Snowy Monaro Regional Council

Options Assessment Report - Bombala Water Supply

June 2020

WATER | ENERGY & RESOURCES | ENVIRONMENT | PROPERTY & BUILDINGS | TRANSPORTATION

Executive summary

The scope of this report was to assess the condition and performance of the existing Bombala Drinking water supply covering the Raw water Pump station and Bombala Water Treatment Plant (WTP) and

Develop options for upgrade to achieve reliable treatment for the next 25 years compliant with current and likely future Australian Drinking Water Guidelines (ADWG) plus “good water industry practice” for the raw water quality conditions.

Conclusions

The main conclusions from condition assessment of the existing Water Treatment facilities were;

- The existing raw water pump station requires a new building and E, I and C works due to very old asset in poor condition and not fit for purpose.
- The existing WTP is now 39 years old and the process (especially alkali, polymer and chlorine) and most electrical systems are older than normal asset life.
- Existing sludge ponds are too small to achieve the requirements of (1) containment of filter wash water and clarifier sludge plus (2) sludge drying

The main conclusions from the assessment of demand, groundwater alternative, existing surface water quality and treatment were;

- The alternative of a future water supply from groundwater was found to be not viable
- The proposed weir on the Bombala River in the centre of Bombala township does not provide an opportunity for a secure alternative water source
- The required future (in 25 years) peak day demand for the new WTP is 1.5 ML/d
- The raw water catchment for this system is unprotected with substantial areas of grazing land for cattle/sheep/deer and septic tanks at rural properties. Based on the Health based Targets (HBT) concept, understood to be soon added to (ADWG), the Source Water Category Classification would be 4. Also, raw water quality conditions are challenging. This is mainly because this water supply from Coolumbooka Dam is from an unprotected catchment with high microbiological risk plus after chlorine is added, it produces levels of disinfection byproducts (eg THMs) that exceed ADWG health limit in the treated water. Also, the water has a continuous level of poor odour, events of very high manganese and iron and is relatively soft with very low water temperatures in winter which requires special features to be added for effective treatment.
- The existing treatment processes at the WTP are not suitable or sufficient for treatment of this combination of raw water risk and water quality conditions. Treatment essentially failed for several days soon after the recent wet weather event in February 2020. The existing process is not suitable for these rapidly deteriorating conditions.
- The existing raw water pump station structures are well beyond asset life and the pumps have no variable flow control and minimal telemetry back to the Water Treatment Plant (WTP). A reliable pump station with ability to modulate flowrate and monitor performance is essential, particularly given the relatively old AC water main connecting it to the WTP.

- The recent special water quality sampling program has highlighted the water quality challenges and inadequate existing WTP performance.

A summary of the options and comparison of options is set out below. All the Options 2 to 5 would be located at the site of the old house on the existing WTP site.

Option 3 is preferred overall on cost and non-cost advantages basis.

Item	OPTION 1 upgrade existing WTP clarifier/filters GAC Disinfection/UV THM stripping	OPTION 2 New site Clarifier/MF GAC Disinfection/UV THM stripping	OPTION 3 New site DAF/MF GAC Disinfection/UV THM stripping	OPTION 4 New site DAF/MF Ozone/GAC Disinfection/UV THM stripping	OPTION 5 New site DAF/MF NF Disinfection
CAPEX	\$8.6m	\$9.3m	\$9.1m	\$9.8m	\$9.6m
NPC	\$12m	\$13.5m	\$13.3m	\$14.2m	\$17m
Performance	✓✓ (clarifier uncertain)	✓✓✓ (small nitrification risk)	✓✓✓ (small nitrification risk)	✓✓✓✓	✓✓✓✓✓
Operability	✓✓ (too compact)	✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓ (
Env&WHS	✓✓ (ongoing poor access to filter valves)	✓✓✓	✓✓✓	✓✓✓	✓(high volume of salty NF waste)
Construction complexity	✓ (existing structure and uncertain time offline needing carting in water risks)	✓✓✓✓ (small building easily fits)	✓✓✓✓ (small building easily fits)	✓✓✓ (bigger building)	✓✓✓ (bigger building)
Easy procurement	✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓	✓✓ (NF equipment)

The above costs do not include Fluoridation. Based on a separate contract for a new building and sodium fluoride dosing system compliant with the NSW code the extra cost is estimated at \$0.65m. This cost is based on recent tenders and independent cost estimates.

Recommendations

The following is recommended based on this assessment of requirements and the options to achieve them;

- Based on projected demand in 25 years' time, the required new treated water output capacity is 1.5ML/d
- The features of the preferred WTP Option 3 to go to concept design are;
  - <u>Process</u>: Pre-oxidation + Dissolved Air Floatation (DAF) + Membrane filtration + GAC + UV + chlorination then chloramination. + THM stripping
  - <u>Location</u>; at existing old house site suited to bushfire rating with construction occurring while keeping the existing plant operating to avoid need to cart in water

- Impact on existing WTP : during concept design stage investigate reuse opportunities (eg existing coagulant bulk storage) to reduce total cost
- New wash water/sludge system; wash water +sludge holding tank and pumping to thickener and then concentrated sludge to existing sludge ponds and supernatant return to WTP inlet

- Construct a separate purpose built new chlorination building to house a duty + standby 920kg drums of chlorine plus duty/standby gas chlorinators and separate service water system
- Because Fluoridation is best located in a separate purpose built building , requires specialist contractors and often completed under a separate funding process it is recommended it be a separate contract
- Continue, at say every 2 weeks frequency, the special water sampling program over autumn /winter focusing on the main issues relevant to optimising the new treatment process design;
  - Raw water at dam; E,coli, pH, alkalinity, colour, turbidity, MIB/Geosmin and DOC
  - Filtered water; turbidity prior to addition of soda ash and chlorine
  - Treated water; DOC, pH, alkalinity and THMs (CWS, Res1 and retic sites)

Table of contents

Table index

Figure index

Appendices

1. Introduction

1.1 Project need

GHD has been engaged by Snowy Monaro Regional Council (SMRC) to carry out an Options Assessment and Concept Design for upgrades to the water supply systems for the towns of Bombala and Delegate in southeast New South Wales. This report covers the town of Bombala.

Bombala is supplied with treated water from a conventional water treatment plant. The plant is located on Cathcart Road to the north east of the Bombala Township. The raw water is sourced from Coolumbooka Dam along Coolumbooka River, upstream of the confluence with Bombala River.

The existing Bombala and Delegate water supply systems face a number of challenges related to the reliable provision of safe, high quality drinking water to their communities. Residents of Bombala and Delegate have expressed severe dissatisfaction about water quality and in response, the NSW Government has allocated substantial funding for upgrades to the water systems servicing these towns.

To date only minor changes have occurred (e.g. new actuated valves at filters and new PLC). The plant remains a challenge to operate due to ageing assets, failed equipment and treatment processes that do not handle high raw water iron & manganese colour events or taste & dour issues adequately. Improvements are needed to achieve performance, operability and health and safety requirements.

1.2 Project scope

This report outlines the results of audit of existing assets and an Options Assessment for the future Bombala Water Treatment Plant (WTP). Specifically, the aims of this report were to:

- Review information supplied by Council, including the analysis of raw water quality data
- Assess the existing WTP, including assessment of its process performance, OH&S compliance and asset condition
- Develop upgrade options, including advantages, disadvantages and cost estimates
- Recommend a preferred upgrade option.

1.3 Purpose of report

The purpose of this report is to develop upgrade options for Bombala WTP and recommend a preferred upgrade option to SMRC.

1.4 Scope and limitations

As part of this Options Assessment, GHD advised Council to undertake a water quality sampling and analysis program. Results from this testing program have been used in this report in order to assess the raw water quality and treatment capability of the existing water treatment plant process train.

The sampling program was of limited duration and did not cover the recent large storm event for several water quality characteristics (results are summarised in Appendix C). In order to determine an accurate raw water quality envelope to inform upgrade options for Bombala WTP, it is recommended that the water sampling program continue to better inform future design stages of this project.

Report based on sampling program and other intermittent results since 2014. Concern was raised that the recent program showed that in some respects the daily operational water quality data is of limited value as the results do not appear to match results done by ALS (NATA credited lab). Refer to Appendix C.

This report: has been prepared by GHD for Snowy Monaro Regional Council and *may only be used and relied on by Snowy Monaro Regional Council for the purpose agreed between GHD and the Snowy Monaro Regional Council as set out in section 1.3 of this report.*

GHD otherwise disclaims responsibility to any person other than Snowy Monaro Regional Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared...

GHD has prepared this report on the basis of information provided by Snowy Monaro Regional Council and others who provided information to GHD (including Government authorities)], which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

GHD has prepared the preliminary cost estimate set out in section 6 of this report using information reasonably available to the GHD employee(s) who prepared this report; and based on assumptions and judgments made by GHD.

The Cost Estimate has been prepared for the purpose of comparison of options and must not be used for any other purpose.

The Cost Estimate is a preliminary estimate only. Actual prices, costs and other variables may be different to those used to prepare the Cost Estimate and may change. Unless as otherwise specified in this report, no detailed quotation has been obtained for actions identified in this report. GHD does not represent, warrant or guarantee that the works can or will be undertaken at a cost which is the same or less than the Cost Estimate.

Where estimates of potential costs are provided with an indicated level of confidence, notwithstanding the conservatism of the level of confidence selected as the planning level, there remains a chance that the cost will be greater than the planning estimate, and any funding would not be adequate. The confidence level considered to be most appropriate for planning purposes will vary depending on the conservatism of the user and the nature of the project. The user should therefore select appropriate confidence levels to suit their particular risk profile.

1.5 Assumptions

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this section of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

The assumptions for this report are

- Plant drawings, provided by Council represent as constructed details
- Demand data and future growth rate projections and water quality data provided by Council are reasonable representation of history and the future for this site

- Observed movement of the filter block (i.e. widening crack in brickwork between clarifier and filter) is not to the extent that the existing plant is unsafe and cannot be fixed. No detailed structural analysis to confirm the extent of damage and required repairs and cost has been provided by Council. GHD has assumed a cost up to $100,000 in comparison of options
- The option of upgrade of the existing WTP (Option 1) is assumed to require this WTP to be offline for extended periods. Extended shutdown is needed for works including at the existing clarifier (eg cleaning, repairs/recoating/modification for sludge blanket/tube-settler), new filter inlet works and control building (eg electrics and new chemical dosing system). That is, the combination of unprotected catchment Cat 4 rating for microbiological health risk combined with evidence of periods of difficult to coagulate source water especially during wet weather events means bypassing the clarifier for direct flow of coagulated water to the filters is considered too high a risk. Allowance has been made for trucking in drinking water at 0.5 ML/day to the Clear Water Storage for a total of at least 30 days (note that it could easily be longer), spread through a low demand months. This trucking in of drinking water requirement is not required for the new WTP options 2, 3 or 4. They can be constructed while the existing plant continues to operate and then cut-over into operation within a day or so.

  Cost of water cartage for the Brogo WTP upgrade amounted to $33,000/ML. Similar pricing was advised by a supplier in Cooma for water cartage between Cooma to Bombala (approx. 90km). This translates to about $0.5 million for 30 days of cartage of water to Bombala WTP for this Option 1.

2. Performance Objectives

2.1 Introduction

This section outlines water supply performance objectives, used to assess the existing Bombala WTP and develop upgrade options.

The overall water supply performance objectives for the Bombala WTP are (in general terms):

- Meet current and future water demand
- Meet treated water quality requirements
- Achieve asset life, environmental and OH&S requirements and reliable operation targets
- Minimise whole-of-life cost

These are further developed below.

2.2 Water Demand and WTP design capacity

The water quantity performance objective is to provide adequate WTP capacity to meet current and future peak day demands for all raw water quality scenarios. The water demand projection needs to cover both Peak Day and Annual Demand for the planning horizon of 25 years.

2.3 Treated Water Quality Requirements

The key guidance documents for drinking water quality are:

- Australian Drinking Water Quality Guidelines (ADWG)
- Health Based Targets (HBT) framework for Raw Water Quality conditions

The ADWG provides water quality limits measured at customer taps.

Table 1 sets out the normal treated water quality requirements that the upstream Water Treatment Plant (WTP) needs to be designed for to achieve the requirements of ADWG and HBT.

Table 1 Treated water quality targets

Parameter	Units	ADWG or "Good Practise" Target	Monitoring Location
E. Coli	org / 100 mL	Not detected	Clear Water Storage (CWS)
pH		Set point* ± 0.2	CWS
Filtered turbidity	NTU	<0.2 @95%, max ≤0.5	Combined Filter outlet
True Colour	Hazen	<5 @95%, max ≤10	CWS
Dissolved Organic Carbon	mg/L	<6 mg/L	CWT to achieve THM requirement
Aluminium	mg/L	<0.1 @ 95%, max ≤0.2	CWS
Iron, total	mg/L	<0.1 @ 95%. max ≤0.3	CWS
Manganese, total	mg/L	<0.02 @ 95%. max ≤0.05	CWS
THMs	mg/L	Max <0.25	Reticulation Network
Taste & Odour - Geosmin - MIB	 ng/ L ng/L	 <5 <5	For good T&O at customer taps
Chlorine Residual (FCR)	mg/L	Set point* ± 0.2	CT>15mg/L-min for free chlorine leaving Res1
Fluoride	mg/L	Set point ± 0.1	At CWS
Treated Water Stabilisation CCPP LSI	mg/L	 -4 to 0 -1 to 0	At CWS
Health Based Targets (HBT)		LRVs for category 4 unprotected catchment	

* Set point for pH normally =7.5 to 7.8. Set point for FCR = 1 to 2 mg/L.

2.3.1 Health Based Targets (HBTs)

The National Health and Medical Research Council (NHMRC) current draft of the Health Based Targets (HBT) document (2018), sets out required Log Reduction Value (LRV) for pathogens based on various Source Water Categories. The HBT document defines what LRVs can be achieved by various treatment processes. Refer *Manual for Application of Health-Based Treated Targets, WSAA (2005)*.

2.4 Asset condition, environmental/OH&S requirements and reliable operation

2.4.1 Asset Life

Asset life decisions need to include consideration of:

- Future development; for example impact of increased peak day and annual demand
- Innovation; for example SCADA hardware and control software continue to reduce in cost; increase in capacity/capability and to have limited support life.
- Design and maintenance/planned replacement; for example correct materials of construction, catholic protection systems, timely replacement of old assets and allowance/prevention of settlement of structures are essential for achieving design asset life.

2.4.2 Reliable Operation

It is required that each treatment system is "fit for purpose" in terms of minimum dependence on proprietary equipment, easy to operate and perform well under design raw water conditions and have adequate asset life.

Reliability in operation needs to be in accordance with good industry practice, for example:

- Automation: Adequate online monitoring equipment, alarms and telemetry to allow automatic response to process or equipment failure and efficient operation.
- Reliability: Duty/standby with automatic standby unit start-up upon fault of the duty unit, for process critical equipment.
- OH&S: Minimisation of manual handling, automation of processes.
- Storage: Sufficient balancing storages to minimise start/stop operation and pressure surge risks, and sufficient bulk storage of treatment chemicals.

2.4.3 Contingency Management

Contingency management is required to ensure continuous treated water supply to customers by considering risks and actions to minimise to "acceptable" including:

- Unexpected equipment failure and associated redundancy
- Local or regional power failure
- Poor raw water quality events

2.4.4 Legislative compliance

Regulations

The WTP must comply with statutory requirements including:

- Chemical storage and handling – Dangerous Goods regulations including the Dangerous Goods Act (DGA)
- Occupational health and safety (OH&S) requirements

Environmental management

Environmental considerations for operation of the WTP include:

- Compliance with waste disposal and noise requirements (EPA)

- Minimisation of energy consumption
- Sludge disposal including backwash supernatant recovery – EPA requirements

2.4.5 Whole of Life Cost

The capital cost together with operating and maintenance costs, needs to be minimised over the adopted planning horizon.

3. Review of Existing Bombala System

3.1 Overview of Existing System

3.1.1 General System Description

Bombala's water is supplied from a dam on the Coolumbooka River. The resulting reservoir has a capacity of 300 ML, which is estimated to be reduced to approximately 250 ML due to siltation (Bombala Urban Water Plan, 2000). After the dam, Coolumbooka River merges with Bombala River just upstream of where it flows through Bombala Township.

The treatment process currently uses a conventional reactivator type clarifier then gravity filtration process to treat raw water, with soda ash, ACH, polymer and chlorine dosing.

The majority of Bombala township is either gravity-fed from Reservoir 1 (450 kL), located at a high point on site at the WTP, or Reservoir 2 (1,900 kL), located on the other side of the valley within which Bombala township is located.

A schematic of the existing treatment process at Bombala WTP is shown in Figure 1.

3.1.2 Raw Water System

Raw water is sourced from the Coolumbooka Dam and it is pumped to the WTP via a DN200 AC pipeline. If the parallel DN150 AC pipe is also in use the inflow rate to the WTP can be increased to about 40 to 45 L/s. A separate emergency pump and pipeline can also be used to deliver raw water to the WTP from Bombala River approximately 5 km downstream of the dam. This source has a licence limit of 20 ML/yr (TBC) and is typically only used in periods of very low levels in the Coolumbooka Dam.

3.1.3 Treatment Process

The raw water is pumped from the raw water pump station and dosed with chlorine (for manganese/iron oxidation) and pre-soda ash (only if ACH dose is very high) before entering a 'flash mixer' tank. In this flash mix tank ACH and LT20 polymer are added. The flash mixing occurs only due to the higher velocities in this small tank. The flocculated water then flows into a reactivator clarifier.

The draft tube mixer in the reactivator clarifier is currently turned off. Settled sludge is periodically discharged to 2 No sludge lagoons through a motorised valve, which is automatically opened for 1 minute every hour. A manual valve is also opened by operators to remove excess sludge on a daily basis.

The settled water from the clarifiers is split between 2 no. rising level multi-media gravity filters. Filter media consists of gravel overlayed by sand and then anthracite filter media. The filters currently require manual backwashing however electric actuated valves have recently been installed to permit automatic backwash in the future.

The filtered water is dosed with chlorine and post-soda ash prior to gravity flow to the Clear Water Storage tank. Treated water is pumped to Reservoir 1 at the top of the hill at the WTP site, where it is gravity fed to the town's reticulation system including the main storage, Reservoir 2.

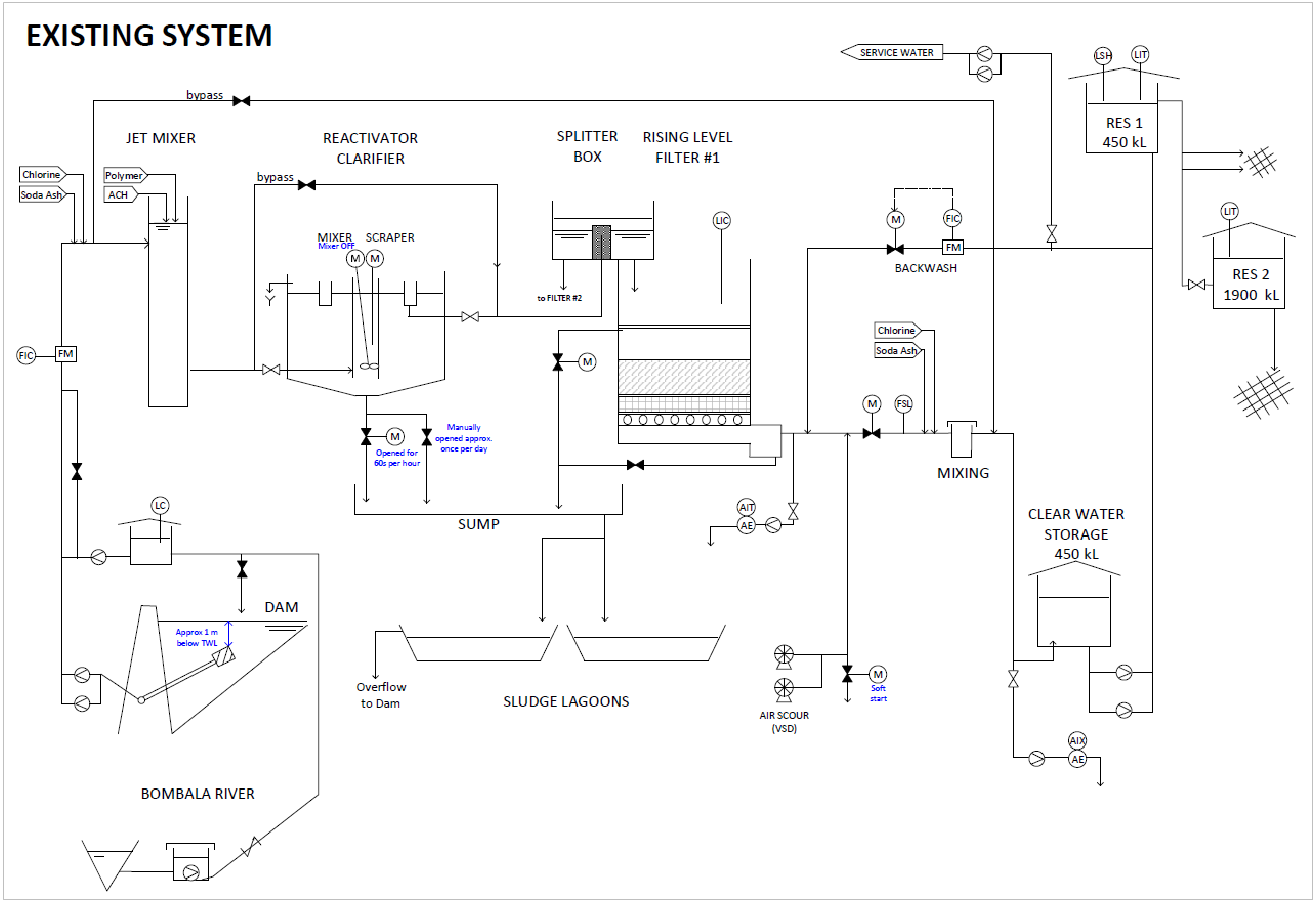

Figure 1 Process flow diagram showing existing process at Bombala WTP

3.2 Water Demand and WTP design capacity

The existing Bombala WTP currently supplies treated water at approximately 180 ML/year. The plant typically operates between 4 to 11 hours per day (at an instantaneous rate of 25 to 30L/s), depending on demand and raw water quality conditions. Figure 2 shows a time series for daily raw water inflow to the WTP for November 2017 to March 2019. This record is considered the more reliable period of measurement compared to earlier data.

