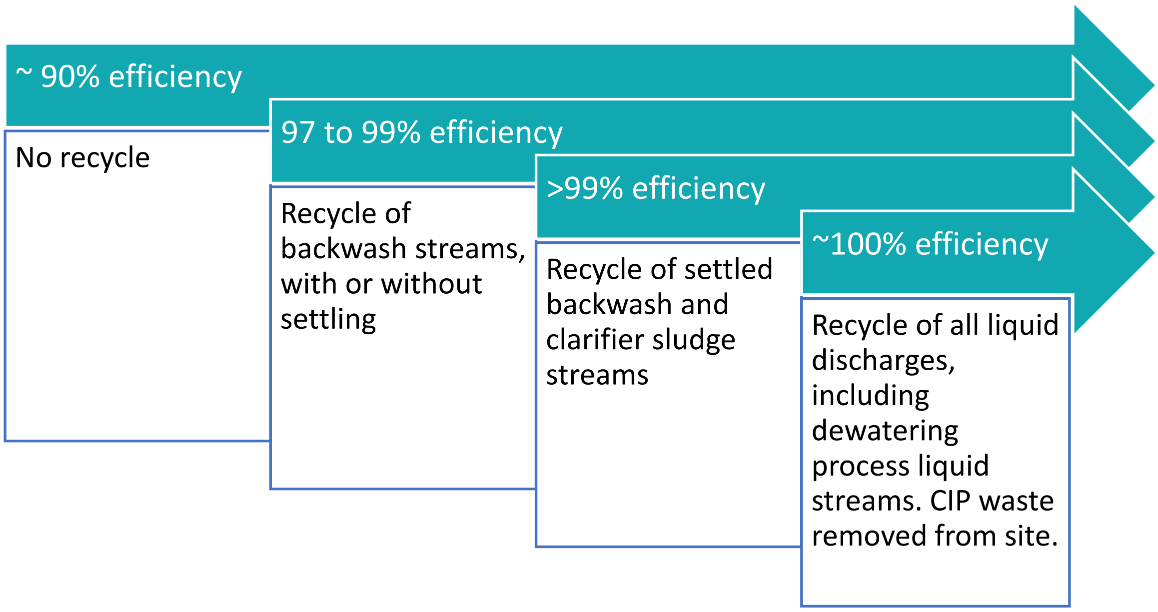
Treatment of	Management options	Comment
Filter to waste	Discharge or return via pumping	Not considered within the 10% recycle limit.
Filter backwashing (membranes or rapid media)	Direct recycle	Higher volume, lower solids.
	Pond settling	
	Clarification	
Clarifier sludge	Pond settling	Higher solids, lower volume
	Clarification	
	Sludge thickener	
Filter backwash and clarifier sludge	Pond settling	
	Backwash clarification and sludge thickener	
Filter backwash, clarifier sludge and mechanical dewatering treatment	Pond settling	Used for discharge of mechanical dewatering centrate/filtrate (unless to sewer), and other process overflows
	Backwash clarification, sludge thickener and mechanical dewatering	Zero liquid discharge plant, or discharge of mechanical dewatering centrate/filtrate
Membrane CIP waste	Pond Settling	Not typically completed when ponds are recycled
	Capture and tanker removal	Where liquid discharges are not allowed

Most WTPs require some form of solids separation process to allow environmental discharges or recycle to occur (unless all waste is discharged to sewer). This can be achieved by either mechanical dewatering (typically using a centrifuge or filter press with solids removed from site).

Where a sewer connection is available, some or all waste streams can be discharged to the sewer for treatment at a wastewater treatment plant.

Management of the liquid side of waste streams can be coarsely grouped by the typical water efficiency through a WTP (or percentage of treated water to raw water, Figure 2).

