Waihī Wastewater Treatment Plant
Technical Assessment of Plant Capacity, Compliance and Remediation to Enable Rezoning of Land

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1 EXECUTIVE SUMMARY

This report investigates capacity at the Waihī Wastewater Treatment Plant with the view of rezoning additional land thereby increasing the influent catchment size.

The facility, a log_3-rated treatment system with a designed hydraulic capacity of 4,000 m^3/day, utilises a multi-barrier approach comprising two facultative ponds, a dissolved air flotation plant for solids separation, sludge dewatering via Geobag systems, and an Ultra Violet disinfection stage prior to discharge into the receiving Ōhinemuri River. While the Waihī Wastewater Treatment Plant generally demonstrates robust operational performance, exceedances in Total Ammoniacal Nitrogen levels suggest systemic vulnerabilities exacerbated by external and internal factors. Recent issues with high E coli discharge are addressed with causes identified and mitigation strategies implemented by the Hauraki District Council Treatment Plant Operations Team to meet future consent compliance.

A phased corrective action plan is already in place, emphasizing biochemical optimisation, process control enhancement, and infrastructural augmentation.

The plant compliance is reviewed in an ongoing capacity to assess the impact of improvements over time and maintain compliance with consented discharge limits.

The wastewater treatment plant is expected to have sufficient capacity to meet demand until the year 2048 under high population growth projections, however, this does not allow for any high load industrial waste.

2 INTRODUCTION

The Waihī WWTP has experienced recurrent exceedances in TAN concentrations, attributable to suboptimal nitrification kinetics, influent variability, and hydraulic constraints. This report outlines a comprehensive diagnostic and intervention framework embedded in wastewater engineering principles.

2.1 Key Challenges

2.1.1 Influent Variability

Upstream inflow and infiltration (I&I) during wet weather events impose significant hydraulic stress, reducing the effective residence time in oxidation ponds and diluting the influent nutrient load, thereby compromising biological nutrient removal (BNR) efficiency. Temperature plays a significant role in BNR efficiency, lower temperatures line up with periods of higher rainfall making it difficult to assess the overall impact of I/I.

2.1.2 Sludge accumulation

The DAF plant effectively removes TSS but produces a concentrated sludge by-product that needs to be managed. This was previously returned to the pond increasing sludge accumulation and reducing HRT. Surveys showed in 2013 40% of available pond volume was taken up by sludge. Following desludging in 2021/2022 the DAF sludge has been redirected to onsite Geobags (from May 2023), though the dewatered by-product (likely high in TAN) is returned to the ponds.

2.1.3 Hydraulic Retention Limitations

The oxidation ponds, critical for preliminary biochemical oxygen demand (BOD) and nitrogen attenuation, are unable to maintain optimal hydraulic residence time under peak flows, impacting nitrification kinetics.

2.1.4 Operational Constraints

The DAF plant effectively reduces suspended solids but may inadvertently elevate the TAN concentration in the clarified effluent due to inadequate upstream nitrification. Furthermore, the UV disinfection system, while effective for pathogen inactivation, offers no attenuation for residual TAN, underscoring the necessity for upstream process optimization.

2.1.5 Suboptimal Dissolved Oxygen (DO) Levels:

Achieving aerobic nitrification requires maintaining DO concentrations between 2.0-3.0 mg/L. Increased aeration is expected to directly increase treatment capacity

3 PROBLEM IDENTIFICATION

3.1 Current and Future Capacity

3.1.1 Treatment Plant Capacity Assessment, 2016[1]

- The 10%ile raw wastewater flow into the Waihī WwTP between July 2013 and June 2016 was 914 m^3/d.
- At a per capita contribution of 250 L/head.d, this equates to a connected population of 3,656, compared with the 2013 Census population of 4,527.
- At a per capita BOD contribution of 70 gBOD/head.d, this equates to a raw domestic wastewater load of 256kg/d on the basis of a population of 3,656.
- Based on a monthly average minimum pond temperature of 9oC and a Pond 1 area of 41,650 m2, the permitted maximum temperature-based loading is 373 kgBOD/d. The 8 kW of mechanical aeration in Pond 1 provides theoretical treatment capacity for an additional 128 kgBOD/d, giving a total treatment capacity for the Waihī WSP of 501 kgBOD/d.