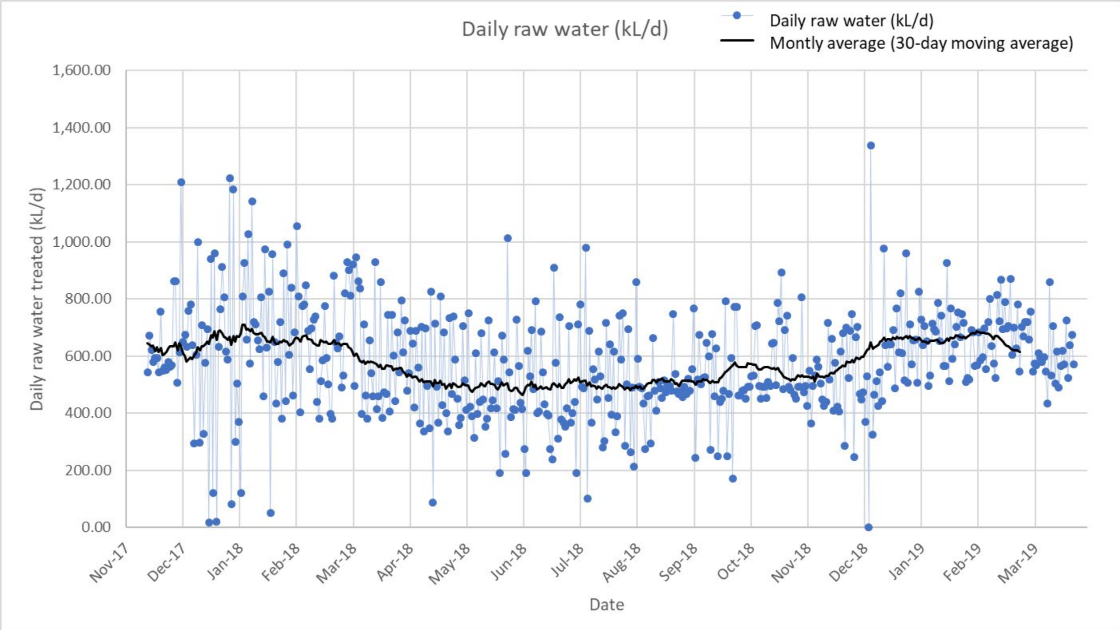

Figure 2 Daily raw water flow to Bombala WTP, Nov-2017 to April-2019

Figure 3 highlights outliers in the daily raw water flow to Bombala WTP from January 2013 to April 2019. All days where 2ML to 2.5ML of raw water was used could be explained by either:

- Lack of raw water demand data immediately before/after "peak" day (suggesting that flow was actually split between the days, but was not captured as data. The comment from Council is that readings are not taken consistently, and hence delays in readings explain these 'peak' days). These points are highlighted by red circles in Figure 3.
- WTP operating at well below capacity on previous days (suggesting that WTP operated for a significant number of hours on "peak" day to fill demand from previous days). These points are highlighted by green circles in Figure 3.

However, there were a number of other days when demand was up around 1.5 ML/d, which may be relatively reliable values.

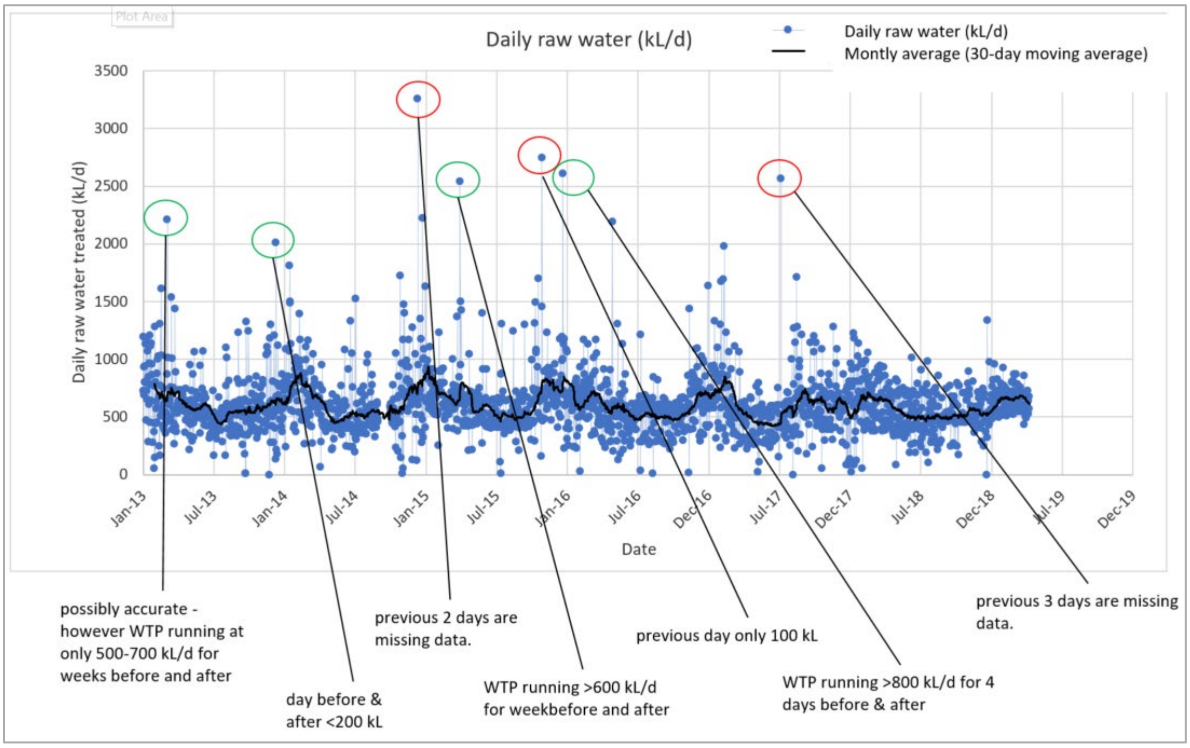

Figure 3 Explanation in daily raw water demand outliers, January 2013 to April 2019

The population of Bombala township is approximately 1,400 (Australian Bureau of Statistics, 2016 Census). Population growth is minimal, and for the purposes of this option assessment a growth rate of 0.1%.[1] is assumed to apply to the next 25 years. Table 2 summarises the current raw and treated water flows (based on 2017/19 data) and the projected design annual and peak day flows for this plant in 2045. These WTP design values are based on expected growth over the next 25 years of a total of 2.5% plus an uncertainty allowance (10%) to allow for dry year unrestricted demand plus some uncertainty (given that earlier less reliable data shows higher demands and that demand record available was relatively short).

Based on this design demand the upgraded or new WTP needs to have a peak day output capacity of 1.5ML/d. To allow for the fact that this is the only supply to town, power and equipment failure risk and that there is limited treated water storage design also assumes this 1.5ML output is delivered over a 22 hour period. Assuming the new plant options all have supernatant return then the only loss is only sludge at up to 0.06ML/d. Consequently , the raw water pumps need to be able to deliver up to 1.56ML/d. Adding allowance for supernatant return for daily filter backwashes plus filter to waste and reduced plant production rate during filter backwashing, means an instantaneous flow rate through the plant of 25 L/s is required. This rate has been adopted as the basis for options assessment. Options with additional treatment processes (eg more than a clarification then filtration process step) may require a higher instantaneous rate.

Own in the brief water quality testing program [1] As per SMRC estimates.

Table 2 Current and projected demand and WTP flows

	2017/19 Raw water	2017/19 Treated Water	WTP Design treated water - 2045
Population	1400		1435
Annual Demand	212 ML/yr (1)	180 ML/yr (2)	240 ML/yr
Peak Day Demand	1350 kL/d (1)	1100 kL/d (2)	1500 kL/d

(1) Data for Raw Water daily flow, Nov-2017 – April 2019.

(2) Data for Clear Water daily flow, Nov-2017 – April 2019.

3.3 Water Quality Requirements

3.3.1 Health Based Targets & Log Removal Values (LRVs)

The HBTs set out required Log Reduction Value (LRV) for pathogens based on various Source Water Categories. As per the HBT guidelines (2018), "*the source water category should be determined by combining the vulnerability assessment with the E. coli band allocated according to results of the microbial indicator assessment*".

The matrix in Figure 4 below defines how this works.

Table 5.4. Confirmed source water category based on comparison of *E. coli* concentration with vulnerability assessment

Preliminary source water category based on vulnerability assessment	Microbial indicator concentration category Maximum *E. coli* result per 100 mL		
	<20 (*E. coli* band 1)	20 to 2000 (*E. coli* band 2)	2001 to 20,000 (*E. coli* band 3)
Vulnerability category 1	Category 1 (/)	Category 2 (*)	Anomalous (x)
Vulnerability category 2	Category 2 (*)	Category 2 (/)	Anomalous (x)
Vulnerability category 3	Anomalous (x)	Category 3 (/)	Category 4 (*)
Vulnerability category 4	Anomalous (x)	Category 4 (*)	Category 4 (/)

Combining the results of the *E. coli* data and vulnerability assessment will result in one of the following outcomes:

/ The two assessments are consistent and support each other

* The result is feasible, but has a lower degree of confidence. Both the *E. coli* data and vulnerability assessment should be re-examined to better understand the reasons for the misalignment. For example, if the *E. coli* results indicates a higher level of microbial risk than inferred by the vulnerability assessment, then the vulnerability assessment of the catchment should be repeated to determine if there are sources of microbial risk that were not previously identified.

X- This result should not be accepted. The results should be critically reviewed to understand the discrepancy. In the interim, the most conservative source water category option under consideration should be adopted. These results should be discussed with the relevant party (e.g. a health authority or other regulator).

Figure 4 Vulnerability versus Microbial indicator concentration category in HBT document (2018)

Vulnerability assessment

A vulnerability assessment consists of identifying sources of, and barriers to, pathogen contamination within the water supply catchment. The results from the vulnerability assessment are used to allocate the source water into one of four preliminary source water vulnerability categories. The vulnerability assessment category is a judgement made on the basis of the outcomes of a risk assessment on the catchment part of the water supply system.

Figure 5 shows a photo of storage behind Coolumbooka Dam, which is the supply source to Bombala WTP. It has an unprotected catchment.

At the time of GHD visit to site, sheep were seen grazing near the dam (yellow circle in figure 5). This is consistent with observations of operators from Bombala WTP indicated that there are often cattle and sheep grazing along the banks of the storage.

It is noted that there is over 26 km of raw water reservoir/river frontage accessible by sheep and cattle within this catchment.

Figure 5 Photo of Coolumbooka Dam from GHD site visit (16 April 2019) showing sheep grazing at edge of dam (circled)

The approximate catchment boundary for Coolumbooka Dam is shown in Figure 6. The figure shows that the catchment area is mainly farmland, with some state or national park and small groups of residential properties.

On this basis the source water is defined as Vulnerability Category 4.

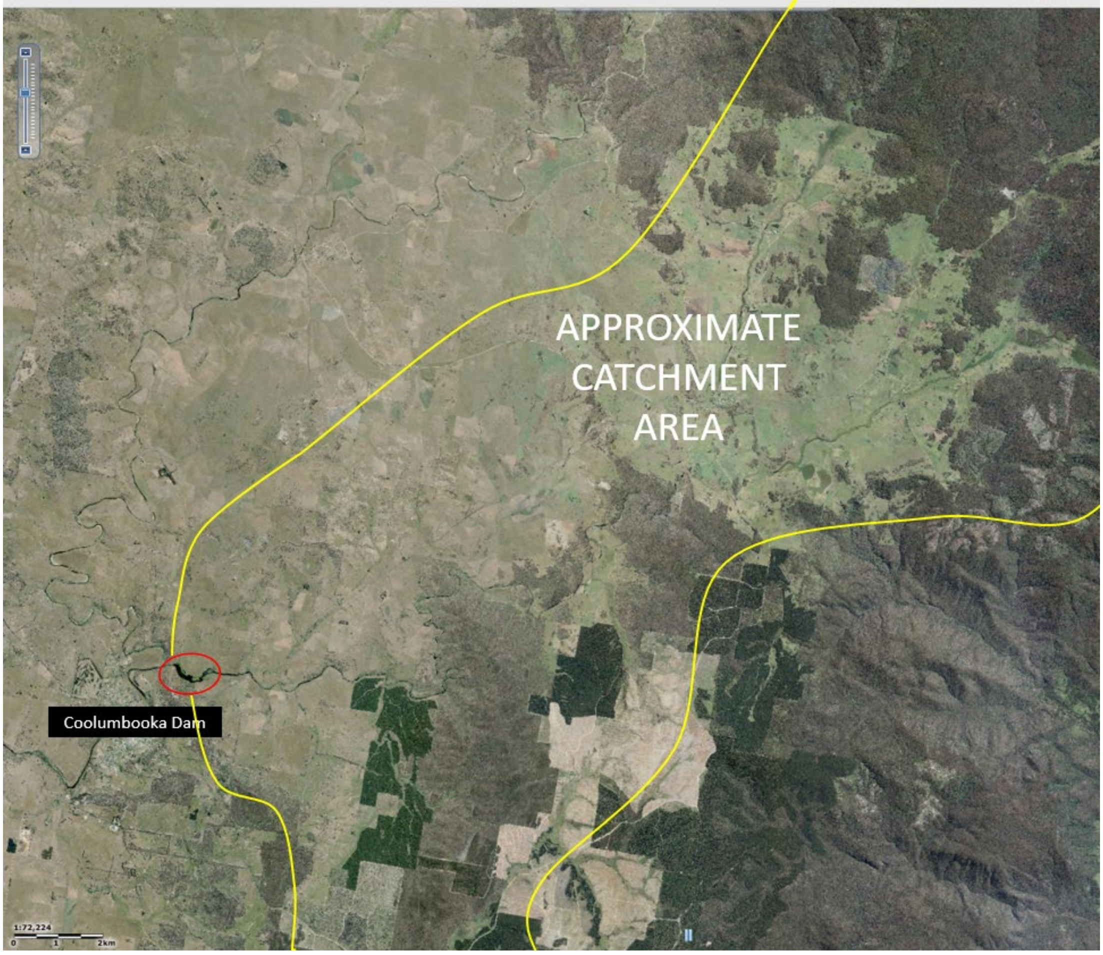

Figure 6 Approximate catchment area of Coolumbooka Dam (estimated from contour lines and location of other rivers in the region)

E.coli testing

The Health Based Targets (HBTs) concept also require that measurements to be made of E.coli concentration in the untreated water going to the WTP. E.coli results for collected data over 2019/20 are shown in:

- Table 3 results as measured each month by NSW Health in 2019.
- Table 4 results as measured by ALS laboratories during the 2019/20 water quality sampling program.

E. Coli results >20 cfu/100mL means the source water to the WTP falls into E.coli band 2 to band 3 under the HBT (refer Figure 4).

Table 3 Results for coliforms in raw water (MPN/100mL, as assessed by NSW Health)

Date	E.coli (MPN/100mL)
30/01/2019	36
19/02/2019	50
18/03/2019	66
15/04/2019	18
21/05/2019	3

Table 4 Results for E. Coli in raw water (MPN/100mL, as assessed by ALS)

Date	Raw Water	Date	Raw Water
28/05/2019	19	11/11/2019	10
27/06/2019	1	25/11/2019	12
24/07/2019	8	5/12/2019	12
30/09/2019	4	16/12/2019	24
8/10/2019	2	23/12/2019	41
14/10/2019	4	30/12/2019	55
21/10/2019	1	9/01/2020	24
31/10/2019	0.5	16/01/2020	13
4/11/2019	1	23/01/2020	36

In the early weeks of the ALS sampling program, the majority of E.Coli results in the raw water inlet pipe to the WTP were lower than the limit of detection in the ALS sampling program. These results suggested that there was residual chlorine in the water and therefore these were not a representative sample of the raw water. GHD notified Council of the issues with sampling from the raw water inlet pipe at the WTP, and hence results shown in the table above are E.Coli results from Coolumbooka Dam, which would not be affected by residual chlorine in this raw water pipeline.

Source Water category

The source water category is therefore determined using the table provided in Figure 4 as follows:

- Vulnerability category 4 + E.Coli band 2 to 3 = **Source water category 4.**

Bombala WTP LRVs

Table 5 shows the required Log Removal Values (LRVs) that need to be achieved to comply with the Source Category 4 under HBT. Also shown is what the existing Bombala WTP is estimated to currently achieve, when operating correctly. That is, to achieve the LRV for coagulation/clarification/filtration requires the filtered water from each filter to be <0.3NTU for 95% of the time and always <0.5NTU. However, operational testing where a sample is taken every day of the combined filtered water shows that this performance is not achieved, especially when raw water quality is poor after stormwater inflow events. This is important as it is during such stormwater events when the protozoan and other microbiological hazards will tend to be highest in the raw water. It is noted that the recent water quality testing program comparing operational data for filtered water turbidity with results from ALS (a NATA registered lab) were about the same (refer Appendix C) , which validates the accuracy of the long-term operational data set for filtered water turbidity. Based on Table 5, the existing treatment process does not achieve the required Log Removal Value (LRV) for protozoa (e.g. Cryptosporidium) and is unlikely to achieve it for virus and bacteria.

Table 5 Bombala WTP Log Removal Values (LRVs) under HBT guidelines

Process	Bacteria	Virus	Protozoa	Comment
LRV Required	**6**	**6**	**5 to 5.5**	based on unprotected surface water source water at **Category=4**
EXISTING PROCESS				
Coagulation/flocculation in clarifier, followed by media filtration	<2.5	< 1	<2.5	Water quality data from the WTP (refer Appendix C) shows that combined turbidity out of the filters is still high, with average 0.6 NTU so low LRV credits possible at present
Chlorination	4	4	0	Assumes CT>15mg/l-min
Total LRV (Existing process)	>4	>4	< 2.5	Given filter performance to date it is likely the LRV = 0.5 (P) to 1(B&V) or less for existing clarifier/filters
Additional LRVs required to meet HBT for Category=4 catchment	***0 to 2***	***0 to 2***	***4.5 to 5.5***	

Table 6 below summarises the performance that is achieved for each of the future treatment options discussed in section 5. For each treatment option, Protozoa controls the number of treatment barriers required.

Table 6 Log Removal Values (LRVs) for future treatment options

Future Treatment Option	Description	Bacteria	Virus	Protozoa
1	Clarifier + Filters + UV + Chlorination **Total**	1 1 2 4 **8**	1 1 0 4 **6**	0.5 3 2 0 **5.5**
2	Clarifier + MF/UF + UV+ chlorination **Total**	1 3 2 4 **10**	1 1-2.5 0 4 **6 - 7.5**	0.5 3 2 0 **5.5**
3	DAF + MF/UF + UV + chlorination **Total**	1 3 2 4 **10**	1 1-2.5 0 4 **6 - 7.5**	1 3 2 0 **6**
4	DAF + MF/UF + Ozone + UV+ Chlorination **Total**	1 3 2 2 4 **12**	1 1-2.5 2 0 4 **8 - 9.5**	1 3 0 2 0 **6**
5	DAF + MF/UF + NF + Chlorination **Total**	1 3 1.5 4 **9.5**	1 1-2.5 1.5 4 **7.5 - 9**	1 3 1.5 0 **5.5**

Notes:

1. LRV for filters assumes turbidity at 95% <0.3NTU
2. LRV=4 @UV dose=22 mJ/cm^2. LRV=2 @ UV dose=5.8 mJ/cm^2

3.3.2 Design raw water quality envelope

GHD advised Council to undertake a detailed sampling and analysis program over a number of months to determine the raw water quality envelope. A summary of all results from both the ALS laboratory data including a comparison with operational on-site water quality testing is included as Appendix C (Water Quality memo).

In addition there have been measurements taken by NSW Health. In addition the report “Bombala WTP site audit and Optimisation Report (City Water 2015)” included some very high raw water colour results for its successful jar coagulation tests with alum.

Based on this data the following design raw water quality envelop has been developed (Table 1). The main contaminants that have a bearing on “fit for purpose” treatment process selection are highlighted.

Table 7 Design raw water quality envelope

WQ Characteristic	Estimated range	Estimated Lower(LL) and upper (UL) limits	Comment
Turbidity (NTU)	1 to 10	33	UL in City Water report
True Colour (Hu)	30 to 80	120	UL in City Water report
Dissolved Organic Carbon (mg/L)	5 to 25	35	UL in 2019/20 data, at DOC>6 mg/L can generate THMs>0.25 mg/L.
pH	7.4 to 8.1	6.6 and 8.9	
Alkalinity (mg CaCO3)/L)	90 to 110	35 and 150	LL from ops 2/20
Total Manganese (mg/L)	< 0.02 to 1	1.9	UL in 22/1/14
Total Iron (mg/L)	0.15 to 1.2	1.5	Highest 26/6/14
Calcium (mgCa/L)	12 to 15	10 and 20	
Total Algae (cells/ml)	300 to 3000	5,000	3220 in 25/3/14
Blue Green Algae (cells/ml)	<10 to 1500	2000	1260 in 22/1/14
MIB (ng/L)	2 to 10	<2 and 25	UL in 2019/20 data
Geosmin (ng/L)	10 to 35	<2 and 65	UL in 2019/20 data
E.Coli (CFU/100mL)	<1 to 110	?	highest 26/6/14
Water Temp (°C)	6 to 23	4 and 25	Operations data and can vary 2°C in a day
TDS (mg/l)	90 to 130	50 to 200	

3.1 Asset condition, environmental/OH&S requirements and reliable operation

3.1.1 Asset condition

Since engaging GHD, it is understood Council has arranged for a structural engineer to undertake a condition assessment on some of the ageing building infrastructure. Results are yet to be sent to GHD.

The condition of the assets was assessed at a site visit attended by GHD staff on 16/4/19. It included a brief structural assessment (visual only). Details of findings of this assessment of structures and equipment is included in the asset register, including asset age, in Appendix A. Generally this plant, constructed in 1981, has mechanical, instrumentation and control systems that are at end of life or in need of upgrade to a modern “good water Industry” standard.

Table 8 summarises key findings of the audit.