Figure 2: Typical liquid stream removal options



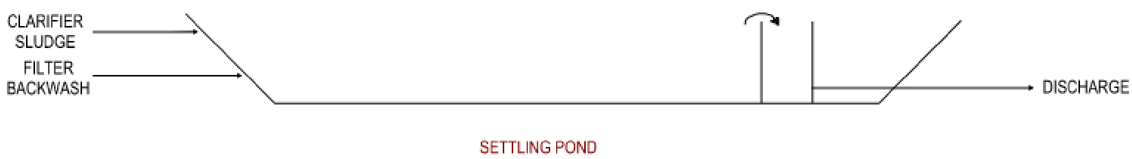
Typical processes used in Aotearoa are described in more detail below.

Direct recycle of backwash water is currently used in Aotearoa. However, the QA Rules state (and current Drinking Water Standards of New Zealand 2005 Revised 2018 (until November 2022)) state that turbidity monitoring is required *to demonstrate that the recycle water has received effective solids/liquid separation.* On this basis, this has not been considered in more detail below as there is no effective solids/liquid separation.

SETTLING PONDS

Ponds systems are simple and effective, with a relatively low capital cost. Both solid/liquid separation and solids dewatering can occur in the same basin (Figure 3). Two ponds are normally provided, with one online and one offline for dewatering.

Figure 3: Typical pond process

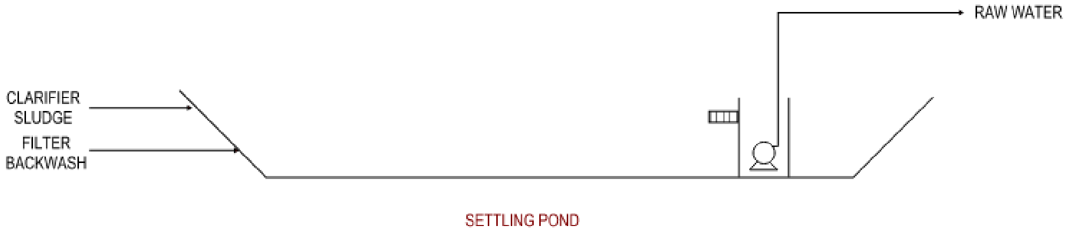


They require a larger land area to allow for settling and dewatering, and with two by 100% duty systems.

When the solids level in a pond becomes high, ponds are changed over, and the liquid is decanted before the sludge is physically removed by a digger and taken to an appropriate landfill/mono-fill as desired.

An outlet screened pumping well can be installed or retrofitted on pond outlets which can then be pumped back to the plant inlet to allow recycle of settled solids (Figure 3). With a large surface area, ponds have a large buffering capacity, allowing for high inflows from media filter backwashing to be buffered and then recycled. This recycle system can provide high levels of water efficiency through a WTP, with losses primarily due to ground soakage or evaporation losses through a pond system.

Figure 4: Typical pond with recycle process



When recycling from a pond, additional considerations are required into what process events may not be suitable for recycle. Some considerations include:

- What other systems drain into a pond and what are their risks, e.g., floor drains, chemical spills, membrane CIP waste and wat events may require plant recycle to be stopped.
- Being open ponds, algal growth, or other airborne contaminants from nearby activities need to be considered where a recycle process is used.

A summary of key parameters for pond systems is provided in table 3 below. Ponds without any recycle have been more common, with retrofitting pumped outlets to allow for recycle becoming more common.