3.1.2 Treatment Plant Capacity Assessment, 2023

- From Oct 2020 to Aug 2023 the 10^{th}%ile inflow to the treatment plant was 1225m^3/day
- Similar per capita contribution 250L/head equates to connected population of 4900, compared with 2018 census population of 5,409 and 2023 census population of 5682.
- A per capita BOD contribution of 70 gBOD/head.d equates to a raw domestic wastewater load of 398kg/d on the basis of a population of 5,682.
- Therefore the current population is expected to be catered for within the existing plants capacity of 501 kgBOD/d.

3.1.3 Treatment Plant Capacity Assessment, 2048 – High Growth Scenario

- High growth projections for population in 2048 Waihī are 5,840[2], equating to 409kgBOD/day, therefore the high growth projection for 2048 is expected to be catered for within the existing capacity of the wastewater treatment plant

[1] Hauraki District Wastewater Treatment Plants Capacity Review – The Wastewater Specialists - March 2017 Hugh Ratsey

[2] Hauraki Growth Strategy “Rationale Ltd 2017 Demographic Projections”

3.2 Influent Characterisation

The influent to the Waihī WWTP exhibits significant variability in both hydraulic and organic loading, particularly during rainfall events, complicating process stability.

3.2.1 Variable COD:TAN Ratios

The optimal COD:TAN ratio for biological nitrogen removal typically ranges between 6:1 and 10:1. It is suspected that during peak industrial flows and wet-weather inflow and infiltration (I/I) events, the influent ratio may fall below 5:1, impeding efficient heterotrophic denitrification[3]. Additional monitoring has been started at the plant to establish if this is correct.

$$COD{:}TAN\ Ratio = \frac{Influent\ COD\ (\frac{mg}{L})}{Influent\ TAN\ (\frac{mg}{L})}$$

Prior to July 2011 the final effluent ammonia was historically very low. It is possible changes in upstream discharges e.g. changes in industrial discharge have led to an increase in TAN to be treated, though no source has been identified to date. Data suggests this is a larger issue during winter when higher rainfall levels are recorded;[4]

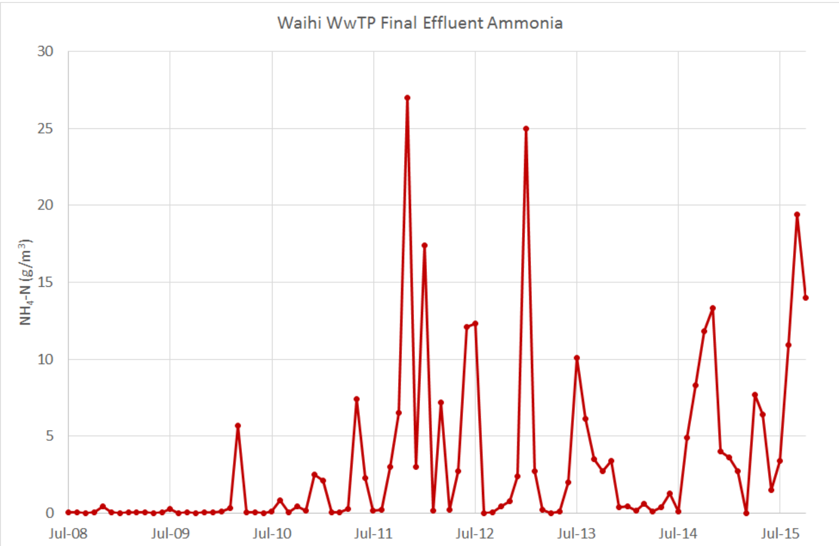

Figure 1 Total Ammoniacal Nitrogen Discharge 2008 to 2015

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[3] *Metcalf & Eddy's Wastewater Engineering: Treatment and Resource Recovery* archive.org
[4] Data compiled by Hugh Ratsey 2015

More recent data of long term Total Ammoniacal Nitrogen discharge compared to compliance limits;