Table 8 Asset condition/capacity summary for existing WTP

WTP area	Comment
Raw Water Pump Station	Pumps need replacements and VSD control. Minimal telemetry back to WTP. Most electrical cabling requires replacement.
Inlet Works	Jet mixer does not function as intended as ACH and polymer are added at the same location rather than separated by at least 20 to 30 second
Coagulation	Dosing system recently replaced and auto duty/standby
Clarifier	Clarifier roof low, not sufficient headroom. Clarifier internals require replacement and repainting.
Filters	Brick wall connecting filter block to clarifier has large vertical cracks indicating the filters may be moving down the hillside.
Media valves and pipework	Recent replacement of filter media and valves with motorised valves but very confined space for O&M.
Chemical storage, dosing systems and dosing lines	Dosing lines in trays not accessible, Soda and polymer systems very old and manual and poor OHS setup. No duty/standby automatic operation. Old poor WH&S fluoridation system that does not operate
OHS and Environmental	Not enough and poor arrangement for safety showers, access to valves and chemical system, leaking Coag bund, no chem delivery bund
Air scour and water backwash systems	Old air scour, only 1 or 2 units available. Backwash water system needs new controls for more reliable gravity backwash
SCADA, PLC, Telemetry & Controls	Operator Interface Screens are basic and have minimal remote operation or data collection from existing online analysers. Plant has no: - duty/standby with auto changeover and flow pace plus trim for coagulation pH and chlorination, - automation of filter backwash - constant level filtration, ability to run 1 filter when other is backwashing and filter to waste - auto batching and duty/standby dosing with auto changeover for soda ash and poly
Instrumentation	No online settled water turbidity, individual filter turbidity, coagulation pH analysers
Sludge	May need sludge pond re-lining and works to prevent wash water overflow to environment
Other	Roof over clarifier/filter area too low for good OHS

3.1.1 Treatment process capability, performance & reliability

Flow performance and capacity

The operating rate of the WTP is currently set at 25 to 30 L/s. The plant therefore operates for approximately 6 to 12 hours per day during large periods of the year.

However, there is no ability to automatically adjust flow rate of the raw water pumps. Also the plant has to stop for filter backwash as there is no valving to allow one filter at a time to be backwashed.

There is no online monitoring of the following flows; service water, filtered water flow to the CWS, sludge output or treated water flow to Res 1.

Treatment performance

To better understand treatment performance and to assess the accuracy of operational data collected daily at the WTP, a detailed sampling program measuring raw, settled, filtered water and treated water was implemented over late 2019/early 2020. Data analysis and comparison with Plant Operational data is set out in Appendix C.

In addition a review was completed of

- 2014/19 water quality data collected by Council,
- DPI-Water and NSW Health
- Jar test work by City Water
- Plant Operational records 2018/20 for water quality and chemical dosing
- Observations at GHD site visit.

The main findings from this assessment are;

Table 9 Treated water quality performance

Parameter	Benchmark for assessment: ADWG and "Good Practise" Targets	Existing plant historical performance
E. Coli	Not detected	Council documents indicate some E.coli detections in treated water
Treated water pH	Set point* ± 0.2	No history of online monitoring at SCADA available. Only post pH correction occurred and observed a wide range in final pH =7.4 to 8.2
Combined Filtered turbidity	<0.2NTU @95%, max ≤0.5 NTU	No history of online monitoring at SCADA available. Not achieved in most results, mainly due to poor performance of both coagulation using ACH after storm events with high colour/variable alkalinity and clarifier
True Colour and Dissolved Organic Carbon(DOC)	Colour <5 @95%, max ≤10 DOC <6 mg/L	Targets not achieved especially during high raw water colour /DOC storm related period, probably mainly due to use of Alchor (ie. ACH) instead of alum coagulant as ACH not great for high colour conditions as very

Parameter	Benchmark for assessment: ADWG and "Good Practise" Targets	Existing plant historical performance
		high doses needed to get to optimum coagulation pH of <6.5
Aluminium	< 0.1mg/L @ 95%, max ≤0.2mg/L	Levels up to 1.9mg/L have been measured by ALS in treated water , consistent with poor coagulation performance
Iron, total	<0.1mg/L @ 95%. max ≤0.15mg/L	Generally achieves targets
Manganese, total	<0.02 @ 95%. max ≤0.05	Levels in raw water up to 1.9mg/L and treated water levels up to
THMs (ADWG Health limit)	Max <0.25mg/L	Very high prechlorine (5 to 6mg/l) and post chlorine (4 to 5 mg/L) doses plus high DOC result in several exceedances of ADWG health limit at Res 1& 2 and in retic, especially over summer
Taste & Odour - Geosmin - MIB	 <5ng/L <5ng/L	Exceeded in most samples. Noted that MIB/Geosmin often increased through the plant
Chlorine Residual (FCR)	Set point* ± 0.2mg/L CT>15mg/L-min	Chlorine has poor control and residual at CWS outlet varies 0.1 to 2 mg/L
Fluoride (F)	Set point ± 0.1 mg/L	Existing fluoride system is not operational, well beyond asset life and a significant WH&S risk if restarted in current arrangement
Treated Water Stabilisation CCPP LSI	 -4 to 0 -1 to 0	Data shows generally achieved provided treated water pH >7.5
Health Based Targets (HBT)	LRVs for category 4 unprotected catchment	Does not always achieve nominal targets - settled water turbidity < 2NTU and/or - filtered water turbidity <0.2NTU Needed to achieve LRV credit for clarification/filtration process

* Set point for pH normally =7.5 to 7.8. Set point for FCR = 1 to 2 mg/L.

It is noted that it is unlikely the operation of the existing clarifier/gravity filter process is adequate to achieve the LRV credit value assigned to this process. That is, the existing process;

- Operates a reactivator clarifier (at rise rate of 1.6m/hr) and if the mixer is running it can break up fragile colour based flocc. It is not a normal treatment technology for high colour and DOC water with low alkalinity (reference: Water Quality and Treatment AWWA 5th Ed, page 7.41). If a clarification process is used under these conditions AWWA recommends flocc –blanket clarification operating at as low as 1 m/hr rise rate
- lacks normal on-line turbidity analyser for each filter,

- has no differential pressure sensor at each filter or automated filter to waste system,
- Has minimal automatic control/SCADA to respond to failure/poor performance.

Performance during the recent storm event over February 2020 highlights the relatively poor performance (refer Appendix D).During this “storm event” period the following occurred;

Raw water

- Apparent colour increased from around 1-2 Hu to 120-140 Hu
- Turbidity rose from a range 2-3 NTU to a range 3.5- 7 NTU with short peak to 19 NTU
- Alkalinity dropped from 130-150 mg/L down to 42 to 80 mg/L

Treated Water in the Clear Water Res 1

- Apparent colour increased from around <1 Hu to as high as 43 Hu
- Turbidity rose from a range <0.1-0.99 NTU to a range 0.4-2.2 NTU
- Chlorine residual drop from range 1 to 2 mg/l down to range 0.1 to 1.5 mg/L

High aluminium level in the treated water also indicates failure of either the filters or the coagulation/sedimentation process to achieve LRV.

Data analysis by ALS has been infrequent but was as follows;

- 1.74mg/L (6 June 2016) and 0.9mg/L (2 Nov 2016).
- DPI-Water noted in correspondence (18 Nov 2016) that “aluminium residuals were again above ADWG”.

3.1.2 Legislative compliance

Compliance with EPA, OHS and WHS regulations

Current chemicals and fluoridation area would not comply with modern OHS requirements due mainly to inadequate space and manual handling (soda ash) and poor location of safety equipment.

Chemical storage and handling

The main issue is:

- Chlorguard systems are not installed in the chlorination room; risk of Chlorine gas leak
- Coagulant Bund is understood to leak
- It is considered good practice to have a chemical delivery bund for liquid chemicals such as Alum and Alchlor
- Potential for overflow and leakage to groundwater from the old sludge ponds

Occupational health and safety (OH&S) requirements

The Condition assessment sets out details, and the main issues include:

- Manual handling of chemical deliveries and dosing is no longer standard practise;
- Trip hazards and constrained spaces throughout plant, particularly under the clarifier/filter block, do not comply with OHS regulations
- Safety shower not standard design (only bathroom-style showerhead) and not enough of them, e.g. should have one at the chlorine room

4. Investigation of Alternative Water Sources

As an extension of the original scope of the project, Council requested GHD to review possible alternative water sources for providing a reliable supply to Bombala.

4.1 Groundwater Investigation

GHD advised Council to undertake a field drilling investigation program to investigate the quality and bore yield potential of the groundwater resources in the vicinity of the townships of Delegate and Bombala.

A groundwater investigation drilling program was therefore undertaken at the townships of Bombala and Delegate. The objective of this drilling program was to investigate potential groundwater resources in close proximity to the current water reticulation infrastructure at both townships.

Two pilot investigation bores were drilled in each town. At Bombala, drilling initially focussed on the shallow alluvial aquifer, followed by the deeper fractured basement rock aquifer. At Delegate, the drilling focussed on the fractured basement rock aquifer.

Based on the work completed the alluvial sediments adjacent to the Bombala River were found to be thin (i.e. <7 m) and clay rich, with no significant inflows recorded. Subsequently, bore BBH2 was continued into the basement rock aquifer system to a depth of 109 m. Although salinity was suitable for potable use, at around 150 mg/L TDS, the pilot bore yield was only in the order of 0.7 L/sec.

Based on these results, there was insufficient yield for ground water to be a reliable future source of supply or to warrant the construction of any test bores or any further groundwater investigations.

The Groundwater Investigation Report has been issued to SMRC separately to this report.

4.2 Weir across Bombala River

Council has previously given some consideration to a scheme to erect a weir across the Bombala River located between the extensions of Caveat Street and Young Street. This progressed to a formal planning proposal in 2017 and was discussed at Council's meeting in February 2020.

The weir proposal intends to raise the standing water level in the Bombala River through the town by up to approximately 1.5 metres, (as described in Envirokey 2016 Terrestrial and Aquatic Biodiversity Assessment) backing up the water level when full as far as the Coolumbooka Weir.

The planning proposal requires rezoning the land to make the construction of the weir permissible under planning controls. It was referred to various State Government agencies in 2017. Responses received are provided in Appendix N to this report. The responses raise various concerns and specific requirements for the proposal.

The response from DPI Fisheries advises that "The Department would require a high quality fishway to be included in the design of the weir in accordance with section 218 of the FM Act." The provision of a fishway across the weir would significantly reduce the capacity of the weir to retain high water levels in periods of low inflows along the river.

Council is shortly to commence an Integrated Water Cycle Management Strategy for Bombala which can review this weir proposal in the context of managing stormwater from the town and river water quality implications.

Whatever other benefits may accrue from the proposed weir, it is not considered to provide a reliable alternative water supply for the Bombala potable water system.

4.2.1 Water quality concerns

- Most of the stormwater runoff from the town will flow into the proposed weir. This stormwater carries with it various pollutant loads including sediment, nutrients, grass clippings, animal wastes, resulting in variable quality in the water flowing into the weir. This will cause some contamination of the water in the weir in every rainfall event. There is also the risk of fuel and chemical contamination from traffic accidents and spills into the stormwater system.
- The sewerage system in Bombala comprises mostly old vitrified clay pipes. There are sewage pump stations in the immediate catchment of the weir. Stormwater and groundwater inflows and infiltration into sewerage systems in periods of wet weather generate peak flows in sewerage systems. Any overflows of sewage from this system due to blockages or extended power outages have potential to spill into the weir. While overflows should be infrequent, there is a direct risk of contaminating the water in the weir, making the water unsuitable for treatment as the potable water supply. Potential sewage contamination of town water supplies is not acceptable.
- GHD understands that there has been no long-term monitoring of water quality in Bombala River at the site of the proposed weir to allow any assessment of the suitability of this water as a raw water source for the proposed Water Treatment Plant.

  The water quality data informs the choice of treatment process adopted in the Water Treatment Plant.

4.2.2 Reliability of supply concerns

- GHD is not aware of water balance calculations of inflows relative to water extraction, evaporation and seepage losses. In extended drought periods, it would be expected that the storage would be drawn down and not provide a reliable source of raw water to the treatment plant.
- The concept design drawings prepared in 2016 for the weir propose a maximum depth of water of approximately 4 metres, only in the narrow channel immediately adjacent to the dam, before allowing for any accumulation of sediment. The bulk of the impounded water would be much shallower than this. Shallow water storages lose significant amounts through evaporation losses.
- The fishway requirement as advised by DPI Fisheries would require a continuous release of water into the river downstream, contributing to an ongoing drawdown of the weir in dry periods.
- The potential size of the weir is too small to replace the existing main supply source at Coolumbooka Weir. At best, the proposed weir could only provide supplementary quantities of raw water at times of higher flows in the river, when inflows into Coolumbooka Weir would make this supplementary supply unnecessary. At times of low flow into Coolumbooka Weir, the flows in Bombala River will also be low, reducing both the quantity and quality of water that could be sourced from the proposed weir.

4.2.3 Approvals

- In view of the significant risk of contamination of the weir from stormwater and sewage overflows, it is unlikely that the NSW Government would give approval for sourcing water from the proposed weir, when the existing Coolumbooka Weir would provide an established source of raw water for the proposed Water Treatment Plant.
- The proposed weir cannot proceed without the prior rezoning of the site to permit this land-use. The communications provided in Appendix N indicate that the NSW Government requires further justification before considering the weir proposal.

4.2.4 Other concerns

- The proposed weir would exacerbate flooding of central Bombala. The current modelling of flood impacts without the weir shows flooding extending beyond Maybe Street and Mahratta Street. The weir would raise flood levels. The flood impact of the proposed weir would have to be modelled as part of the approval processes.
- The Bombala River is recognised as platypus habitat. Changes to this habitat would face detailed scrutiny by NSW Government before any approval could be granted.
- The cost of constructing the proposed weir, fishway and raw water intake pump station and rising main to the treatment plant site would add significant cost to the Water treatment Plant project.

In summary, the proposed weir in Bombala River in the town cannot provide a viable secure water source to the Water Treatment Plant.

The weir proposal could be considered by Council under the separate Integrated Water Cycle Management Strategy, if the various concerns can be addressed and if necessary approvals can be obtained. The weir proposal is not required or viable for supplying town water to Bombala.

5. Options for future Water Treatment

5.1 Development of suitable Water treatment process trains

5.1.1 Treatment challenges

The key treatment challenges associated with the raw water source for Bombala WTP are;

- Achieve Log Removal Values (LRVs) for bacteria, virus and protozoans based on Source Water Category=4 under Health Based Targets
- High levels of soluble iron, manganese and DOC
- Continuous medium level of Geosmin and occasional events of MIB related taste and odour
- Relatively soft and variable pH/alkalinity water during higher microorganism risk periods of storm events
- Single WTP for Bombala township which has a limited usable treated water storage capacity (ie. one peak day demand)
- Cold (down to 4°C) and variable water temperature conditions
- High levels of THM forming organics

The WTP also needs to achieve the following design requirements;

- “Fit for Purpose” treatment barriers to achieve treated water targets based on the raw water quality envelope and HBT for the unprotected catchment conditions
- Sized for net treated water production of 1.5 ML/d
- Achieve asset life, environmental and OH&S requirements and reliable operation objectives (e.g. adequate automatic, duty/standby for critical equipment

5.1.2 Treatment process options

A brief survey of available treatment technologies was completed and is summarised in Appendix H.

The preferred processes, based on the design raw water quality envelope and the treated water targets are highlighted in Appendix H. The discussion regarding the alternatives of a Dissolved Air Floatation (DAF) or suitable settling process are outlined in Appendix J.

Due to site constraints, and the need to remove mainly colour/organics in low turbidity and variable pH/alkalinity/water temperature conditions, the preferred settling process is lamella plate clarifier as an option to DAF. The CAPEX for these processes is much the same for small plants such as Bombala WTP.

Other important decisions on process are discussed below for MIB/Geosmin removal and for organics removal to keep THM levels acceptable.

5.1.3 MIB and Geosmin removal

The main processes for removal of odour from MIB and Geosmin are;

- Powdered Activated carbon (PAC); for this site the expected dose would average about 15mg/l and at time get to 30mg/L
- Granulated Activated Carbon (GAC) ; for this site the detention time in the GAC filter , or the Empty Bed Contact Time (EBCT) should be 15 minutes

A comparison of costs for the above design basis (refer Appendix I) indicates the GAC approach is preferred as the estimated NPCs, within the accuracy of the estimates, are about the same. However, the PAC has the significant disadvantage of being a difficult material to handle and batch up for dosing and equipment has a relatively high maintenance cost.

Consequently GAC is recommended for this site.

5.1.4 Organics and THM removal

A key challenge for this surface water supply for Bombala is the relatively high level of Dissolved Organic Carbon (DOC) that can arise in the raw water. The 2019/20 water quality testing program (Appendix C) shows the DOC can be up to 24 to 34mg/L and most of the time is around 6 to 15 mg/L. The 2018/20 operating history of relatively high chlorine dose at this plant, up around 8 to 10 mg/L, needed to achieve a treated water chlorine level of 1 to 2mg/L confirms that this high DOC level is present most of the time.

When the plant is operating well the existing coagulation/clarification/filtration process achieves about 45 to 50% removal of the DOC, which is in line with what is expected based on GHD experience elsewhere.

Results from Bombala WTP and experience at other plants with high DOC and THM levels, e.g. Rosslynne WTP and Aires Inlet WTP in Victoria and Morgan WTP in SA, indicate that if DOC is <5 to 6mg/L prior to chlorination then THM levels in the downstream treated water network do not exceed the ADWG health limit of 0.25mg/L. A correlation between THMs and DOC is included in Appendix L.

It is also well known that dosing of ammonia and chlorine to create mono-chloramine for chloramination based disinfection will stop the THM formation reaction. However, chloramine is a weak disinfectant, especially for virus. Consequently, for this unprotected source waters with a HBT category 4 classification, it is recommended that if chloramination is adopted, then chlorine should be added first prior to the existing CWS and then after the CWS add ammonia to create the chloramine residual in the water going to the customers in Bombala.

Finally, THMs can be stripped out of water using surface mounted aeration systems, such as the PAX system (refer Appendix K). GHD have recently commissioned this type of system at Rosslynne WTP in its 10ML treated water tank. The technology has been rigorously tested to confirm that the >30 to 35% THM removal found in jar test work at this site, occurred in the full scale system.

Based on the above a number of process design options for DOC removal and THM control were developed and are summarised below (Figure 7) in terms of concept and expected performance.

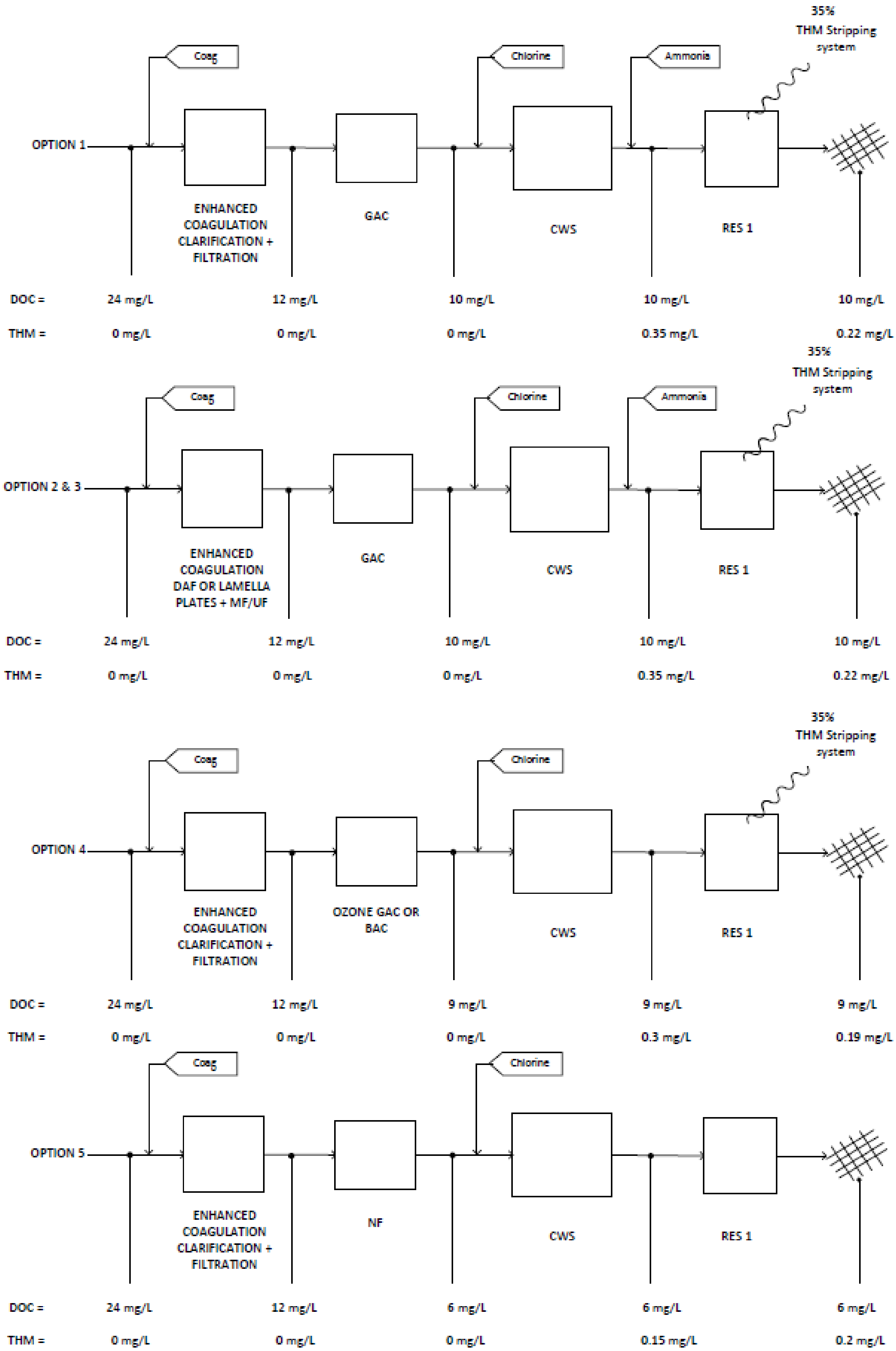

Figure 7 DOC removal and THM control future WTP options

5.1.5 Chlorination and chloramination

Primary disinfection for bacteria and virus would be by chlorination with the required detention time to achieve CT >15mg/l-min occurring in the existing Clear water Storage (CWS). In addition for Options 1 to 3, where organics removal is limited it is proposed to also then add ammonia to create a mon-chloramine residual for achieving long-term disinfection residual in the reticulation system and also to quench additional THM formation in the treated water. For options 4 and 5 there will be extra organics removal and it is considered that the chloramination step is not needed.