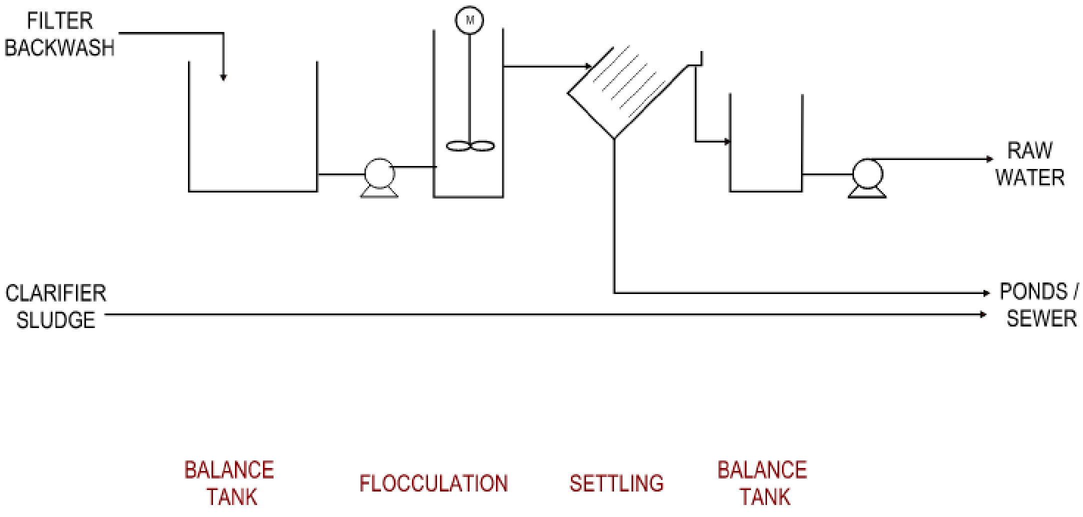
Table 3: Pond system summary

Process	Capital cost	Land area required	Operating cost	Operating risk	Water efficiency
Without recycle	Low	High	Low	Low	Low (90%)
With recycle	Low	High	Low	Medium	Excellent (>99%)

BACKWASH SETTLING

A clarifier or similar settling tank can be used to provide solid liquid separation from a membrane or filter backwash stream (Figure 5). A circular clarifier/thickener or lamella clarifier is most commonly used. Depending on the process used, additional coagulant or polymer can be added to further improve settling.

Figure 5: Typical pond with recycle process



This process creates a more concentrated waste stream, similar to clarifier sludge (4,000 to 10,000 g/m^3). The supernatant from the settling unit is typically recycled, meaning that approximately 99% of the raw water is recovered for treated water.

This process allows for a higher rate system, meaning that less land area is required. Operational costs include the addition of coagulant or polymer, dependent on the main plant process.

Table 4 below provides a summary of the backwash settling process.

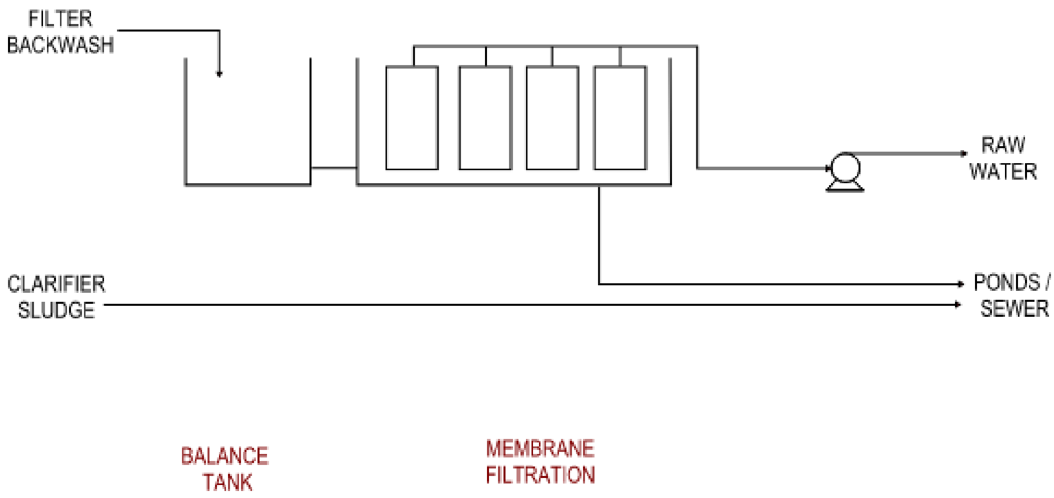
Table 4: Backwash settling system summary

Process	Capital cost	Land area required	Operating cost	Operating risk	Water efficiency
Settling process with recycle	Medium	Low	Medium	Low/medium	Excellent >99%

SECOND STAGE MEMBRANE FILTRATION

Although not common in Aotearoa, the use of membrane treatment of filter backwash prior to recycling can be considered (Figure 6). With high influent solids loadings, this process is more suited to submerged membrane systems.