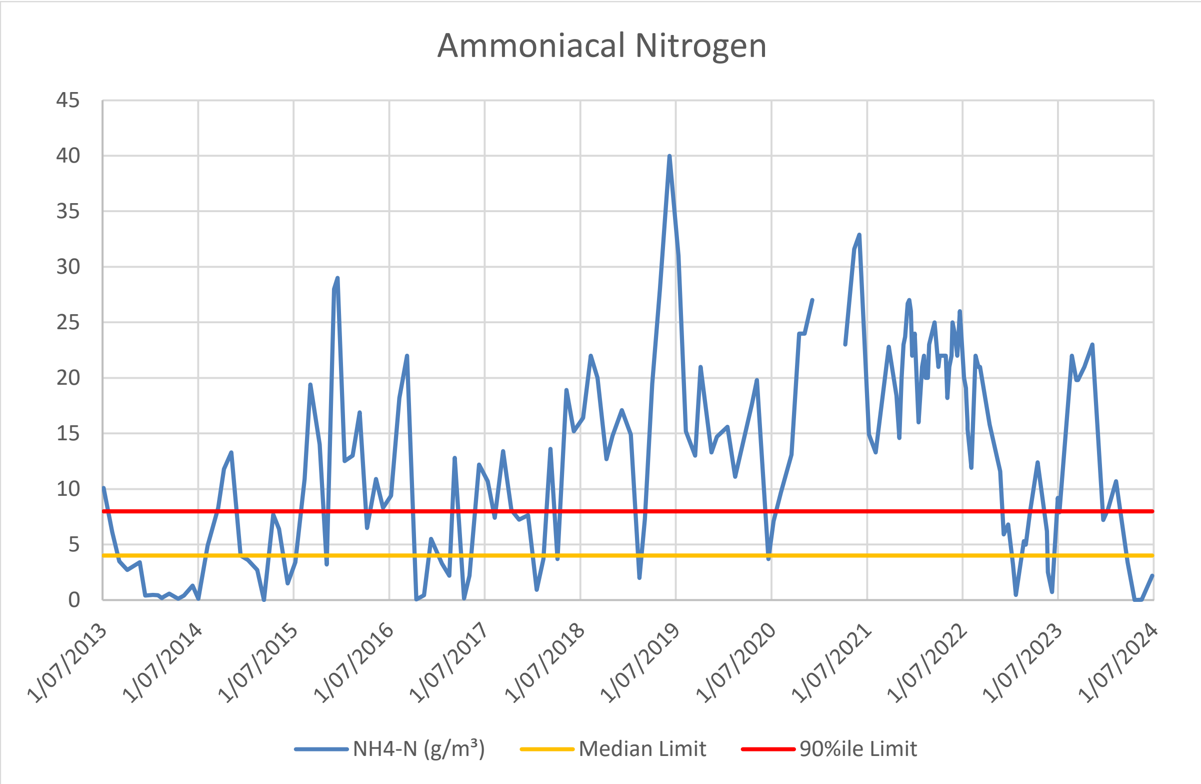


Figure 2 Total Ammoniacal Nitrogen discharged from 2013 to 2024 compared to consent limits

3.2.2 Dilution Effects

Excessive I/I during wet-weather events increases the total flow while reducing the concentration of influent nutrients. This phenomenon dilutes the feed to the oxidation ponds, reducing microbial substrate availability and hindering nitrifier proliferation.

Current treatment plant inflow Vs outflow demonstrates high levels of inflow and persistent infiltration over rain events and the following weeks. During dry periods (e.g. Oct 2020 to May 2021) the treatment plant mean production was 2490m^3/day. The mean plant production during extended wet weather (e.g. July 2022 to March 2023) is 3640m^3/day, a 32% increase. The median inflow is 3190m^3/day (including the Auckland anniversary and cyclone Gabrielle events), while plant capacity is 4000m^3/day indicating that the plant has approximately 20% flow capacity remaining. Based on a BOD contribution of 70g/head, a 2017 report on the WWTP estimated the plant had 3,500 population equivalent capacity remaining provided the ponds were de-sludged and DAF by-product was redirected. [5]