Council have requested chlorine dosing be from duty/standby 920kg drums and this would be accommodated in a separate purpose built building.

Aqueous ammonia would be used for dosing of ammonia.

5.1.6 Summary of Future Treatment Process Options

Based on the above assessments it was determined that suitable alternative treatment process trains for treatment of this raw water are;

- **Option 1**: Raw water aeration/mixing/oxidation + modify clarifier + retain and upgrade existing filters + GAC + UV +Chlorination then chloramination
- **Option 2:** Raw water aeration/mixing/oxidation + Lamella Plate Clarifier + MF +GAC + UV+ chlorination then Chloramination + THM stripping
- **Option 3**: Raw water aeration/mixing/oxidation + DAF + MF + GAC + UV+ chlorination then Chloramination + THM stripping
- **Option 4**: Raw water aeration/mixing/oxidation + DAF + MF + Ozone/GAC + UV+ Chlorination + THM stripping
- **Option 5**: Raw water aeration/mixing/oxidation + DAF + MF + NF + Chlorination

5.1.7 Fluoridation

Fluoridation is not a raw water treatment issue. It is recommended for this small size plant, that a sodium fluoride system be adopted using 2.5kg jar feed arrangement to a saturator in a suitable package system. The service water for this system would have to be softened. The fluoridation system would be located in a separate purpose built building in all options.

5.2 Option 1: Upgrade and Retain exiting treatment plant buildings/structures

As noted previously the existing Reactivator clarifier is not considered the best option for this high colour/DOC and relatively soft water supply, especially during wet weather events. However, conversion to a floc-blanket type process and addition of tube settler pack should provide adequate performance.

The dual media filters are a reasonable process as they are dual media but it is not certain whether they have sufficient dual filter media to achieve an L/d ratio >1000. However, the filtration rate is good at <10m/hr at the design flow set at 25 L/s.

As noted in the condition assessment there also needs to be considerable work on improving automation, replacing some chemical systems and electrical systems and generally improving operability and OHS features.

There is also a need to improve the raw water quality by minimising manganese and iron leaching from the bottom of the stratified Coolumbooka Dam (refer to water quality memo in Appendix C).

The other main issue is to achieve good chlorine based disinfection without creating treated water that exceeds ADWG health based limit for THMs.

With these observations in mind the following new works are proposed for this option;

Coolumbooka Dam

- Install bottom mounted mixing/aeration system in Coolumbooka Dam next to the dam wall. A 15 kW air compressor would be installed in the existing emergency Bombala river relift pump station at the site (refer Appendix E for details of this concept). This system would operate on a 24hr/7day time clock to keep the dam destratified in terms of water temperature and Dissolved Oxygen (DO). The reference paper in Appendix E shows this treatment process is quite effective in minimising level of soluble iron and manganese in the raw water. Also, this process should reduce observed MIB/Geosmin as the water quality measurements over 2019/2020 show it is present in stagnant bottom water (refer Water Quality memo in Appendix C).

Raw Water Pump Station

This pump station is well past its asset life and does not have ability to automatically vary flowrate. The following works are proposed;

- new raw water pumps and VSD
- Telemetry from RW pumps back to WTP
- New Raw Water pump station building, including removable roof and/or monorail beam and hoist.
- New switchboard and electrical cabling
- New sump pump to achieve duty/standby for this dry well

Oxidation of manganese and iron

It is expected there will still be a need to oxidise residual soluble manganese (PP) at the plant and it is proposed to dose potassium permanganate to achieve this objective. It may require at times a low dose of prechlorine as well, but high dose rate of prechlorine would be avoided to maintain low THM production. A new mixed 5 minute detention time oxidation tank is required with pre soda ash dosing (when needed) to achieve pH >7.5 in this tank. New pH and ORP analysers would monitor and trim doses of pre-soda ash and PP/prechlorine when required.

Clarifier/filter area:

- new roof at clarifier to provide OHS standard headroom
- new clarifier internals and scraper to achieve floc-blanket arrangement and repainting plus install tube settler pack at top of clarifier

Filters:

- Complete structural assessment and stabilisation of filter block concrete structure
- controls to allow each filter to be automatically sequenced through drain down/air scour/water backwash/refilling/filter to waste at correct rates
- New filter backwash flow meter and better flow control valve (Duty +standby)

- New filter to waste pipework, actuated valve and turbidimeter.
- Constant level control to replace existing rising head operation

Disinfection:

- Install UV to achieve 4 log removal for protozoans
- Separate building for new duty/standby automatic chlorinators, eductors, service water pumps and gas cylinders on load cells and with chlorguard units and compliant mechanical/natural ventilation system booster pumps

GAC

- Install GAC filters supplied with filtered water from the existing filters prior to entry to the existing Clear Water Storage (CWS). Design would be for EBCT=15 minutes and filtration rate <15m/hr plus downstream filtered water tank and duty/standby relift pumps and pipework back into the existing CWS. The relift pumps would also enable backwashing of the GAC filters.

THMs Stripping

- Install PAX type THMs stripping in Res 1 (Appendix K). GHD has recently completed commissioning of this type of system in a 10ML tank and the PAX system achieved 35% THM removal. It is a relatively low cost and low power consumption approach to remove THMs. It involves installing a surface aeration and bottom mixer system within the tank and a blower on the top of the tank to force ventilate the tank to blow away stripped THM compounds.

Chemical systems:

- new automated soda ash and polymer batching and dosing systems and reorganisation of the existing chemical /control building (refer Appendix G)
- conversion to alum coagulant dosing as it is more effective for DOC removal and produces a better settling flocc and also construction of a delivery bund and road upgrade for coagulant deliveries
- new pre-soda ash dosing with controls to achieve flow pace plus trim to coagulant pH set point
- add ammonia dosing and controls and a total chlorine residual analyse for control of chloramination type secondary disinfection after primary chlorination to CT>15mg/L-min target
- chlorine dosing from a new separate fit for purpose building
- sodium fluoride dosing from a new separate fit for purpose building
- new more accessible dosing lines in trays at plant

Washwater and sludge

The existing sludge pond needs to have reduced flows of dilute wash water to them to enable sludge to be dried out for disposal to landfill. Also at present about 15% of inflow to the plant is lost in backwash/sludge water requiring excessive raw water pumping from a yield constrained source. In response the following is proposed;

- wash water tank with mixer and pumps on VSD and pipe with mag-flow meter to transfer filter wash water and clarifier sludge to a thickener

- Coagulant and/or Polymer dosing system and thickener and pipework to a supernatant tank and sludge pipe to existing sludge ponds
- supernatant tank and pumps on VSD and pipeline to return supernatant at controlled rate, nominally 5% of plant inflow rate back into the raw water main feeding the plant prior to where coagulant is added

Other works

- removal of old house at site to allow construction of GAC filters and balance tank and relift pumps
- repairs to concrete work in existing chemical areas and bunds
- Removal of old soda ash and polymer batching and dosing systems from chemical dosing / Office building
- New lined separate buildings for Chlorine and Fluoride and sequential reorganisation of existing Chemical dosing / Office building (refer Appendix G) to achieve construction of new chemical systems, analyser racks and electrical and control equipment (in old fluoride room) while existing plant operates. The objective is to minimise expensive plant shutdown for construction and commissioning new works.
- new Air scour blowers on VSD in enlarged blower room
- upgrade SCADA to achieve full automatic control, collection and use of historical performance data from online analysers and provide suitable Operator interface screens for remote monitoring and operation
- additional online analysers for raw water turbidity and pH , settled water turbidity, filter to waste turbidity, coagulation pH, treated water pH, final water total chlorine and pH
- Additional safety showers at chemical areas.

Temporary water supply during upgrade

In order to complete these upgrades, tankering water is assumed to be required to allow for the time that the existing plant is offline (e.g. to complete the upgrade work at the existing.

Cost of water cartage for the Brogo WTP upgrade amounted to $33,000/ML and similar pricing was advised by a supplier in Cooma for water cartage between Cooma to Bombala (approx. 90km). A 10% margin for uncertainty was also applied.

The total cost for trucking of water (based on 30 days) was estimated at about $15,600/day, for a total of just under $0.5 million (based on the need to provide 0.5 ML/day in 39 no. tanker trips @ 13 kL/ tanker).

It is noted that the time offline may be longer as it is uncertain as to the time taken to complete the work in the clarifier, at the filter inlets/filter to waste and to replace old electrics and commission a final PLC control system

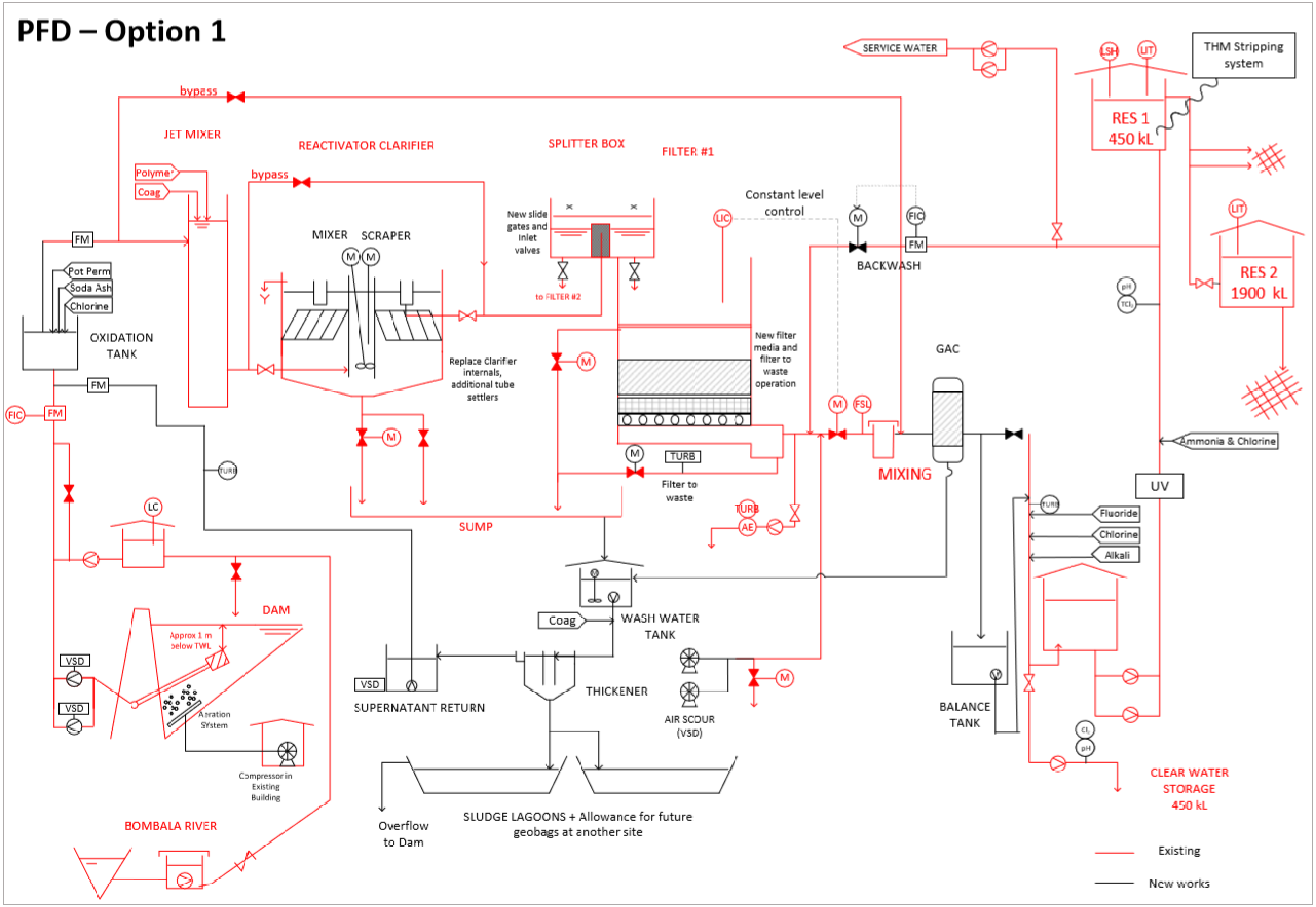

Figure 8 Process flow diagram for Option 1

Figure 9 Concept design layout for Option 1

5.3 New WTP Options

5.3.1 New WTP Building

The new WTP options all would have a large lined ColourBond building, containing main WTP process units, chemical storage, control room and electrics. The figure below shows the concept. Design would need to consider requirements to overcome the specific site bushfire risk.

Figure 10 2.5 ML/d Lancefield DAFF water treatment plant main building

5.3.2 New WTP location

In options 2, 3, 4 and 5 it is proposed that the new WTP be constructed on the site of the existing used house. (Refer Figure 11).

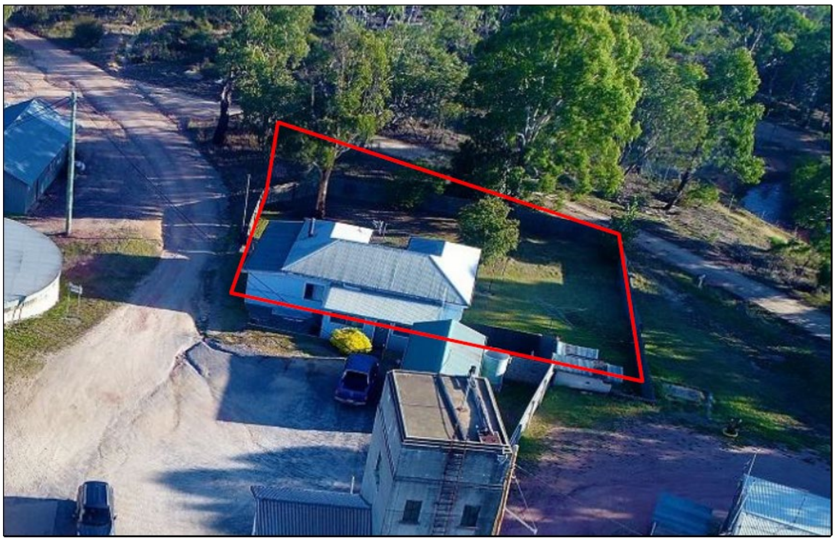

Figure 11 Preferred location of new WTP for Options 2 and 3

For comparison of options it is assumed the existing plant building for chemicals, electrics or controls will not be re-used.

The existing old house offers the following advantages:

- The relatively flat area with sufficient space for any of the plant layouts of options
- Construction without interruption to the current process.

- The existing raw water pipeline, treated water pipeline and pipeline to the sludge lagoons run near the block and hence connecting would require only short pipe lengths.
- Located next to the existing 'ring road'.
- Relatively low bushfire risk

An alternative siting locations was considered, where the new WTP would be located to the east at end of the 'ring' road, behind existing buildings. This option was rejected as it has steep slope, requiring significant earthworks to level the ground and extend a 2:1 batter around edge of building and higher bushfire risk. Also, trucks would have to back into a delivery bund before continuing around the ring road. Raw water and treated water pipelines into and out of the new WTP, and pipeline to the sludge lagoon would be longer. For these reasons this alternative site location was not preferred.

A schematic showing the alternative site location is contained in Appendix F.

5.3.3 Common works for all options

The following works outlined for option 1 in the previous section (refer section 5.2) are also required for the new WTP options 2 to 5. All options require:

- Mixing/aeration of the dam
- All works at the existing raw water pump station
- Oxidation tank and potassium permanganate and pre-chlorine (if required at very low dose) dosing for manganese oxidation
- New soda ash and polymer batching and dosing systems
- New ammonia dosing (options 1,2 and 3 only)
- Mixed Washwater/sludge holding tank and pumps and pipeline to thickener
- Thickener
- Supernatant return pump station and pipeline
- Coagulant and/or Polymer dosing to the thickener feed
- Connection to the existing Clear water Storage
- Reuse of the sludge ponds
- Purpose built new fluoridation and chlorination buildings and dosing systems

The extra works that are common between options 1, 2, 3 and 4 only;

- GAC filters and UV disinfection
- THM Stripping system located in 0.45 ML Res1 tank

Also in Option 4 and 5 do not require mono-chloramine based final disinfection as they have greater organics removal. Finally Option 5 does not require the THM stripping system due to greater DOC removal or UV due to multiple membrane barriers.

5.3.4 Option 2: New WTP (Lamella Plate Clarifier + MF + GAC+ Chloramination)

In Option 2, a new WTP would be constructed where the existing abandoned house is located (as shown in Figure 11). The proposed process train is characterised by the following main steps:

- Lamella Plate Clarifier

- Microfiltration (MF) or Ultrafiltration (UF)
- Granulated Activated Carbon Filter (GAC Filter)
- UV
- Chlorination then mono-chloramine based Chloramination + THM stripping

The Process Flow Diagram for Option 2 is shown in Figure 12 and the proposed site layout is shown in Figure 13.

5.3.5 Option 3: New WTP (DAF + MF +GAC+ Chloramination)

In Option 3, a new WTP would be constructed where the existing abandoned house is located (as shown in Figure 11). The proposed process train is characterised by the following main steps

- Dissolved Air Filtration (DAF)
- Microfiltration (MF) or Ultrafiltration (UF)
- Granulated Activated Carbon Filter (GAC Filter)
- UV
- Chlorination then mono-chloramine based Chloramination + THM stripping

The Process Flow Diagram for Option 3 is shown in Figure 14 and the proposed site layout is shown in Figure 13.

5.3.6 Option 4: New WTP: (DAF + MF + Ozone/GAC + Chlorination)

In Option 4, a new WTP would be constructed where the existing abandoned house is located (as shown in Figure 11). The proposed process train is characterised by the following main steps:

- Dissolved Air Filtration (DAF)
- Microfiltration (MF) or Ultrafiltration (UF)
- Ozone
- Granulated Activated Carbon Filter (GAC Filter)
- UV
- Chlorination + THM stripping

The Process Flow Diagram for Option 4 is shown in Figure 15 and the proposed site layout is shown in Figure 16.

5.3.7 Option 5: New WTP: (DAF + MF + NF + Chlorination)

In Option 5, a new WTP would be constructed where the existing abandoned house is located (as shown in Figure 11). The proposed process train would be:

- Dissolved Air Filtration (DAF)
- Microfiltration (MF) or Ultrafiltration (UF)
- Nano Filtration (NF)
- Chlorination

The Process Flow Diagram for Option 5 is shown in Figure 17 and the proposed site layout is shown in Figure 16.