Figure 6: Second Stage Membrane recycle process



As the purpose of the process is for solids/liquid separation only, there is no need to meet any requirements for protozoal log-removal credits. Measurement of the filtrate turbidity only is suitable to meet regulatory requirements for a recycle stream. This means that older membranes used on the main process can be repurposed for treatment of backwash streams.

With high solids loadings, membrane recovery is lower that for the main treatment process. Solids build up on the membranes requires more frequent backwashing and lower recovery is typically available than compared to backwash settling. Because of this, the waste stream from the membrane process is of a higher volume and lower solids than that of a backwash clarifier. The membrane filtered water for recycling is lower in solids than a backwash settling system.

Membrane fibers are also susceptible to damage from solids and have limitations on exposure to polymers. Membranes are a physical barrier, so the addition of coagulant is not required for this solids removal application. Pumping through the membrane is still required.

Table 5 below provides a summary of the second stage membrane process.

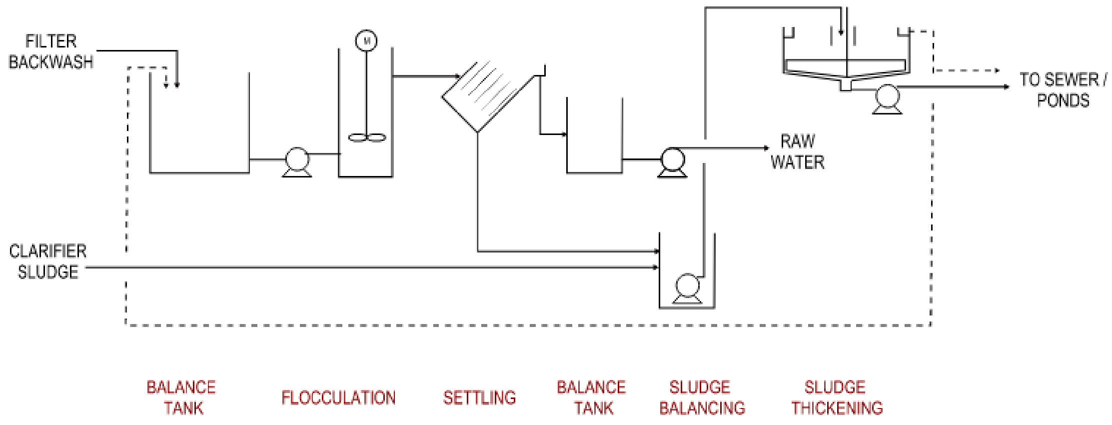
Table 5: Second stage membrane summary

Process	Capital cost	Land area required	Operating cost	Operating risk	Water efficiency
Second stage membrane filtration	Medium	Low	Low/Medium	Low	Good >97%

BACKWASH SETTLING AND SLUDGE THICKENING

The addition of a thickening process to backwash settling allows further concentration of solids by providing further treatment of clarifier sludge and backwash settling sludge (Figure 7).

Figure 7: Typical backwash settling and sludge thickening process



A circular thickener with a mechanical rake is commonly used. Polymer is typically added to this process to further enhance settling. This process would be more suited to a sewer discharge to reduce trade waste fees.

Supernatant from a sludge thickener is typically recycled back into the backwash settling process, although can be discharged off site if required. This process allows for greater than 99% recovery of raw water.

Control of polymer dosing requires careful management so to avoid process upsets within the thickener, and any downstream carryover and filter blinding or membrane damage.

The polymer type needs to be considered for WTPs using membrane processes, where certain polymers be detrimental to membrane life.

Table 6 below provides a summary of the backwash settling and sludge thickening process.

Table 6: Backwash settling and sludge thickening summary

Process	Capital cost	Land area required	Operating cost	Operating risk	Water efficiency
Backwash settling and sludge thickening	Medium/High	Medium	Medium	Medium	Excellent >99%

BACKWASH SETTLING, THICKENING AND DEWATERING

Mechanical dewatering is added to the solids from a sludge thickener to create a dewatered solids stream that can be removed from site for disposal 9Figure 8). This process has similar operational risks to backwash settling and thickening in terms of management of recycle streams, with the additional complexity of the operation of mechanical dewatering systems.