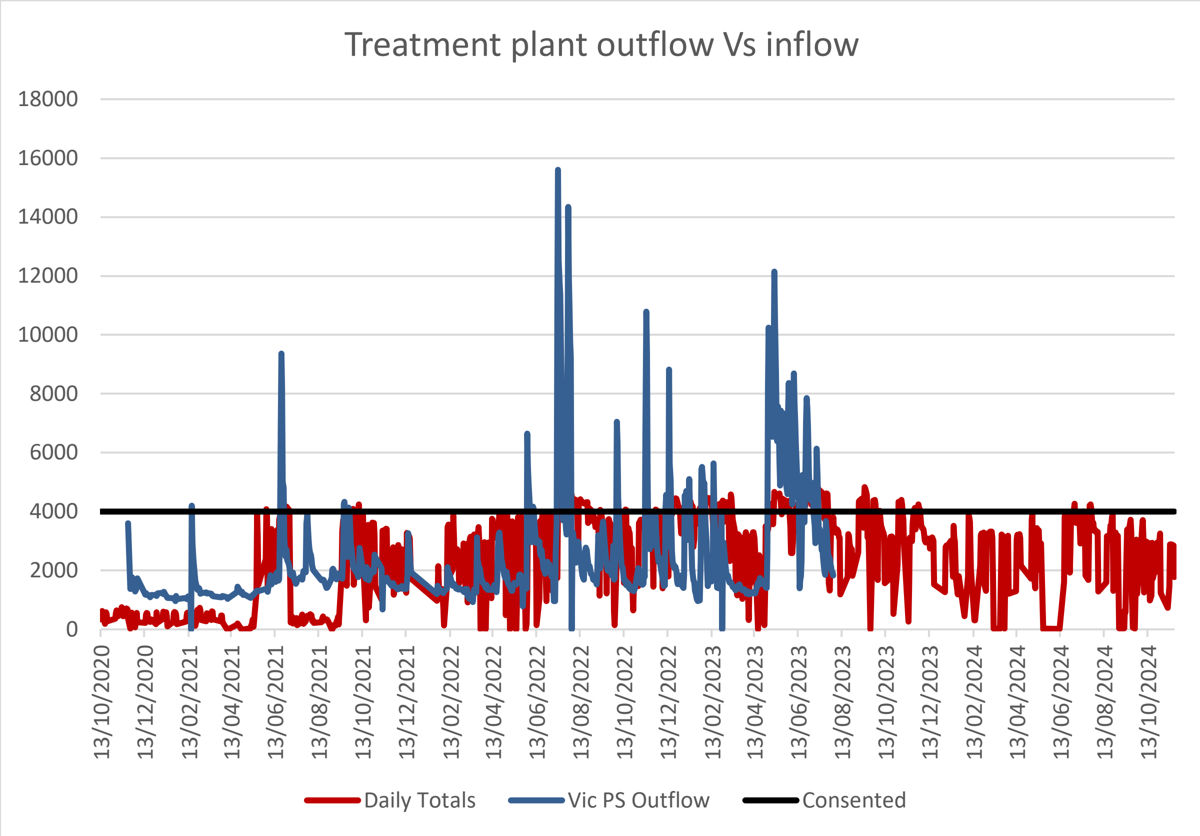


Figure 3 Comparison of daily treatment plant inflow Vs daily treated totals highlighting rainfall influence on inflow

3.2.3 Nitrifier Inhibition

Presence of inhibitory compounds (e.g., high free ammonia (NH_3) or nitrite (NO_2^-) can disrupt nitrification. At high pH (>8.5), free ammonia concentrations increase according to:

$$NH_3 = \frac{TAN}{1 + 10^{(pKa - pH)}}$$

For the WWTP, we currently measure pond pH, but do not measure influent pH. This is recommended to be added to the monitoring regime to predict in future if unexpected industrial flows are at the source of the issue. Regular monitoring at WW pump stations could be implemented to further narrow down the search within the catchment.

[5] Hauraki District Wastewater Treatment Plants Capacity Review – The Wastewater Specialists - March 2017 Hugh Ratsey

3.3 Process Dynamics

The current process exhibits limitations in its ability to consistently achieve nitrification due to design and operational constraints.

3.3.1 Suboptimal Dissolved Oxygen (DO) Levels:

Achieving aerobic nitrification requires maintaining DO concentrations between 2.0-3.0 mg/L. Measurements in the oxidation ponds frequently fall below 1.5 mg/L, limiting the activity of *Nitrosomonas* and *Nitrobacter*:

$$NH_4^+ + 1.5O_2 \xrightarrow{yields} NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + 0.5O_2 \xrightarrow{yields} NO_3^-$$

An investigation is underway to establish the most cost effective upgrades to the plant aeration. This involves a number of variables. The high energy demand of traditional aerators often results in a significant increase in plant running costs. Alternative new technologies are being assessed through a cost benefit analysis which have a higher capital cost and lower running costs.