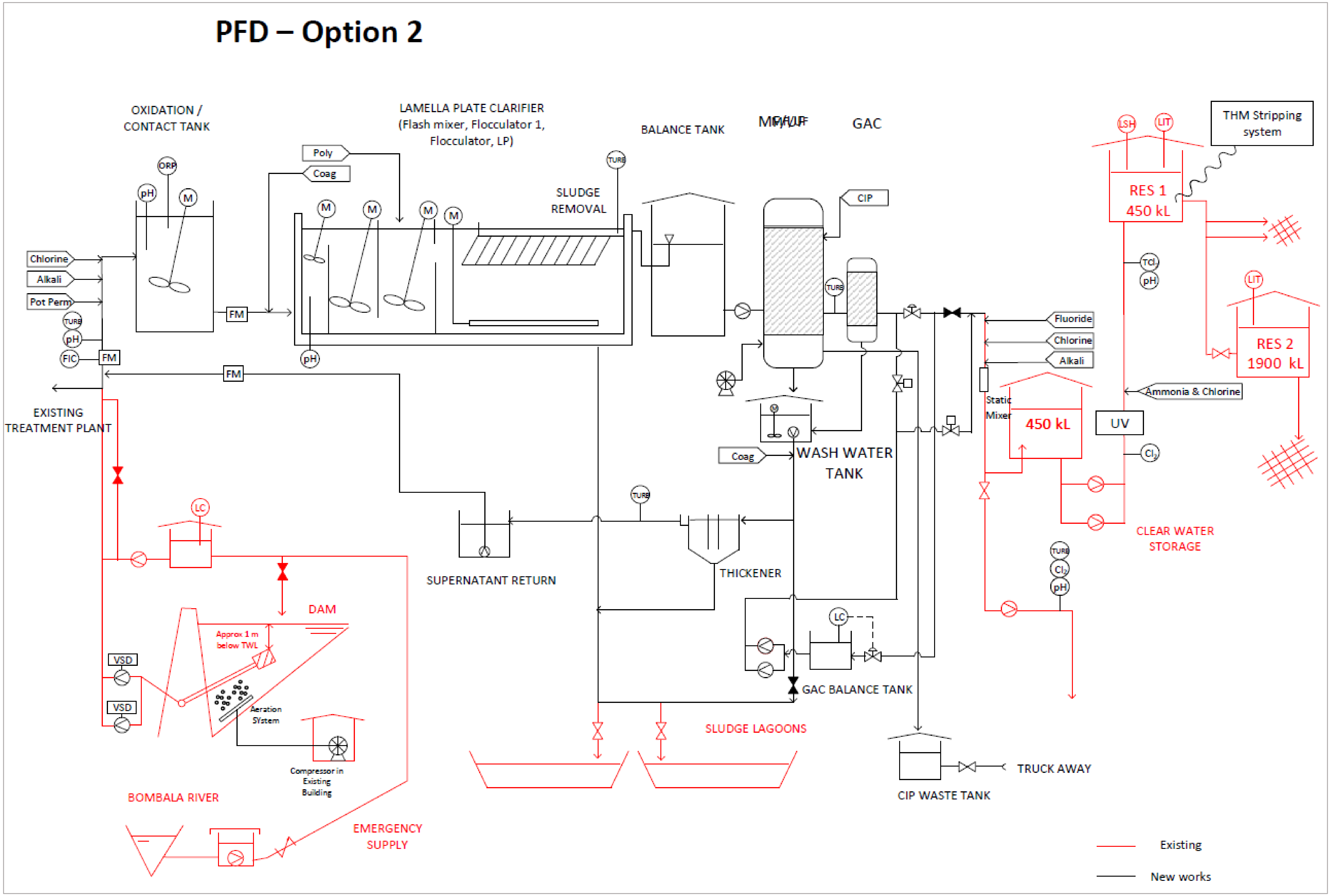

Figure 12 Process flow diagram for Option 2: New WTP

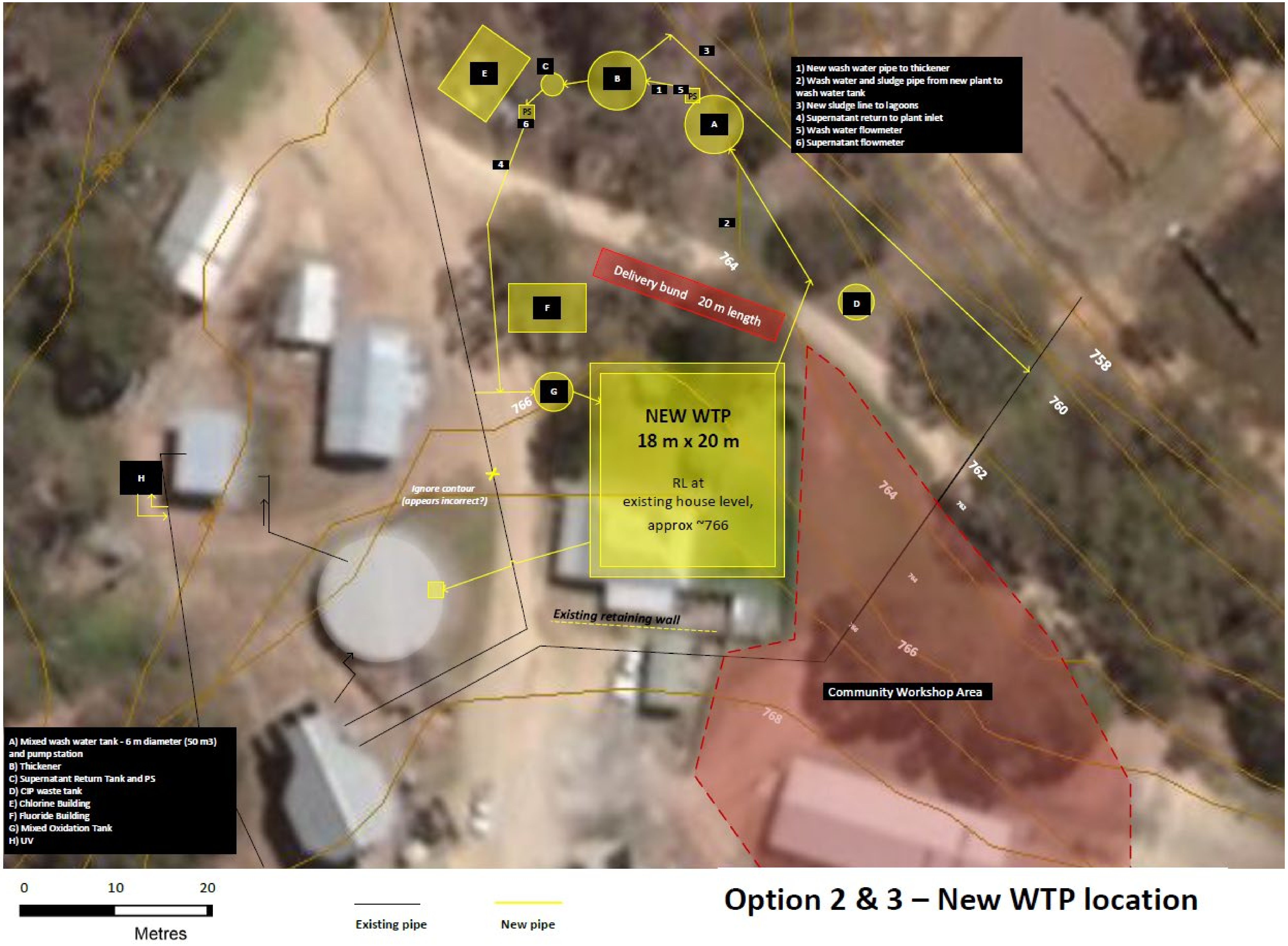

Figure 13 Concept design layout for Option 2 & 3: New WTP

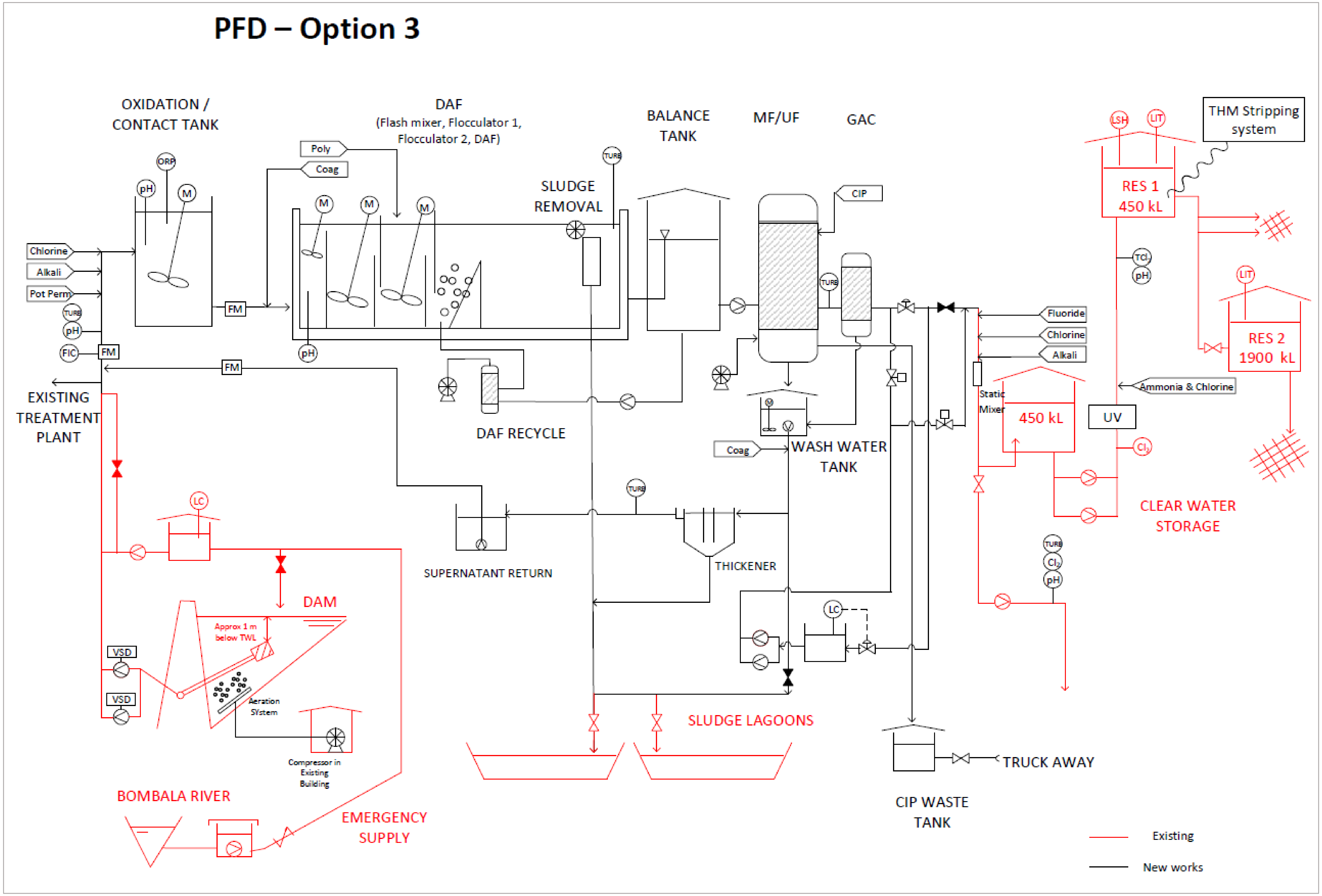

Figure 14 Process flow diagram for Option 3: New WTP

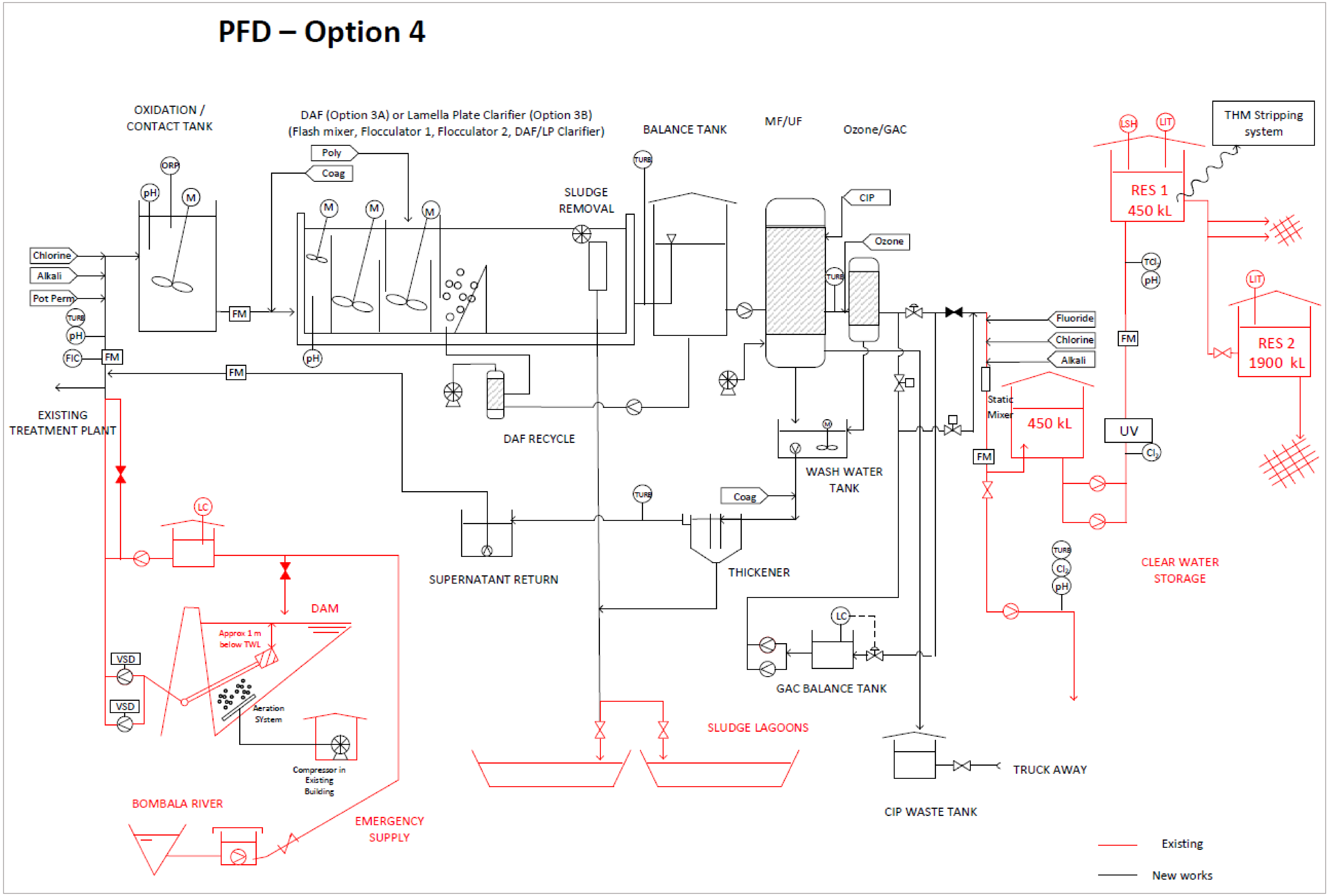

Figure 15 Process flow diagram for Option 4: New WTP

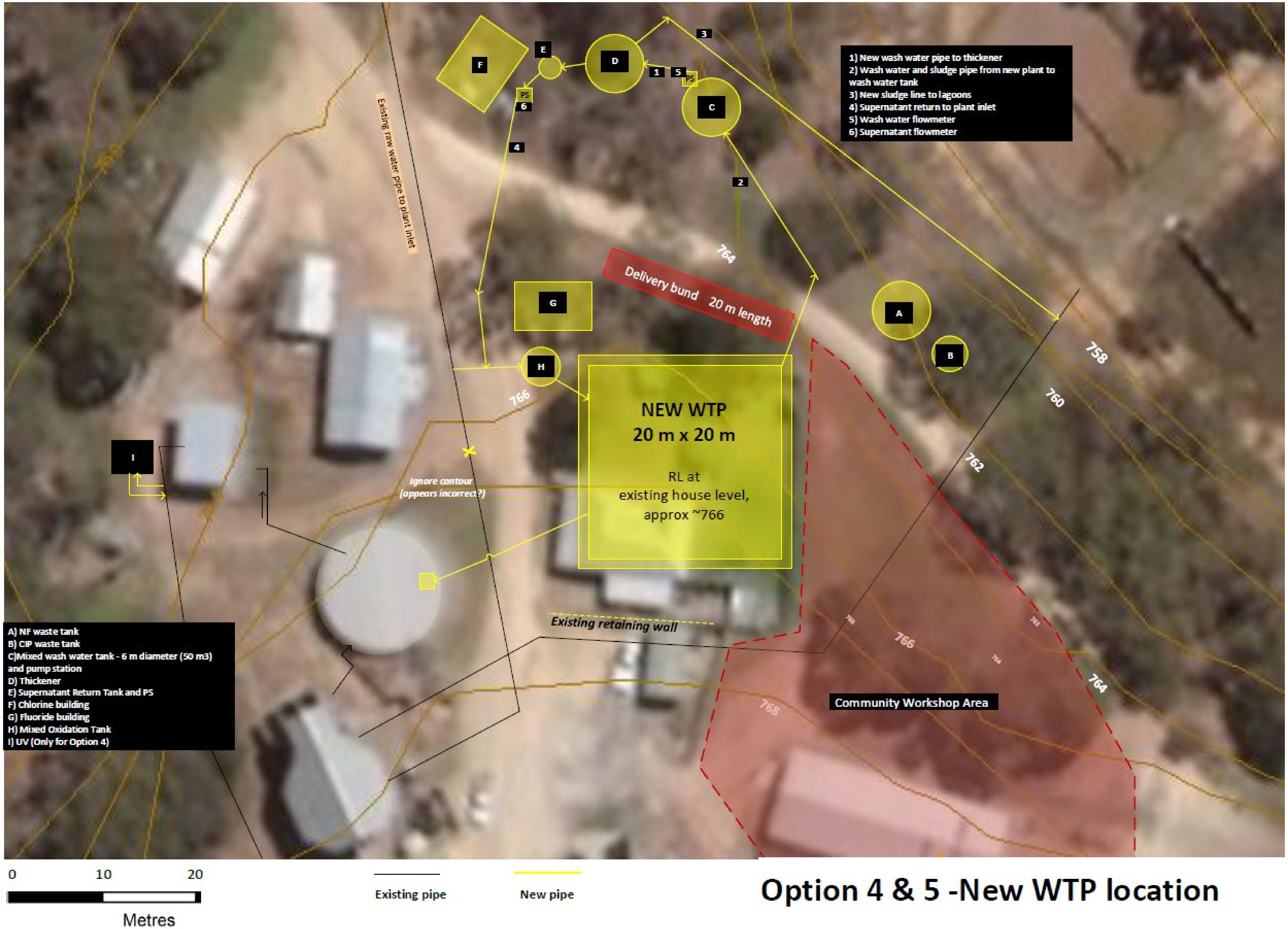

Figure 16 Concept design layout for Option 4 & 5: New WTP

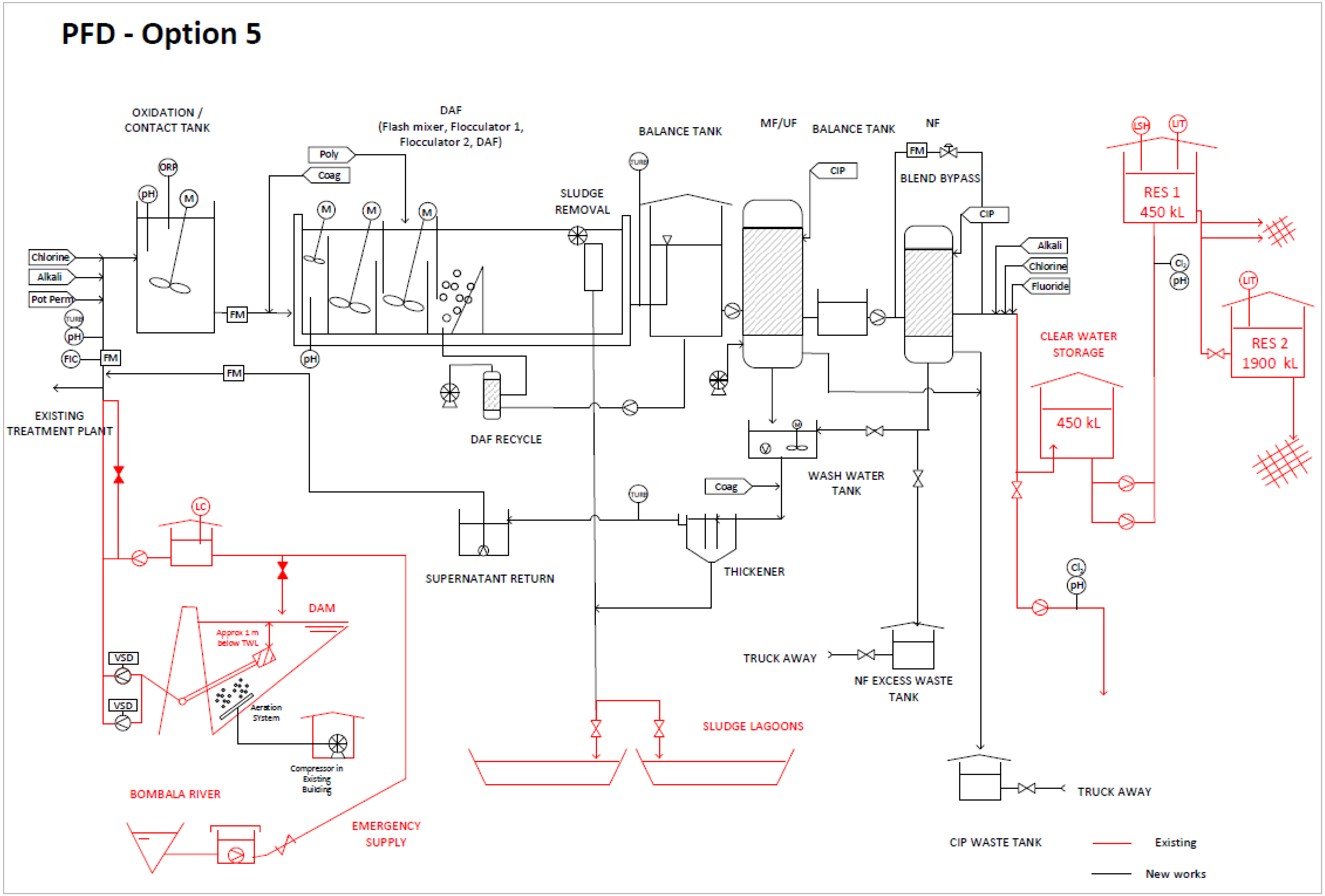

Figure 17 Process flow diagram for Option 5: New WTP

6. Comparison of Options

6.1 Introduction

The relative CAPEX, OPEX, Net Present Cost (NPC) and non-cost related advantages and disadvantages, for each option are discussed in this section of the report.

Refer to Figure 9 (Option 1 site layout) and Figure 13 &16 (WTP site layout for Options 2 & 3 and 4 & 5 respectively) for site layouts for each option.

Refer to Appendix 0 for the breakdown of costing of CAPEX, OPEX and NPC.

This comparison of options does not include the “Do Nothing” Option as the existing WTP is considered not an acceptable option for the future primarily based on;

- Documented extended failures of the existing treatment process, particularly during higher risk poor raw water quality events associated with wet weather inflows to the dam
- The existing reactivator type clarifier is not a suitable process for a raw water that is variable water temperature/softness, low water temp in winter and generally has high organic/colour and low turbidity
- Measurements that show it is unable to achieve ADWG health limit for THMs in the treated water sent to the town
- insufficient treatment barriers to achieve Health Based Target
- insufficient treatment barriers to achieve normal drinking water limits for odour producing chemicals (eg MIB and geosmin) and stain/taste producing manganese
- Bombala resident complaints of poor odour./taste water (refer previous Business case appendices) , most likely due to MIB/Geosmin and manganese
- Bombala resident complaints and media reports of dirty some water (refer previous Business case appendices) plus treated water quality data (showing aluminium levels >1mg/l) plus detection of substantial sludge build-up in the CWS which indicates significant volumes of dirty water (probably mainly due to non-optimal coagulation process) are getting through the WTP process to CWS and to customer taps
- Significant OHS and lack of duty/standby risks associated with existing chlorine, soda ash , fluoride and polymer systems plus these systems are well beyond normal 25 yr asset life
- Significant other mechanical/electrical systems that are not operable (eg clarifier internals, spare filter air blower and fluoride) and/or are in beyond normal asset life (eg duty air scour blower)

6.2 Comparison of New WTP site layout to upgrade of Existing

6.2.1 Cost comparison

The comparison of options is summarized in Table 10 below. It is noted that the accuracy of relative cost estimates for this options comparison stage is about 30%.

Based on this accuracy assumption options 1, 2, 3 and 4 are of comparable CAPEX and NPC.