The addition of mechanical dewatering:

- Typically requires the addition of polymer into the feed stream, with careful control and optimization to manage the dewatered sludge dry solids % and
- Has additional maintenance costs with additional unit processes
- When mechanical dewatering is unavailable, thickened sludge would need to be removed from site via tanker.
- Has a liquid waste stream (centrate or filtrate) which is often high is polymer and contaminants that requires discharge.

Figure 8: Typical backwash settling, sludge thickening and mechanical dewatering process

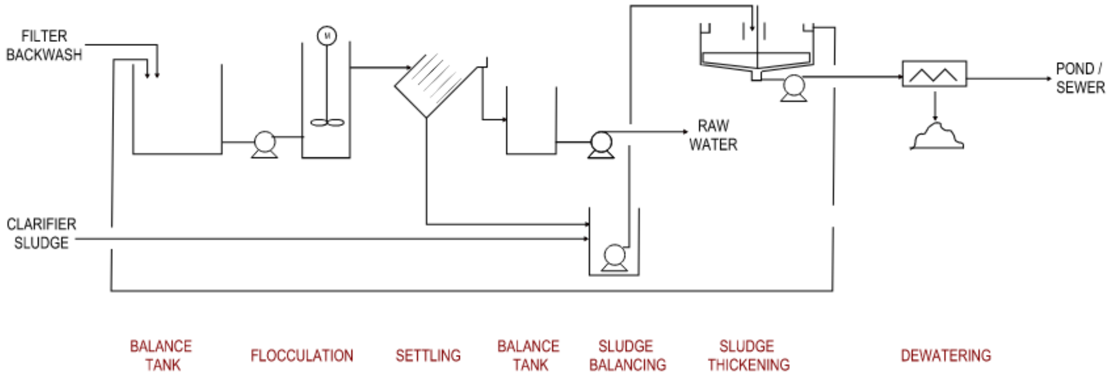


Table 7 below provides a summary of the backwash settling, sludge thickening and dewatering process.

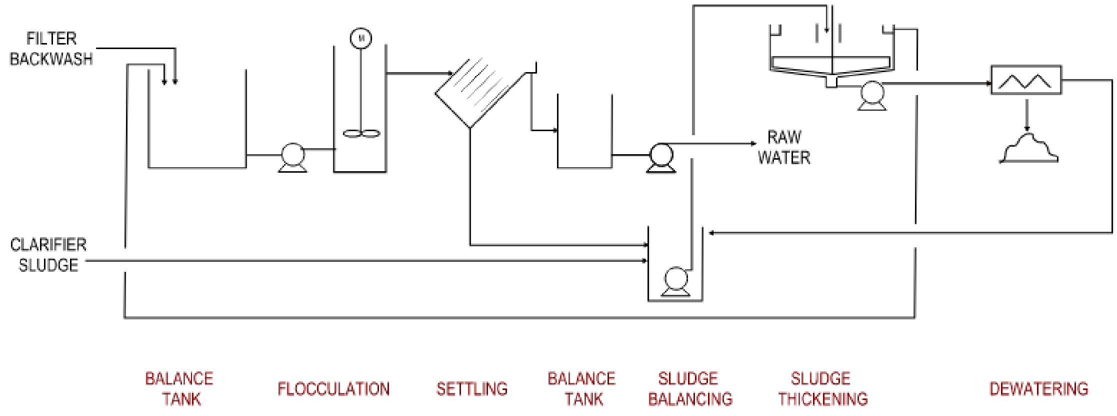
Table 7: Backwash settling, sludge thickening and dewatering summary

Process	Capital cost	Land area required	Operating cost	Operating risk	Water efficiency
Backwash settling, thickening, and dewatering	Medium/High	Medium	Medium/high	Medium/High	Excellent >99%

ZERO LIQUID DISCHARGE

The holy grail of water efficiency also brings the highest process risk. A zero liquid discharge plant is similar to the settling, thickening and dewatering system above, but with the recycle of the filtrate/centrate waste stream through the thickening system (Figure 9).