3.3.2 Inadequate Sludge Retention Time (SRT):

Effective nitrification requires an SRT >15 days to support the slow-growing autotrophic nitrifiers. The observed SRT is currently unknown, but is calculated by:

$$SRT\ (days) = \frac{V(m^3) \times MLSS(\frac{mg}{L})}{Q\left(\frac{m^3}{day}\right) \times EffluentTSS\ (\frac{mg}{L})}$$

Where MLSS is the Mixed Liquor Suspended Solids (mg/L) low SRT is a direct consequence of high hydraulic throughput during peak flow events and pond short circuiting (see below). MLSS is not currently measured, probes can now be purchased to enable this function. Future upgrades could consider installation to facilitate better operational decision making.

3.3.3 Dead Zones and Short-Circuiting:

Hydraulic inefficiencies in the oxidation ponds lead to non-ideal flow conditions, with dead zones reducing the effective volume available for biological processes.

Residence time distribution (RTD) analysis could be undertaken to prove this is an issue within the main pond system.

$$\frac{D_L}{uL} = D$$

Where:

- DL = Longitudinal dispersion coefficient (m^2/s)
- u = Flow velocity (m/s)
- L = Length of the reactor or system (m)

DL can be determined at Waihī WWTP by using either dye or a salt slug and measuring the concentration at the pond outlet over time.

$$D_L = \frac{\sigma^2 \times u}{2 \times t_m}$$

Where

- σ^2 is the variance of the tracer concentration profile
- u is the flow velocity (discharge over cross sectional area)
- t_m is the Mean travel time of the tracer

This could be achieved onsite using sodium chloride and a conductivity meter installed at the pond outlet. Lateral and longitudinal dispersion could also be observed by introducing a dye at inlet at the same time as salt slug and observing dispersion over time with an aerial drone.

3.4 Hydraulic and Structural Limitations

Hydraulic and structural constraints further reduce the plant’s capacity to manage TAN effectively.

3.4.1 Reduced Residence Time

Theoretical hydraulic residence time (HRT) for the primary oxidation pond is calculated as:

$$HRT\ (days) = \frac{Pond\ Volume\ (m^3)}{Influent\ Flow\ (\frac{m^3}{day})}$$

During peak flows, the effective HRT drops below 4 days, compared to the design target of 5-7 days, negatively impacting nitrification efficiency.