The important outcomes from the comparison of non-cost advantages and disadvantages/risks are;

- Option 1 CAPEX could be higher if there was longer offline period for construction requiring drinking water to be carted in.
- Option 1 has a risk of not achieving adequate performance as the existing Reactivator type clarifier, even when modified to a sludge blanket + tube-settlers has performance risk for treating soft high DOC content water.
- Option 5 has the least risk of not achieving the THM target but a high waste production
- Options 2 has a lamella plate clarifier which may not be as efficient in treatment as Dissolved Air Floatation in Option 3 or 4
- Option 4 has expensive and high power ozone and requires a bigger building than options 2 or 3
- Chloramination (in options 1, 2 and 3), as the final disinfection process, has a small risk of nitrification in the extreme parts of the downstream reticulation system. Nitrification is a process whereby residual ammonia becomes a food source for non-health related biofilm in the pipe network. When it gets going, usually after the mono-chloramine residual decays away to <0.5 to 1mg/L, the residual disinfectant residual then disappears in these areas of the network and water becomes stagnant and a mild poor taste/odour arises. To avoid it a booster chlorine and ammonia dose at a tank in the retic is sometimes needed or a routine water flushing program is implemented to reduce long detention times

Table 10 Comparative costs, advantages, disadvantages and MCA Scoring for each option

		Option 1. Retain & upgrade existing treatment process (add Oxn+ UV +GAC + chloramination)	Option 2: NEW Lamella Plate Clarifier + MF + GAC + Chloramination	Option 3: NEW DAF + MF/UF + GAC + Chloramination	Option 4: NEW DAF + MF/UF + Ozone/GAC + Chlorination	Option 5: NEW DAF + MF/UF+ NF + Chlorination
CAPEX*		$8.6m	$9.3m	$9.1m	$9.8m	$9.6m
OPEX		$265k /year	$329k /year	$331k /year	$340k /year	$576k /year
NPC	6%pa for 25yrs	$12.0m	$13.5m	$13.3m	$14.2m	$17.0m
Relative Advantages		•Max reuse of existing assets •Retains process well known to WTP operators	•Good for high colour/ v good for high turbidity events •Allows option of PAC instead of GAC •MF/UF very robust in operation and easy to run	•Best for high algae and high colour and low/moderate turbidity •MF/UF very robust in operation and easy to run •GAC is best option for long-term MIB/Geosmin removal	•Best for MIB/Geosmin removal •MF/UF very robust in operation and easy to run •Disinfection by chlorination only and hence no complexity of ammonia dosing and nitrification risk of chloramination	•Best treatment for DOC and THMs •Can bypass NF when DOC is low concentration •Disinfection by chlorination only and hence no complexity of ammonia dosing and nitrification risk of chloramination
Relative Disadvantages		•Many existing WTP assets are 39 yrs old, which is excessive for Mech/Elect systems •Clarifier may not be reliable treatment process for the high colour/low turbidity/variable alkalinity & water temp conditions •Risk of plant offline for longer than expected in construction/commissioning requiring more carting in of water supply to the CWS at estimated $14,000/d •Nitrification T&O risk and process complexity of chlorination then chloramination •Uncertain asset condition/residual life of filters and clarifier as only visual inspections and there are signs of movement of the filters •Continued confined space at filter valves (OHS)	•MF/UF is new technology for Council •CIP cleaning waste for MF/UF for offsite disposal •Nitrification T&O risk and process complexity of chlorination then chloramination	•MF/UF is new technology for Council •CIP cleaning waste for MF/UF for offsite disposal •Nitrification T&O risk and process complexity of chlorination then chloramination	•High Power for Ozone/GAC and MF/UF •MF/UF is new technology for Council •CIP cleaning waste for MF/UF for offsite disposal •Nitrification T&O risk and process complexity of chlorination then chloramination	•Uncertain on % MIB/Geosmin removal in NF •NF has 20% of inflow going to waste as high DOC water and it is uncertain as to treatment allowing some to return as supernatant, Consequently, need to design for overall losses from plant at about 20 %, so plant is bigger than all other options •CIP cleaning waste for MF/UF and NF offsite disposal •Highest process complexity
Relative score against MCA (Best=5, Worst=1)	Performance Operability Enviro&WHS Construction complexity Easy procurement	✓✓ (performance of modified clarifier uncertain) ✓✓ (too compact at clarifier/filters) ✓✓ (ongoing poor access to filter valves) ✓ (existing structure and uncertain time offline risks) ✓✓✓✓	✓✓✓ (nitrification risk) ✓✓✓ ✓✓✓ ✓✓✓✓ (small building easily fits) ✓✓✓✓	✓✓✓ (nitrification risk) ✓✓✓ ✓✓✓ ✓✓✓✓ (small building easily fits) ✓✓✓✓	✓✓✓✓ ✓✓✓ ✓✓✓ ✓✓✓ (bigger building) ✓✓✓	✓✓✓✓✓ ✓✓✓ ✓(high volume of salty NF waste) ✓✓✓ (bigger building) ✓✓ (NF equipment)
Order of preferred option	(best=1)	**4**	**2/3**	**1**	**2/3**	**5**

* The above costs do not include Fluoridation. Based on a separate contract for a new building and sodium fluoride dosing system compliant with the NSW code the extra cost is up to $0.65m. This cost is based on recent tenders and independent cost estimates.

7. Conclusions & Recommendations

7.1 Conclusions

The main conclusions from condition assessment of the existing plant were;

- The existing raw water pump station requires a new building and E, I and C works due to very old asset in poor condition and not fit for purpose.
- The existing WTP is now 39 years old and the process (especially alkali, polymer and chlorine) and most electrical systems are older than normal asset life.
- Existing sludge ponds are too small to achieve the requirements of (1) containment of filter wash water and clarifier sludge plus (2) sludge drying

The main conclusions from the assessment of demand, groundwater alternative, existing surface water quality and treatment were;

- The required future (in 25 years) peak day demand for the new WTP is 1.5 ML/d
- The alternative of a future water supply from groundwater was found to be not viable
- The construction of a weir on the Bombala river does not provide a suitable raw water supply to the WTP
- The existing raw water pump station structures are well beyond asset life and the pumps have no variable flow control and minimal telemetry back to the Water Treatment Plant (WTP). A reliable pump station with ability to modulate flowrate and monitor performance is essential, particularly given the relatively old AC water main connecting it to the WTP
- The raw water catchment for this system is unprotected with substantial areas of grazing land for cattle/sheep/deer and septic tanks at rural properties. Based on the Health based Targets (HBT) concept, understood to be soon added to (ADWG), the Source Water Category Classification would be 4. This requires multiple treatment barriers to achieve the required high level of removal of bacteria/virus /protozoan (e.g. Cryptosporidium)
- Raw water quality conditions are challenging for treatment. This is mainly because this water supply from Coolumbooka Dam is from an unprotected catchment with high microbiological risk plus after chlorine is added, it produces levels of disinfection byproducts (eg THMs) that exceed ADWG health limit in the treated water. Also, raw water is soft with ongoing odour due to MIB/Geosmin and has very low water temperatures in winter. These characteristics require special features to be added for effective treatment. Events of very high manganese and iron occur. The existing treatment processes are not suitable or sufficient for treatment of this combination of risk and raw water quality conditions.
- The existing WTP is now 39 years old and the process (especially alkali, polymer and chlorine) and most electrical systems are older than normal asset life. Some minor improvements have recently occurred (e.g. motorised filter valves, new coagulant dosing system and limited SCADA upgrade) but performance of this plant is generally below standard (e.g. THMs are too high). Treatment essentially failed for several days soon after the recent wet weather event in February 2020. The existing process is not suitable for these rapidly deteriorating conditions.
- The recent special water quality sampling program was very useful in providing better understanding of the water quality challenges for this surface water supply from Coolumbooka Dam. However, it was of limited duration and did not cover the recent large storm event for several water quality characteristics (results are summarised in Appendix C).

New WTP options that are considered suitable for the raw water quality conditions are:

- OPTION 1: Modify/add to existing plant; Pre-oxidation + tube settlers into modified clarifier + upgraded gravity filtration+ GAC + UV + chloramination. Work would include a new 920kg drum based chlorination system in a separate building plus a separate building for a new future sodium fluoride dosing system plus reorganise the existing main WTP chemicals/office/building
- OPTION 2: Pre-oxidation + Lamella Plate clarifier + Membrane filtration+ GAC + UV + chloramination then chloramination + THM stripping
- OPTION 3: Pre-oxidation + Dissolved Air Floatation (DAF) + Membrane filtration + GAC + UV + chloramination then chlorination+ THM stripping
- OPTION 4: Pre-oxidation + Dissolved Air Floatation (DAF) + Membrane filtration + Ozone/GAC + UV + chlorination+ THM stripping
- OPTION 5: Pre-oxidation + Dissolved Air Floatation (DAF) + Membrane filtration + nano filtration + chlorination

A summary of the options and comparison of options is set out below. All the Options 2 to 5 would be located at the site of the old house on the existing WTP site.

Option 3 is preferred overall on cost and non-cost advantages basis.

Item	OPTION1	OPTION 2	OPTION 3	OPTION 4	OPTION 5
CAPEX	$8.6m	$9.3m	$9.1m	$9.8m	$9.6m
NPC	$12m	$13.5m	$13.3m	$14.2m	$17m
Performance	✓✓ (clarifier uncertain)	✓✓✓ (small nitrification risk)	✓✓✓ (small nitrification risk)	✓✓✓✓	✓✓✓✓✓
Operability	✓✓ (too compact)	✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓ (
Env&WHS	✓✓ (ongoing poor access to filter valves)	✓✓✓	✓✓✓	✓✓✓	✓(high volume of salty NF waste)
Construction complexity	✓ (existing structure and uncertain time offline needing carting in water risks)	✓✓✓✓ (small building easily fits)	✓✓✓✓ (small building easily fits)	✓✓✓ (bigger building)	✓✓✓ (bigger building)
Easy procurement	✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓	✓✓ (NF equipment)

Note that the above costs do not include Fluoridation. Based on a separate contract for a new building and sodium fluoride dosing system compliant with the NSW code the extra cost is up to $0.65m. This cost is based on recent tenders and independent cost estimate for a similar size plant in NSW.

7.2 Recommendations

The following is recommended based on this assessment of requirements and the options to achieve them;

- Based on projected demand in 25 years' time, the required new WTP capacity is 1.5ML/d with a peak instantaneous flowrate of 25 L/s
- The key features of the preferred Option 3 to go to the next stage of this project are;
  - treatment process; Pre-oxidation + Dissolved Air Floatation (DAF) + Membrane filtration + GAC + UV+ chlorination then chloramination + THM stripping
  - buildings: designed to suit bushfire rating of the area
  - Location; at existing old house site and decommission existing WTP but possibly reuse existing building for some of the chemical systems and for administration/spares storage
  - New wash water/sludge system; wash water/sludge holding tank and pumps to thickened and then concentrated sludge to existing sludge ponds and supernatant tank and supernatant return pumps to WTP inlet
- Construct a separate purpose built new chlorination building to house a duty + standby 920kg drums of chlorine plus duty/standby gas chlorinators and separate service water system
- Because Fluoridation is best located in a separate purpose built building as it requires specialist contractor and often is completed under a separate funding process.
- Continue, at lower frequency of sampling, the special water sampling program over autumn /winter focusing on the main issues of
  - Raw water at dam; E,coli, pH, alkalinity, colour, turbidity, MIB/Geosmin and DOC
  - Filtered water; turbidity prior to addition of soda ash and chlorine
  - Treated water; DOC, pH, alkalinity and THMs (CWS, Res1 and retic sites)

It is also not recommended to pursue any further the options of groundwater or a weir on the Bombala River as a new source of water supply to the WTP.

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Appendices

Appendix A – Existing plant asset register

Refer to following page

Table 11: Asset register (visual assessment as per site visit 16/4/19)

Asset	Category	Sub-Asset	Size	Details	Year constructed	Effective Life	Residual Life	Comment / Strategy
Raw Water Source	Civil	Coolumbooka Dam	250 - 300 ML		~1939	100	19	In use
		Coolumbooka Weir		Handrails replaced ~1980	~1980	50	20	In use
Raw Water pumps and Main	Pipework	Pipeline from Dam to RW Pumps	DN 200 CICL		~1939	100	19	In use
		Pipeline from Bombala river, downstream of dam	? AC		Pre 1980	50	< 11	Only used then water level in dam is low.
		Secondary pipeline from dam...	DN 150 AC		Pre 1980	50	< 11	Only used when extra flow is obtained from Bombala River, downstream of dam.
	Mechanical	Raw Water pump station	2 x 50 kW	D/S pumps, observed 67 amp @240V/phase	~1981?	40	1?	In use. Age and kW uncertain
		RW Pump stn monorail and hoist		manual	1981	30	-9	Hoist old manual chain type and monorail too low
	Electrical	Raw Water pump station	steel	D/S pumps	1981?	35	-4?	In use. Age uncertain
WTP	Civil	Main plant and TW pump Building	Main 15.5m x 11.6 m pumps 7 x 4.5m	Brick structure	1981	50	11	In use.
		Walkways above clarifier and filters		Galv steel	1981	35	-4	in use
		Roof over clarifier and filter area		Galv steel	1981	35	-4	In use
		Jet Mixing tank	6 m height	Concrete	1981	80	41	In use.
		Reactor Clarifier	10.25 m diameter with inner shroud at 4.88m diam	Concrete	1981	80	41	Upflow rate = 1.92m/hr @30L/s, is too high for high organics/colour/low turbidity water. Need 1 to 1.2m/hr in floc-blanket type clarifier, reactivator type more suited to high turbidity or softening Significant vertical cracks in brick wall connecting the filter block to the clarifier.
		Filters	2.3 m by 3.4 m for each filter	2 no. concrete filter block. Boby Rapid Gravity type filters	1981	< 80? Cracks/moving	< 41?	Filtration rate =9.8m/hr at plant flow=30L/s
		Mixing Tanks – Soda Ash	1.37 m diameter at 1.5 m deep = 2.2 m^3	2 no. tanks –FRP, 20kg bags batch to 5%w/v	1981	25	-14	Manual batching to 5%w/v
		Storage – Polymer	0.76 m diameter	FRP	1981	25	-14	Manual batching to 0.2%w/v
		Storage bund– ACH or alum		Concrete	1981	50?	11?	Concrete has leak according to ops
		Storage Tank ACH or Alum	10kL (approx.)	PE	2018?	25	-14	Tanks shown in original drawings no longer used
		Fluoride batching system		GRP	1981?	25	-14	Basic manual system
		Sludge Lagoons	560 m^3 each 24 m x 18 m (surface) 1:2 slope wall	2 no. sludge lagoons with baffles	1981	40	1	Lagoons need clay lining
	Mechanical	Backwash flowmeter and control valve			1981	25 flow meter 40 valve	-14 1	
		Treated water pumps and motors	22kw @38L/s	2No	1981 and 2007?	40	1 22	1 pump motor label 2007 other one looks older
		Dosing Fluoride	Sodium Fluoride	1No and float activated service water	1981	25	-14	Old and poor condition, no softener for service water
		Blowers – Air scour	VSD controls	2 no.	1981 blowers 2017 VSDs?	30 15	-9	One blower taken offline for repair at time of visit
		Dosing – Polymer	12l/hr?	LT20	1981	25	-14	
		Dosing – ACH/alum	12 to 14.4L/hr carrier water 300L/hr	digital	2018	25	23	
		Dosing soda ash	400L/hr	Metering,	1981	25	-14	

Asset	Category	Sub-Asset	Size	Details	Year constructed	Effective Life	Residual Life	Comment / Strategy
		Chlorinators	1 pre +1 post Chlorinator/ ejector sets 1kg/hr each	Manual adjustment of rotameter valves	1981 Chlorinators	25	-14	Very basic control OHS risk (ie no chlorguards) Gas leak detectors unknown age
		Chlorine cylinders	2no x 70kg bottles with vac regulators		Vac regs 2018?	15	13?	No standby and no weight sensor under cylinders
		motorised filter inlet, outlet and wash water valves			2017 actuators 1981 valves?	25 40	22 1?	When were valves installed?
		Motorised Sludge Valve (clarifier outlet)			2017 actuators 1981 valve?	25 40	22 1?	When were valves installed?
		Chemical Mixers	Soda ash, polymer		1981	25	-14	In use
		Reactivator clarifier draught tube mixer and sludge scrapper			1981	25	-14	Not in use
		Service Water System		Pumps look recent	1981?	25?	-14?	Undersized for systems and no flow meter or VSD control for pressure
	Pipework	From filter sump to sludge lagoons	DN250 or 300?	AC	1981	50	11	
		Backwash from Res 1 to filters	DN250	DICL?	1981	80	41?	
		Rising main to Res 1	DN250	DICL?	Pre 1980	80	<41?	
		Gravity Main from Res 1	DN250	DICL?	Pre 1980	80	<41?	
	Other	Filter Media	Filter floor has laterals	Sand/coal media, PVC laterals with PVC nozzles	2018	20	18	Replaced the sand in July 2018. Prior to replacement, there was only 400 mm of sand and no anthracite found.
	Electrical	TW pumps and main WTP Switchboards		1981	35			Comment from Elec engineer?
		SCADA			15			
Distribution	Civil	Clear Water Storage *(originally named Res 1, pre 1980)*	455 kL 12.8 m diameter 3.58 m high	RC Tank with galv steel roof	Tank - 1938 Roof installed in 2000* (anecdotal, from site visit)	80 40	-2 20	Tank last cleaned 2018. Visual inspection of inside tank during site visit did not show corrosion on galv steel beams access ladder or roof
		Reservoir 1 *(originally named Res 2, pre 1980)*	455 kL 8.5m diameter 8.35 m high		1981?	80	41?	Beyond scope but looks < 30yr old
		Reservoir 2 (*originally named Res 3, pre 1980)*	1,917 kL			80		Beyond scope

Appendix B – OHS issues as noted during site visit 16/04/19

Table 12 OHS issues, as noted during site visit 16/4/19

Area	Comment	Photo
Safety Shower	Safety Shower are not standard supplied showers	
	Service water flow – it is not clear whether this is sufficient to supply both the Safety Showers and the chlorinators at the same time	N/A
Trip hazard	Trip hazards under Chlorinator/Filter Block	
Chemical Handling	Soda Ash dosing is manual. 25kg bags are unloaded into mixing tank.	
Chemical Handling	No delivery bund to contain spilled chemicals from delivery tanker	
Chlorinator	Exhaust fan in chlorinator room did not turn on when tested at site visit	
	ChlorGuards not installed	
WTP boundary	Asbestos at house adjoined to WTP boundary.	

Appendix C – Water Quality Testing: Memorandum

Refer to the following page for the Water Quality Memo & location of sampling points

Memorandum

30th April 2020

To	Snowy Monaro Regional Council		
Copy to	Catherine Sherry, GHD		
From	Laura De Rango, GHD Mike Chapman, GHD (review/approval)	Tel	03 8651 9245
Subject	Update on Water Quality Monitoring at Bombala WTP Site	Job no.	3137056

Bombala Water Quality Monitoring Update

1 Introduction

- ALS monitoring started on 6 May 2019 and this looks at data until 23rd January 2020.
- This memo compares ALS results against Bombala WTP operational monitoring.
- This is an update of the memo sent to SMRC in December 2019, and incorporates new data from ALS which was taken in January 2020.
- It is noted that sampling did not continue through the storm event which occurred in late January/early February and so it is unknown how the raw water quality changed during this event. Some indication is given by the on-site operational testing of Iron and Manganese which shows very high concnetrations during the storm event, however no ALS sampling was taken during this time
- The water quality sampling locations (location 1 through to 7) are shown on a Proces Flow Diagram of the existing Bombala WTP at the end of this memo.

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Memorandum

2 Results

2.1 Dissolved Organic Carbon (DOC)

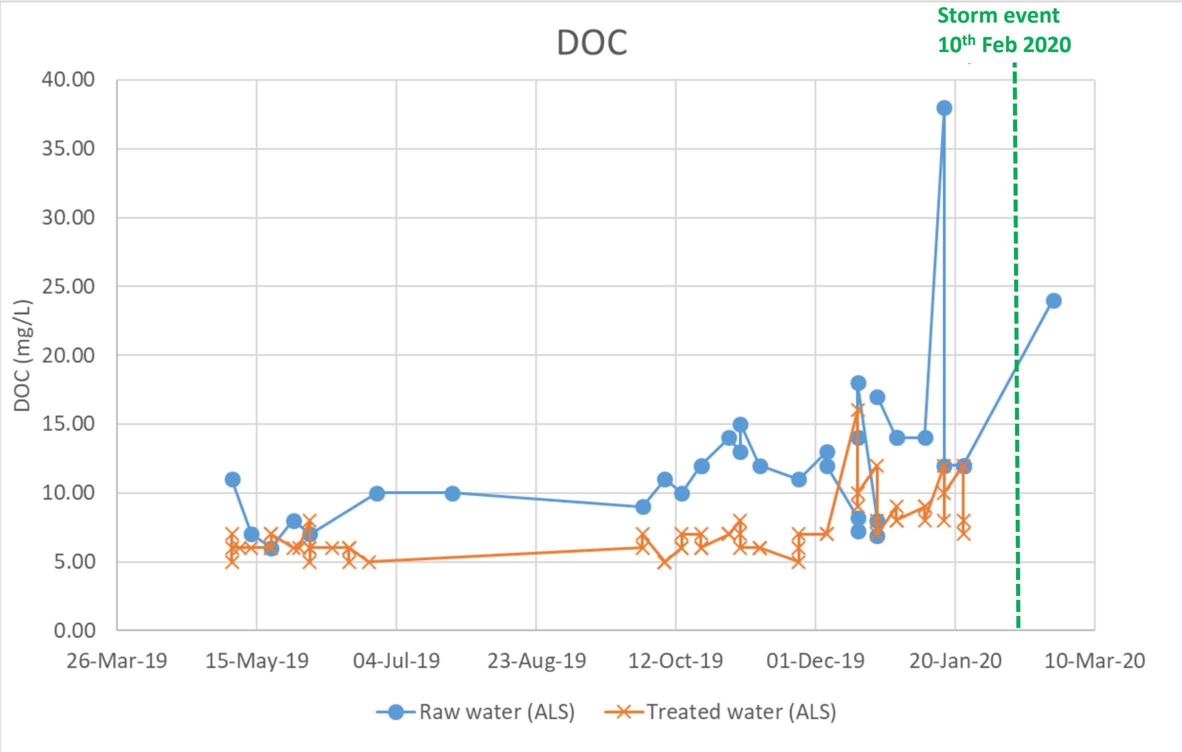

Figure 1 DOC results of raw water (includes dam surface, dam at 1m depth, at raw water pump station, and intlet to WTP) and treated water

ALS results in Figure 1 show;

- Reduction in DOC by this WTP ranged from zero to 60%.
- DOC of treated water ranges from 5 mg/L to 16 mg/L, which is high. (Refer section on THMs).

Recommend continue to collect DOC results over summer/autumn higher colour periods.