Figure 9: Zero liquid discharge



This process requires considerable operational management and increased process risks as the only removal path of contaminants from a WTP is via dewatered solids.

Introducing the recycle of the dewatering process liquid stream requires the consideration of the following:

- The amount of polymer used through the WTP, particularly the dewatering process.
- The operation of the dewatering process during plant operation to manage the introduction of recycled polymer throughout the system. Dosing of polymer allows some acrylamide to be dissolved into the liquid stream and where this is operated when the WTP is not running, there is a possibility that high acrylamide levels are recycled into the raw water on plant start-up.
- The level of polymer dosed and the capacity of the dewatering process relative to the pant operating flow, such that carryover of polymer and acrylamide is managed appropriately. Commonly a dewatering process is sized for the peak solids throughput and runs as a batch process less frequently during normal raw water quality. This needs to be considered for the operation of the process.
- How chemical cleaning systems (e.g., membrane cleaning) is managed. This is not suitable for being recycled and needs to be removed from site. Reduction in chemical discharges can be achieved through heating and re-use applications.

Table 8 below provides a summary of the zero liquid discharge process.

Table 8: Zero liquid discharge summary

Process	Capital cost	Land area required	Operating cost	Operating risk	Water efficiency
Zero liquid discharge	High	Medium	High	High	Supreme >99.9%

CONCLUSIONS

The water industry is in a period of change with regard to freshwater quality and the requirements for discharges to our environment. This is driving us to consider the efficient use of our water and requiring changes to treatment processes – introducing waste streams to existing WTPs.

Discharges from WTPs can be to land, water, or sewer, which inform the available discharge quantity and quality for any WTP. We consider a need to provide a more consistent approach towards the setting of typical discharge limits (chlorine, pH, suspended solids and aluminium in particular) to reduce the effort, time and cost associated in obtaining discharge consents.

The availability of water can also influence the management of waste streams, with the introduction of a recycle system to a WTP able to increase the overall capacity without any increase to the water taken from the source.

Treatment and recycle of most waste streams is possible within a WTP, however with increased recycle, comes increased operational risk. These risks are summarised in Table 9 below

Table 9: Risk of process recycle

Option	Approximate Water efficiency	Operational Risk	Comments
No recycle	90%	Low	All discharges to environment. Larger discharge consent required.
Backwash recycle (no settling)	95 to 99%	Medium	No solids settling prior to recycle. QA Rules state that turbidity monitoring is required *to demonstrate that the recycle water has received effective solids/liquid separation.*
Settled backwash recycle	95 to 99%	Low-medium	Buffering or discharge of flows >10% required. Backwash settled sludge for dewatering or discharge.
Recycle of Backwash settling, clarifier sludge thickening	>99%	Medium	Thickening processes typically have polymer and carry-over can occur with poor dosing control. Careful polymer selection required for membranes
Recycle of Backwash settling, clarifier sludge settling, dewatering	>99.9%	High	Careful process control required to balance a ‘batch’ dewatering process with a continuous plant operation. Dewatered solids and spent cleaning chemicals removed from site.

There are multiple process options that can be considered for the treatment of waste streams. A relative high-level summary is provided in table 10 below

Table 10: Summary of typical waste management options

Process	Capital cost	Land area required	Operating cost	Operating risk	Water efficiency
Pond system without recycle	Low	High	Low	Low	Low >90%
Pond system with recycle	Low	High	Low	Medium	Excellent >99%
Settling process with recycle	Medium	Low	Medium	Low/medium	Excellent >99%
Second stage membrane filtration	Medium	Low	Low/Medium	Low	Good >97%
Backwash settling and sludge thickening	Medium/High	Medium	Medium	Medium	Excellent >99%
Backwash settling, thickening, and dewatering	Medium/High	Medium	Medium/high	Medium/High	Excellent >99%
Zero liquid discharge	High	Medium	High	High	Supreme>99.9%

REFERENCES

Water New Zealand Water Supply Managers Group (1998), '*Management of Water Treatment Plant Residuals in New Zealand Handbook*'