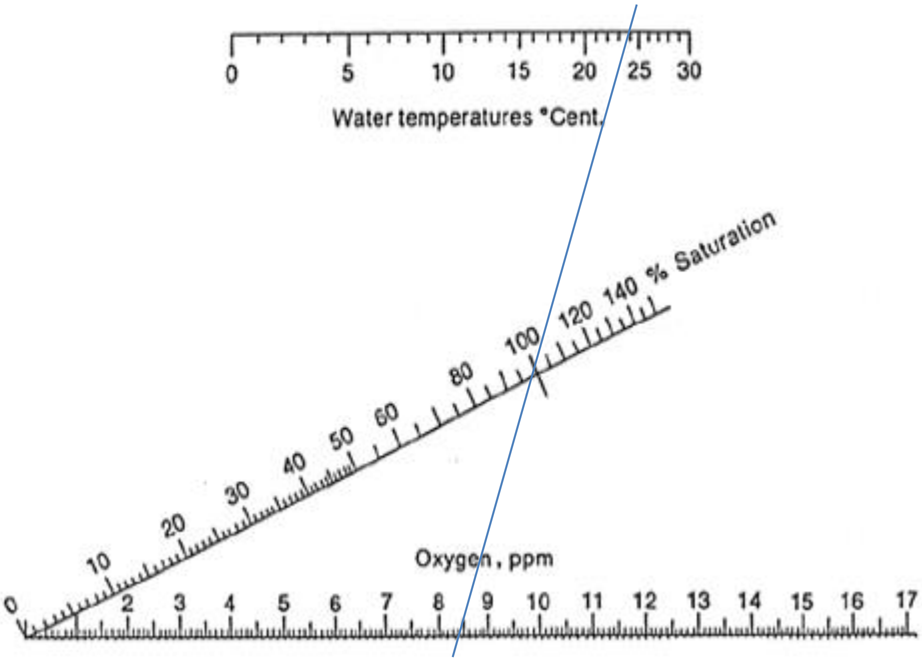
3.4.2 Aeration System Efficiency

The oxygen transfer efficiency (OTE) of the existing oxygen wheels is estimated at <10%, well below the industry benchmark of 20-25% for modern aeration systems. The oxygen transfer rate (OTR) is governed by:

$$OTR\left(kg\frac{O_2}{hr}\right) = K_L a \times (C_s - C)$$

where $K_L a$ is the oxygen transfer coefficient, C_s is the saturation DO concentration, and C is the actual DO concentration.

Chart below used to estimate C_s using pond temperature, note g/m3 == ppm == mg/L.



Historically the plant had 8kW of surface aeration, with an estimated SOTR range between of 0.8 and 2.5 Kg O_2/hr. After recent upgrades the plant has 23kW of surface aeration, with a second 7.5kW unit added in Aug 22 and a third 7.5kW added in Feb 24. Both new aerators are a modern design with improved efficiency rates. Increased SOTR expected to be 44.5 kg O_2/hr.

4 E. COLI DISCHARGE CHALLENGES RESOLVED

The Waihī WWTP faced elevated E. coli discharge levels from February to June of 2024 with other isolated events in 2023, primarily linked to issues with the DAF operation air compressor and elevated levels of TSS. High I/I volumes also disrupt the plant's operational stability, particularly affecting the dissolved air flotation (DAF) process and subsequent UV disinfection. The system is complex and interdependent.

4.1.1 Impact of I/I on Hydraulic Loading

Increased flow rates reduce hydraulic residence time in both the ponds and the DAF unit.

During rainfall events, Q increases due to stormwater ingress, resulting in a significant reduction in HRT, which diminishes sedimentation efficiency and allows higher concentrations of total suspended solids (TSS) to breakthrough the DAF unit over and above its capacity.

4.1.2 Correlation between TSS and UV Efficiency

TSS levels are critical in determining UV disinfection efficiency. Suspended particles can shield microorganisms from UV radiation, reducing effective E. coli inactivation. The relationship between UV transmittance (UVT) and TSS can be approximated as:

$$UVT = e^{-k.TSS}$$

Where:

- κ = Attenuation coefficient (dependent on water characteristics)
- TSS = Total suspended solids (mg/L)

Higher TSS values lead to exponential reductions in UVT, impairing the ability of the system to achieve required microbial log reductions.

At the WWTP the lamps were replaced early 2024 and cleaned approximately every 3 months (the maintenance manual states this is required every 6 months). There is space for additional lamps to be installed, the team is currently investigating adding additional lamps to HDC LTP to make the plant more flexible during periods where the DAF unit is overwhelmed or not 100% operational.

4.1.3 DAF Process Disruption

Frequent ramping up and down of the DAF process in response to flow variability further contributes to suboptimal TSS removal. The DAF process efficiency is governed by the air-to-solids ratio (A/S):

$$\frac{A}{S} = \frac{Q_a \times C_a}{Q_s \times C_s}$$

Where:

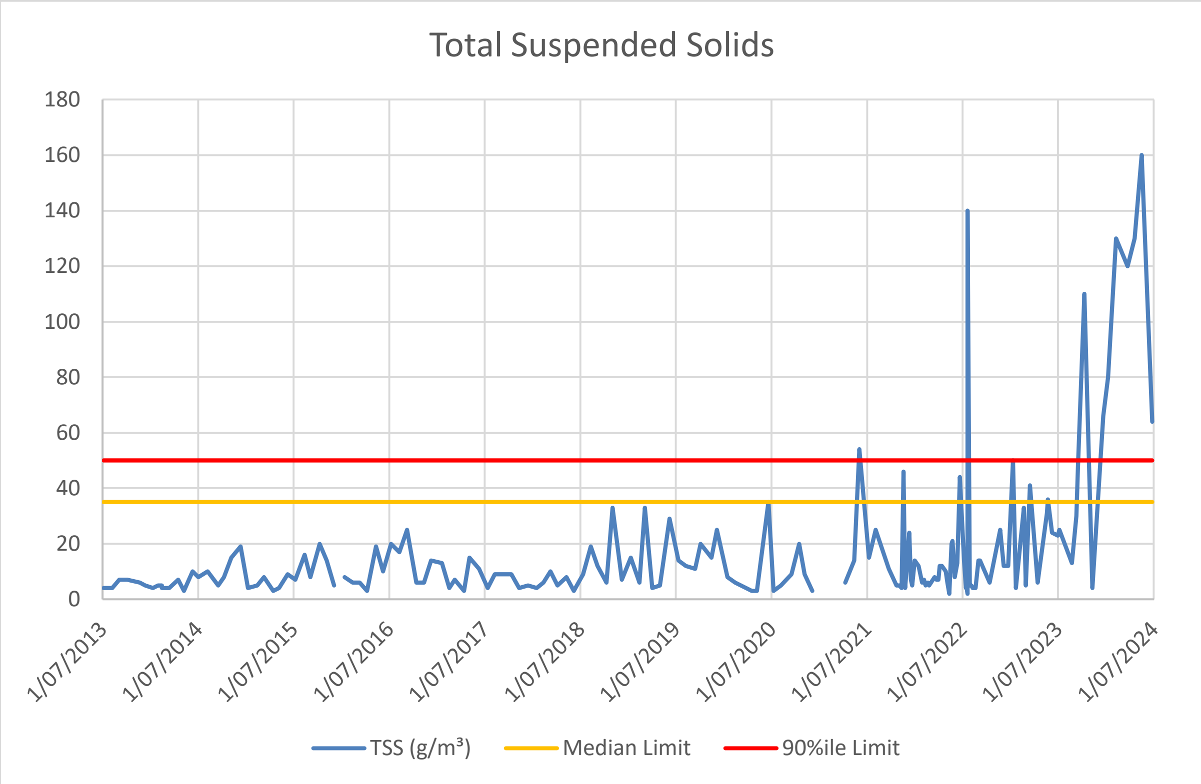
- Qa = Air flow rate (m^3/min)
- Ca = Concentration of air (mg/L)
- Qs = Sludge flow rate (m^3/min)
- Cs = Concentration of solids (mg/L)

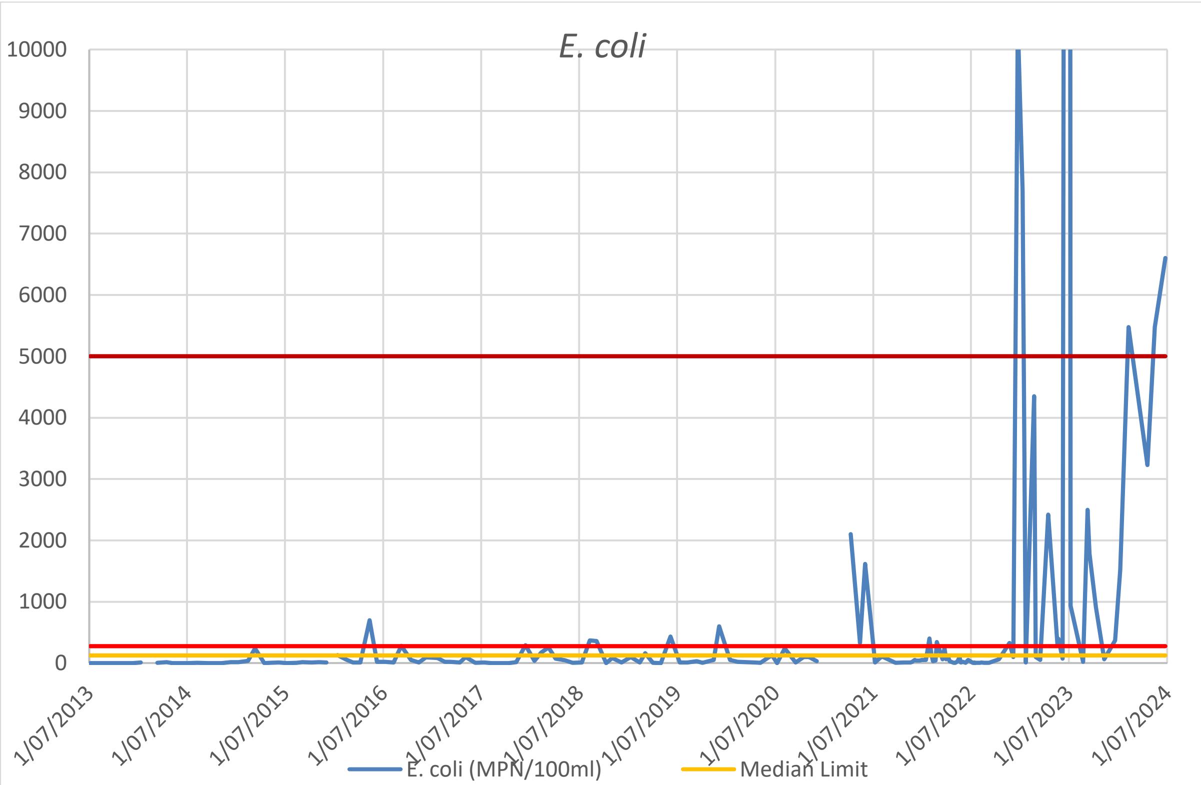
Rapid changes in Qs and Cs during high flows lead to imbalances in the A/S, reducing flocculation and settling efficiency.