2.2 E. Coli

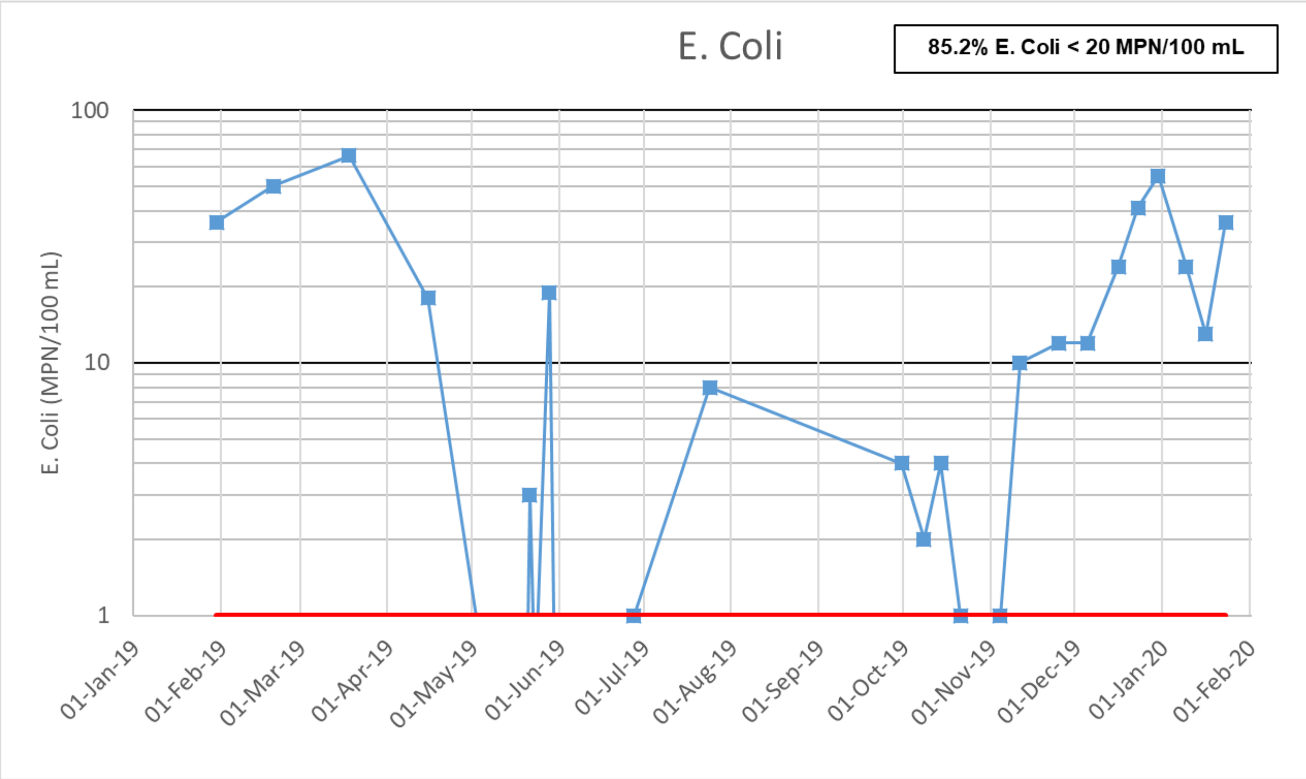

Figure 2 E. Coli results for raw water

Results indicate;

- High levels of E. Coli can be experienced in summer.
- Early results (Jan to April 2019) are from Health NSW record sheets and show high values.
- When combined with catchment vulnerability, the Health Based Targets (HBT) guideline in draft Australian Drinking Water Guidelines (ADWG) document would, on the basis of these E.coli results, define this raw water as at least category 3 based on earlier results.

Recommend continue to collect results.

2.3 Total Trihalomethanes (THMs)

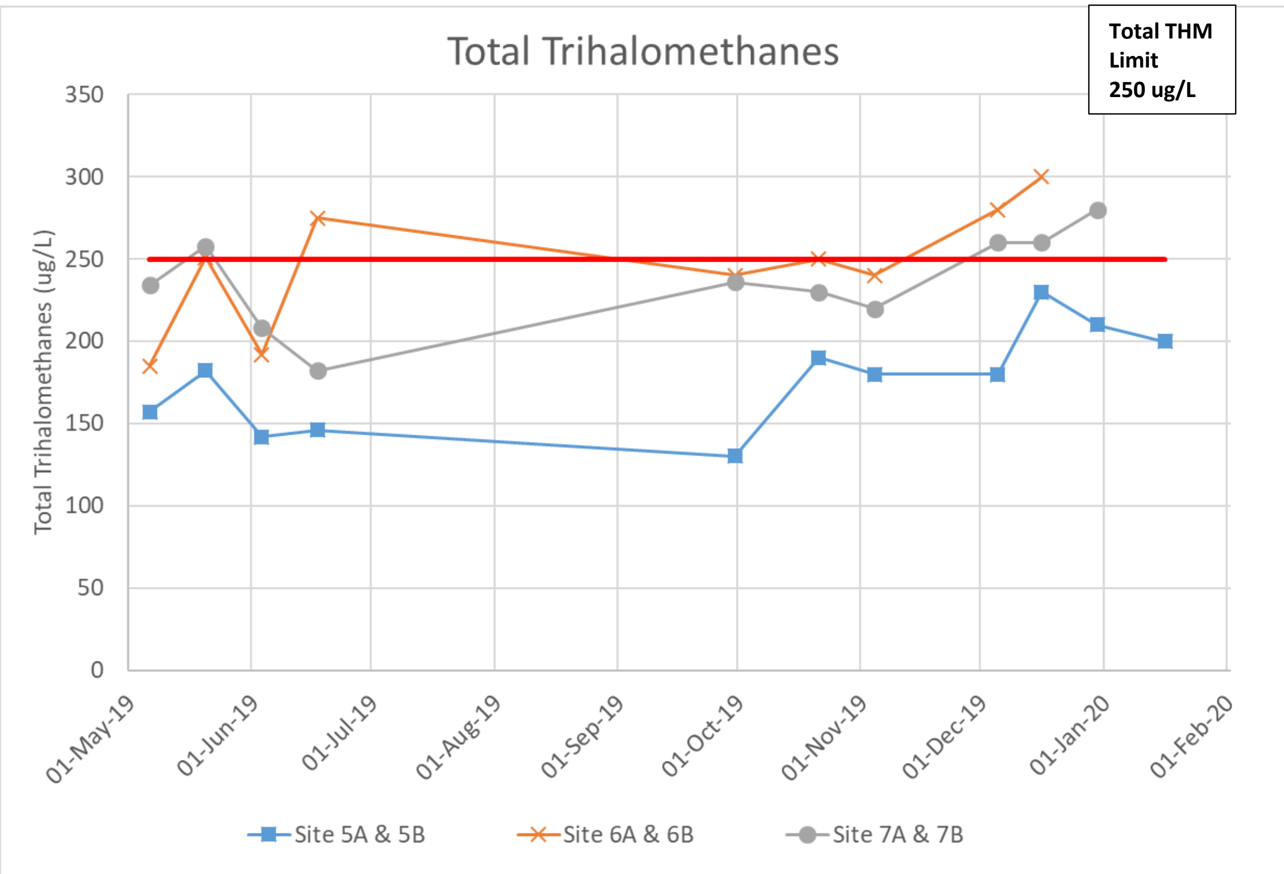

Figure 3 THMs results at sites 5A & 5B, 6A & 6B, and 7A & 7B

Results show;

- THMs rise in reticulation system and have exceeded the ADWG limit of 250 ug/L at sites 6A & 6B and sites 7A & 7B.
- High values are consistent with treated water containing relatively high levels of DOC plus the prechlorination process at this plant to minimise manganese and iron.

Recommend continued measurement over summer/autumn period when it is expected that THM values will increase.

2.4 Turbidity

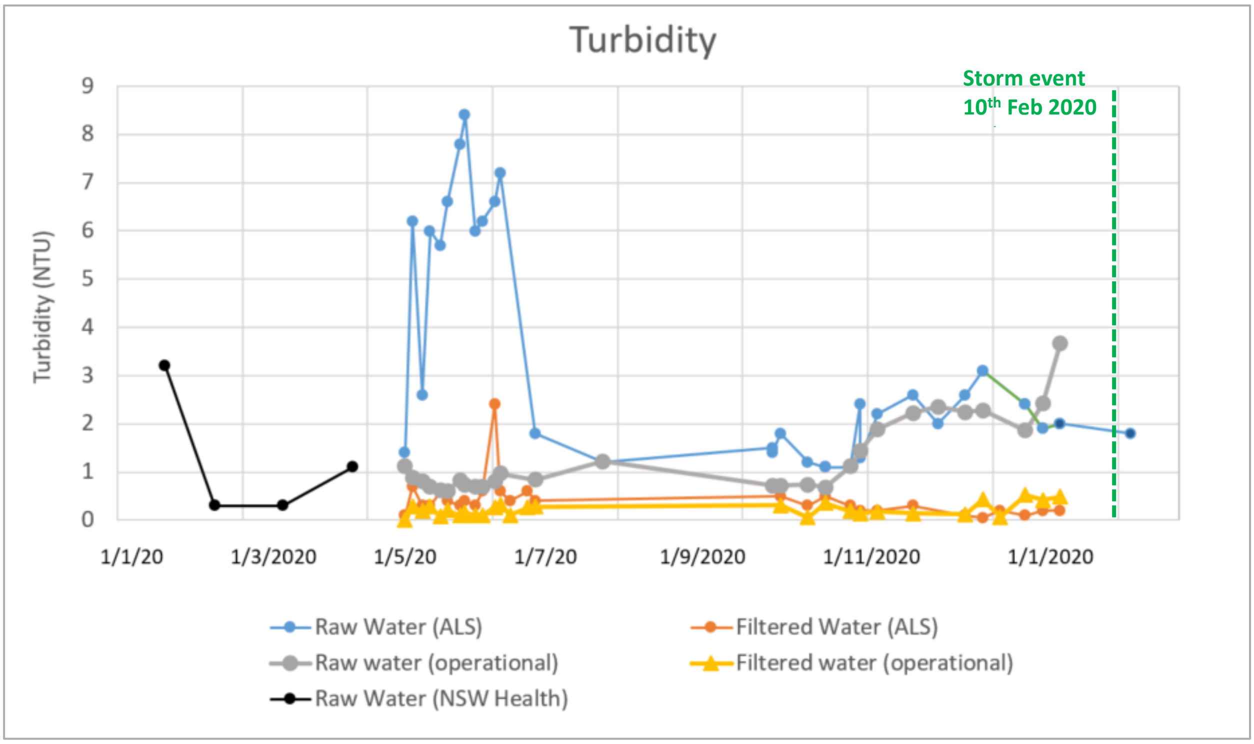

Figure 4 ALS and operational turbidity results of raw and filtered water

Results show;

- Operational data for raw water is almost an order of magnitude less than ALS data. This is probably due to incorrect sample point at inlet to WTP, which is affected by prechloriation and ACH dosing.
- Operational results for filtered water turbidity are often lower that ALS result which is significant as Log Removal Value (LRV) under Health Based Targets is set from filtered water turbidity results.

Table 1 Comparison of ALS and operational data for filtered water turbidity

	ALS data	Operational data
% ≤ 0.5 NTU	78.6	96

Table 1 shows that filtered water turbidity from ALS would mean the filters fail the HBT requirements for LRV, which require 95% <0.3 NTU and max of <1 NTU.

Recommend relocate raw water operational sampling point to dam taking sample from the surface or discharge side of pumps and only take sample after pump has been running for say 15 minutes. In addition, ongoing measurement of turbidity by ALS and careful matching of filtered water turbidity measurements by Operations (lab test and online analyser) with samples going to ALS.

Memorandum

2.5 True Colour

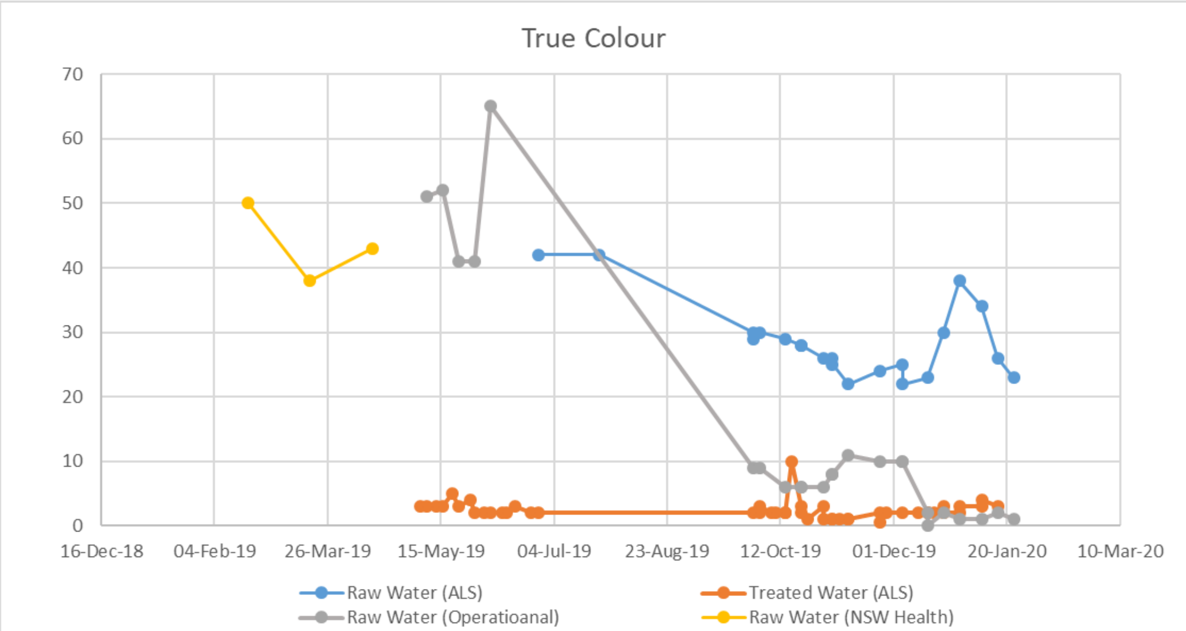

Figure 5 True colour results of raw and treated water

Results show;

- ALS results for raw water are 3 to 4 times higher than the operational results for raw water.
- This is likely to be due to the operational sample point being at the WTP where raw water is decolourised by prechlorine.

Recommend relocate raw water operational sampling point to dam taking sample from the surface or discharge side of pumps and only take sample after pump has been running for say 15 minutes. Continue to do ALS and operational sampling to verify if there is a high colour period in summer/autumn (based on historical WTP operational data).

2.6 pH

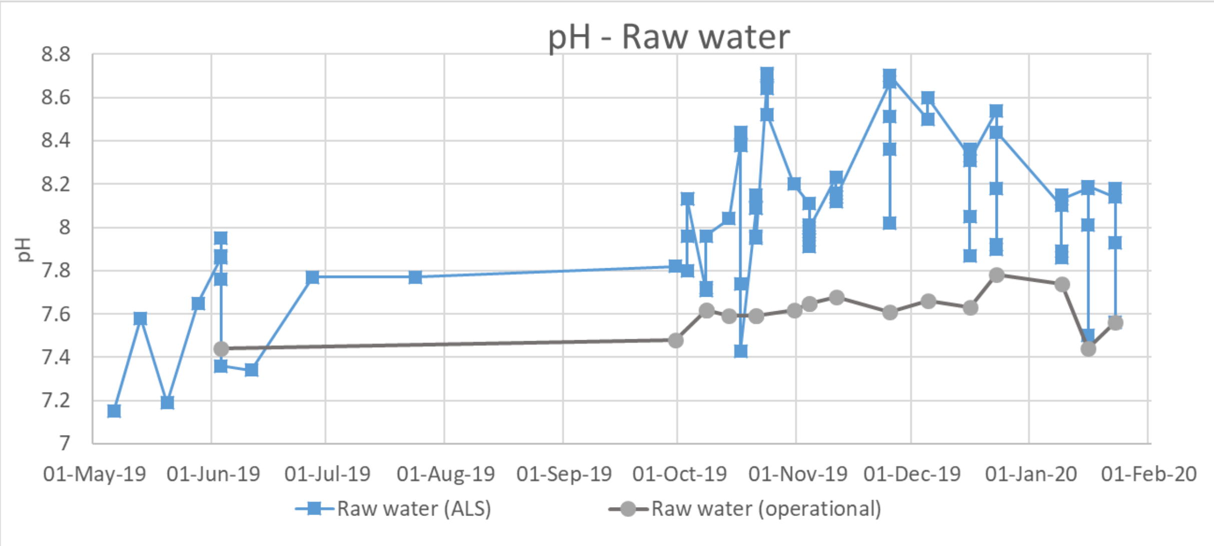

Figure 6 ALS (showing depth profile in dam) and operational pH results of raw water

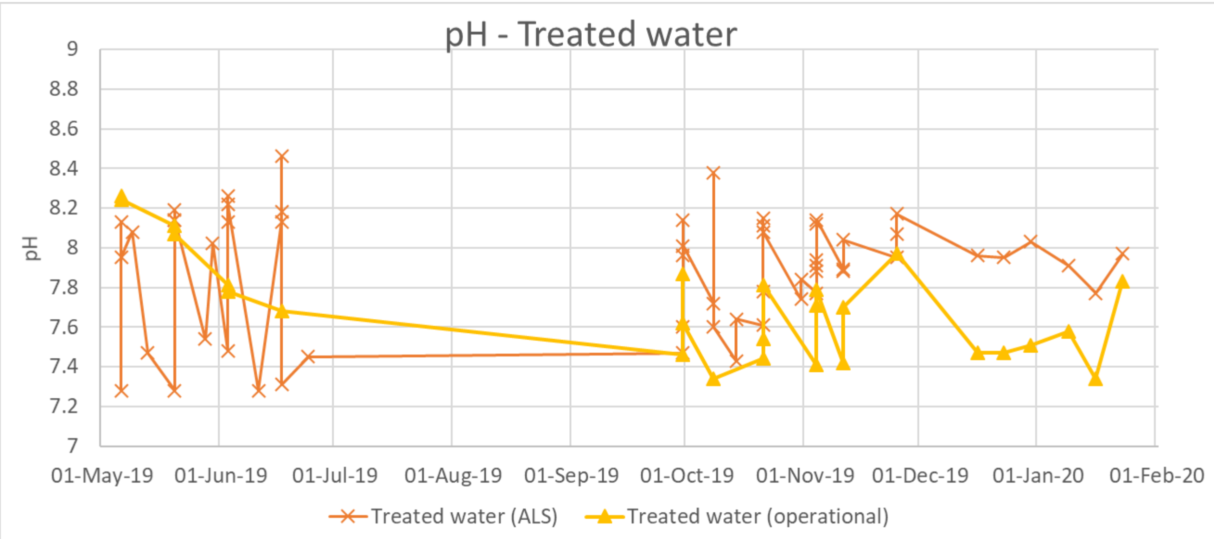

Figure 7 ALS and operational pH results of treated water

Results indicate;

- Operational pH data for raw water is generally slightly lower than the ALS pH data, probably due to differences in pH analyser calibration.
- Operational pH data for treated water is reasonable match to ALS data.

<u>Recommend</u> continue to do ALS measurements and match to Operational data over summer/autumn period.

Memorandum

2.7 MIB & Geosmin

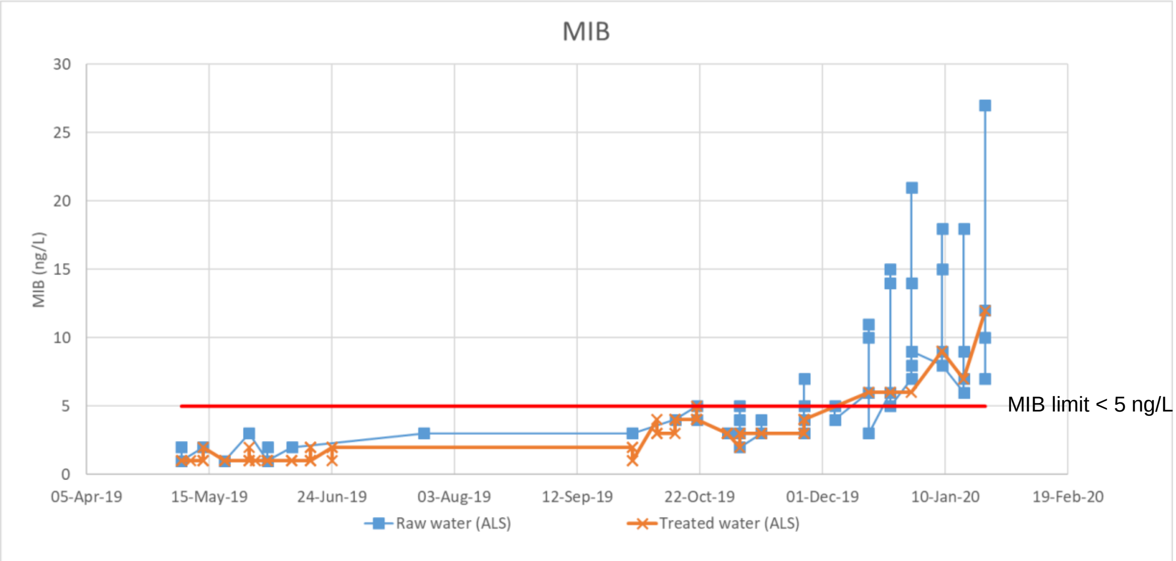

Figure 8 MIB results of raw water (showing depth profile in dam) and treated water

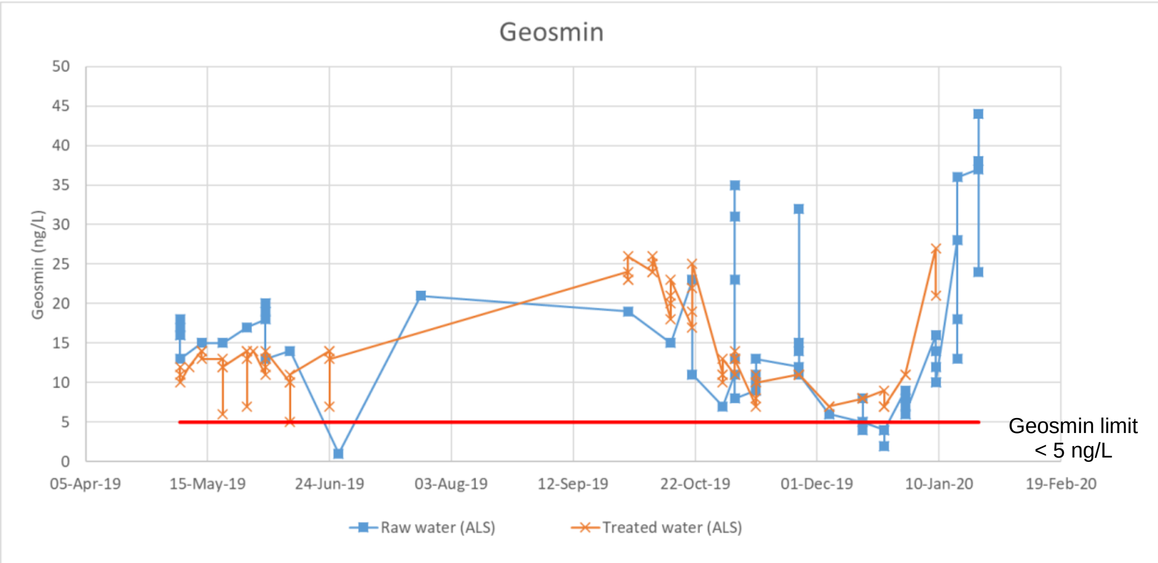

Figure 9 Geosmin results of raw water (showing depth profile in dam) and treated water

Table 2 Range of MIB + Geosmin results for raw and treated water

	Raw water	Treated water
MIB (ng/L)	1 - 27	1 - 12
Geosmin (ng/L)	1 - 44	6 - 66
MIB + Geosmin (ng/L) (on a given day)	4 - 71	7 - 78

Results show;

- That taste and odour is significant compared to targets for "good water quality" of:
  - MIB < 5 ng/L
  - Geosmin < 5 ng/L
  - MIB + Geosmin < 10 ng/L
- Main T&O problem is Geosmin, which is easier to treat using GAC filtration or Powdered Activated Carbon dosing, compared to MIB.