During periods where the DAF has not been operational, sitting sludge has solidified in lines and led to temporary blocking of the discharge to the Geobags resulting in diversions to the primary pond exacerbating sludge retention and increasing concentrations of TAN in the pond. A flushing system is being introduced to prevent this from occurring.

The above relationships are demonstrated by the high correlation between TSS and E. coli discharge.

Figure 4 Comparison of TSS and E.Coli when viewed with consent discharge limits





4.2 Implications for Compliance

The combined effects of reduced HRT, increased TSS, and diminished UVT create a cascading failure in achieving microbial compliance. Elevated E. coli levels in the discharge highlight the need for:

1. Addressing upstream I/I issues to stabilize hydraulic loading.
2. Ensuring Qa and Ca is kept at optimal levels
3. Implementing real-time flow equalisation measures to buffer peak flows.
4. Optimizing the UV disinfection system to compensate for variability in UVT during rainfall events.

By mitigating these factors, the WWTP can achieve more consistent compliance with effluent standards.

After months of diagnosing potential system failures, an issue was identified with the compressor supplying air to the DAF plant and following switching off the drying unit (which was heating the incoming air) the performance of the DAF improved significantly.

E. coli discharge levels have since returned within consented limits.

5 SOLUTIONS

5.1 Already Implemented

The following solutions have been identified and implemented;

- Continue additional monitoring and sampling of plant processes (e.g. measuring pH, temp, DO in pond) to better understand performance at critical stages within plant
- Continue to procure additional aeration for the ponds, replacing the current fleet over time (two new aerators purchased 3 12 2024), third part of current LTP
- Continue to redirect DAF sludge away from ponds
- Continue with scheduled maintenance of UV bulbs
- Continue with installation of SCADA at Wellington St WWPS to measure inflow and track changes in I/I
- Continue funding for I/I catchment assessments in Waihī, targeting any industrial areas and identify low cost/high reward opportunities for reducing rain related inflow

5.2 Yet to be implemented

- Undertake Residence Time Distribution Analysis to confirm short circuiting issues.
    - Procure impermeable curtains within the pond if required to address short circuiting. Funding has been allocated for this work.
- Investigate continuous measurement of pH at the inflow to the treatment plant (or at WWPS in town if possible) to evaluate if contribution of industrial waste is leading to overloading issues.

6 CONCLUSION

The Waihī wastewater treatment plant already has the capacity to receive and treat wastewater for all of Waihī, including the high growth projection scenario out to 2048. No industrial waste or high water use industry has been factored into this conclusion.

Common biological and infrastructural interventions to ensure compliance with regulatory standards for TAN while future-proofing the Waihī WWTP against operational fluctuations have been investigated and found to be mostly in place already, following previous recommendations of best practice.

While there are operational considerations for the long term compliance of the WWTP it has sufficient capacity, under current regulatory requirements, to cope with the identified growth (and resulting rezoning) planned for the next 30 years.