Recommend ongoing monitoring of all current sites for both MIB and Geosmin over the summer/autumn period. It should show the sources of Geosmin.

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2.8 Total Manganese

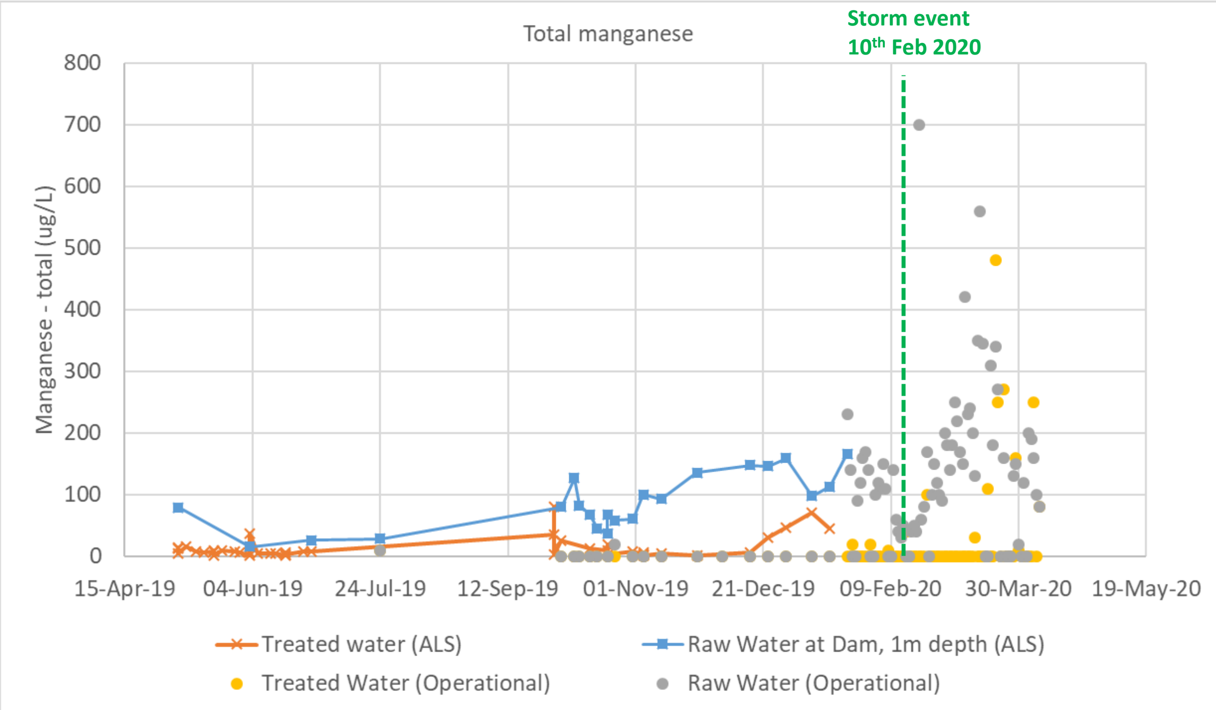

Figure 10 Total manganese results of raw and treated water

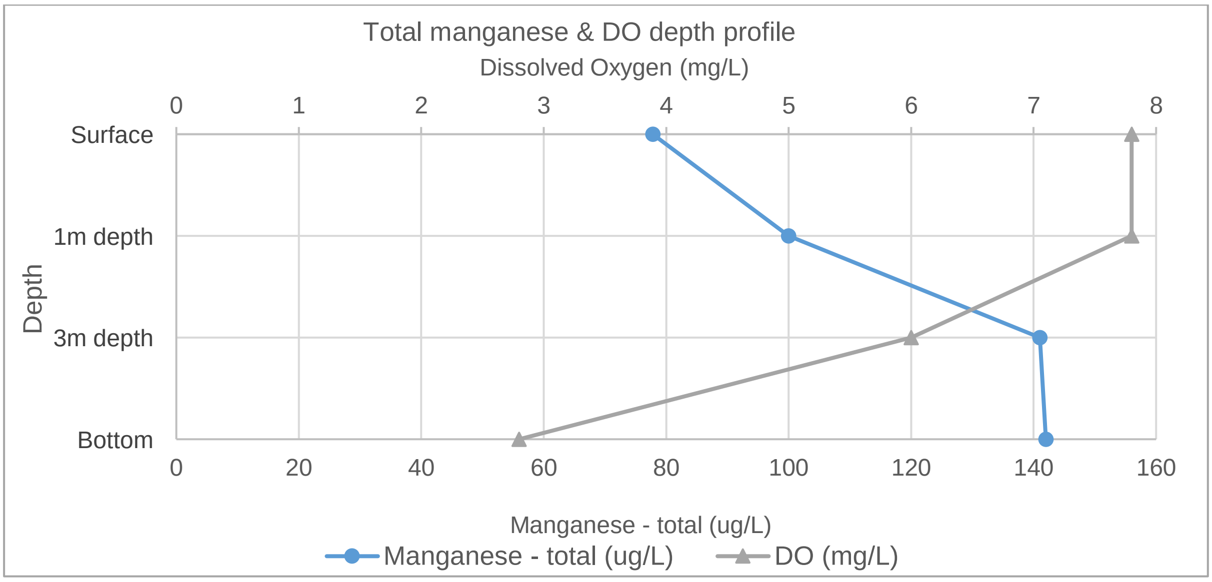

Figure 11 Depth profile of manganese and dissolved oxygen in the raw water supply dam

Memorandum

Table 3 Total Manganese depth profile at Coolumbooka Dam (ug/L)

	Surface	1m depth	3m depth	Bottom
6/05/2019	85.3	79.2	78.8	82.1
3/06/2019	16.3	16	16.4	18.1
27/06/2019		26.3		
24/07/2019		28.3		
3/10/2019	87.7	80.2	106	94.3
8/10/2019	67.9	127	137	
10/10/2019	77.2	82.7	85.9	87.4
14/10/2019	59	68.4	74.7	77.2
17/10/2019	43.2	45.3	107	181
21/10/2019		36.5		29.9
21/10/2019		67.9		29.9
24/10/2019	58.7	58.5	76.7	75.9
31/10/2019	61.8	61	96	175
4/11/2019	77.8	100	141	142
11/11/2019	89	92.9	103	152
25/11/2019	92.4	136	150	174
16/12/2019	150	148	206	490
23/12/2019	107	146	1000	1460
30/12/2019	145	159	186	2430
9/01/2020	98.5	98	890	1490
16/01/2020	73.6	113	1290	
23/01/2020	94.6	166	1650	

Results show;

- Relatively low levels of manganese in the treated water compared to the raw water and that it is removed by the WTP. The main treatment step is likely to be the high prechlorine dose. However, this prechlorine dose is increasing the treated water THM levels and may not be sustainable in the future.
- The depth profile in Figure 11 shows when dissolved oxygen (DO) level is low in deeper water in the reservoir, then the manganese level starts to increase and the manganese is mainly in soluble form, which is harder to treat at this WTP.
- Where both operational data and ALS data for Manganese concentration is available (Oct-Nov 2019), the operational results are significantly lower than ALS testing. Therefore, in the storm even when these operational concentrations jumped to 50-800 ug/L, it can be inferred that the true concentration (if tested by ALS) would have been siginificantly higher again.
- Table 3 shows how Manganese concentrations vary with depth in Coolumbooka Dam. Manganese concentrations increase with depth and therefore there is a potential to get very high Manganese concentrations when water from the bottom of the dam is entrained in the raw water supply pipe. Aeration

Recommend ongoing monitoring of all current sites for Manganese over the summer/autumn period. Aeration of the Dam would encourage mixing, prevent stratification and hence prevent the very high manganese concnetrations being entrained in the raw water pipe.

Memorandum

2.9 Iron

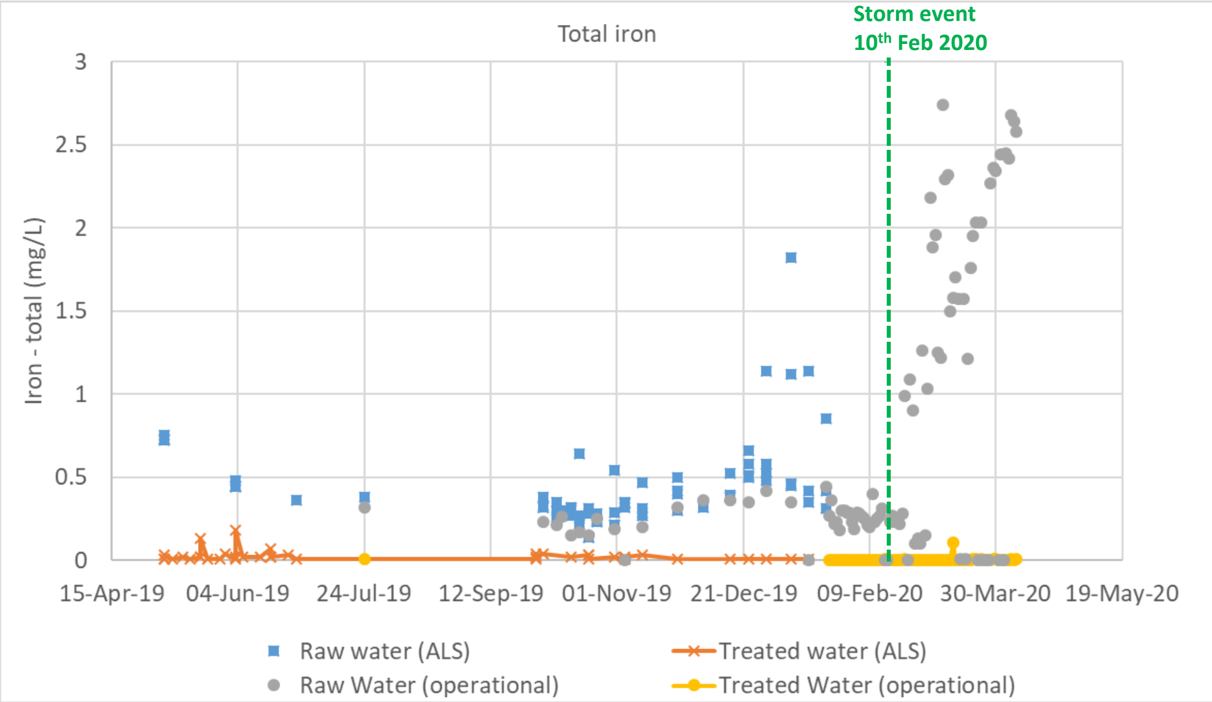

Figure 12 Total iron results of raw and treated water

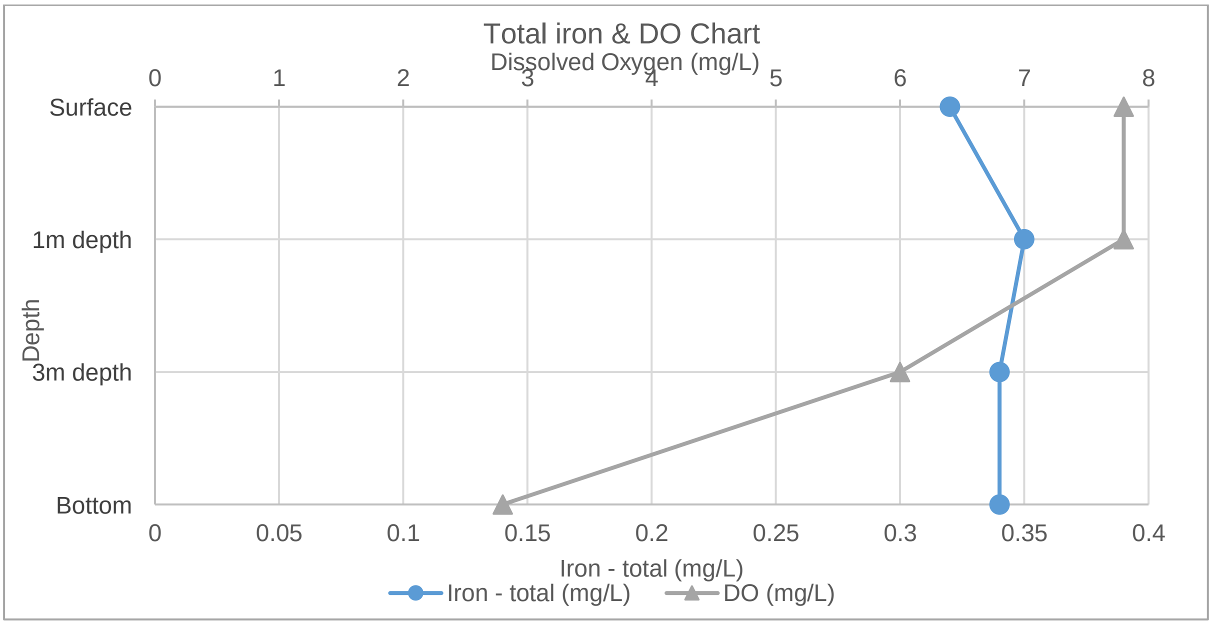

Figure 13 Depth profile of total iron and dissolved oxygen in the raw water supply dam

Results show;

- Relatively high levels of iron in the raw water that are removed by the WTP. The main treatment step is likely to be the ACH plus prechlorine dose. However, this prechlorine dose is increasing the treated water THM levels and may not be sustainable in the future.
- The depth profile in Figure 13 shows when dissolved oxygen (DO) level is low in deeper water in the reservoir, the iron level does not appear to increase due to leaching from sediments
- The operational data for Iron concentraton is similar to results given by ALS testing.

Recommend continue iron measurements by ALS over summer/autumn to confirm if leaching from sediments occurs later in the stratification cycle in the dam and to confirm the effectiveness of the current WTP process for its removal.

Memorandum

2.10 UVT

Results show;

- Treated water has relatively low values of UVT and are consistent with high values for DOC.
- As shown in Figure 14 there is a correlation between DOC and UVT for treated water that is similar for treated water from other systems.
- Based on the current limited data set a design UVT value for UV disinfection process at Bombala WTP would be about 80%. However, this needs to be confirmed by what is measured by ALS over the high demand period over summer.

Recommend continuation of UVT measurements in the same filtered water samples as where turbidity and DOC are measured, as both these can affect UVT measurements.

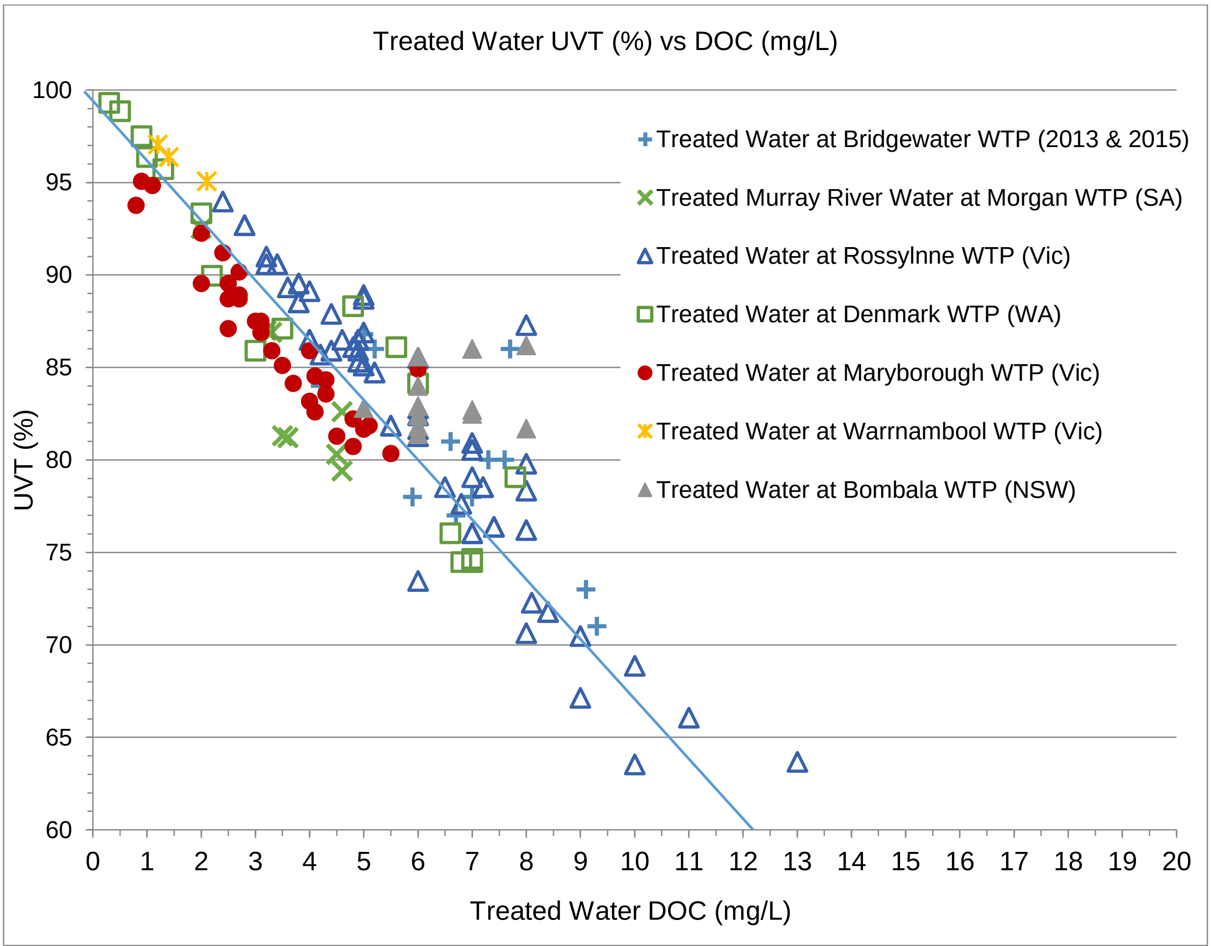

Figure 14 Correlation between UVT and DOC of treated water

Memorandum

2.11 Summary of ALS and Operational Data

A summary of results to date is set out in Table 3. Highlighted values indicate where a large difference between ALS results and WTP Operational results occur. The differences need to be reconciled as considerable time oes into collection and analysis and coding up the more frequent (and important) Operational results.

Table 4 Summary of ALS and operational data for raw and treated water

Parameter	Units	ALS Average	ALS Min	ALS Max	Operational Min	Operational Max
Raw water						
Turbidity	NTU	3.4	1.1	8.4	0.7	3.7
Colour - true	PCU	28.7	22.0	42.0	0	65
pH	-	8.0	6.1	8.7	7.3	8.3
Total alkalinity as $CaCO_3$	mg/L	113	87	316	<1	159
E. Coli	MPN/ 100 mL	13.1	0.5	66	-	-
MIB + Geosmin	ng/L	21	7	65	-	-
Manganese - total	ug/L	226	16	2430	<20	700
Iron - total	mg/L	0.4	0.1	1.8	0	2.7
Treated water						
Turbidity	NTU	0.4	0.1	2.4	0.01	0.52
Total trihalomethanes	ug/L	220	130	310	-	-
Total alkalinity as $CaCO_3$	mg/L	136	76	167	-	-
pH	-	7.89	7.28	8.6	7.3	8.3
E. Coli	MPN/ 100 mL	No data	No data	No data	-	-
MIB + Geosmin	ng/L	16.7	6.0	29.0	-	-
Manganese - total	ug/L	14.82	43	81	-	-
Iron - total	mg/L	0.03	0.01	0.18	-	-
UVT	%	82.8	76.1	87	-	-

Memorandum

3 Conclusion and Recommendations

3.1 Conclusion – Raw Water

- Operational data is significantly lower for raw water quality compared to ALS data for:
  - Turbidity
  - True colour
  - pH
- This seems to be due to the operational sample point being at the WTP not at the reservoir. That is, results are affected by prechlorine and perhaps ACH dosing.
- Generally, this raw water has high values for:
  - True colour
  - MIB & Geosmin
- E. Coli levels are consistent with category 3 of the HBT guidelines in that levels greater than 20 MPN/100 mL occur. The recent ALS E. Coli results (Jan 2020) confirm the previous NSW Health E Coli results (Jan 2019), both of which show E. Coli at >20 MPN/100 mL.

3.2 Conclusion – Filtered Water

- Filtered water turbidity results, based on ALS data, would also fail the HBT criteria for Log Removal Value for protozoans, bacteria and virus for the clarification/filtration process. That is, to achieve LRVs requires filtered water turbidity to be <0.3 NTU for 95% of data and all data to be <1 NTU.

3.3 Conclusion – Treated Water

- MIB and Geosmin in the treated water give combined results of 7-78ng/L, which is significantly greater than the recommended 'good water quality' Taste & Odour limit of MIB+Geosmin <5ng/L
- THMs are very high and above the ADWG limit of 250 ug/L.

3.4 Recommendations

- Investigate and rectify why the raw water turbidity, true colour and alkalinity levels are so different between the ALS data and the Operational data.
- Continue all aspects of this sampling progmram. This is recommended to:
  - Confirm the high THM levels over summer/autumn period.
  - Confirm operational data which shows a significant increase in Manganese and Iron in the stratified dam. Soluble Manganese removal at the WTP may not be as effective.
  - Confirm that MIB and Geosmin increase over summer due to algae and/or stratification of the dam.

Memorandum

Regards

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Principal Engineer Water Treatment and Desalination

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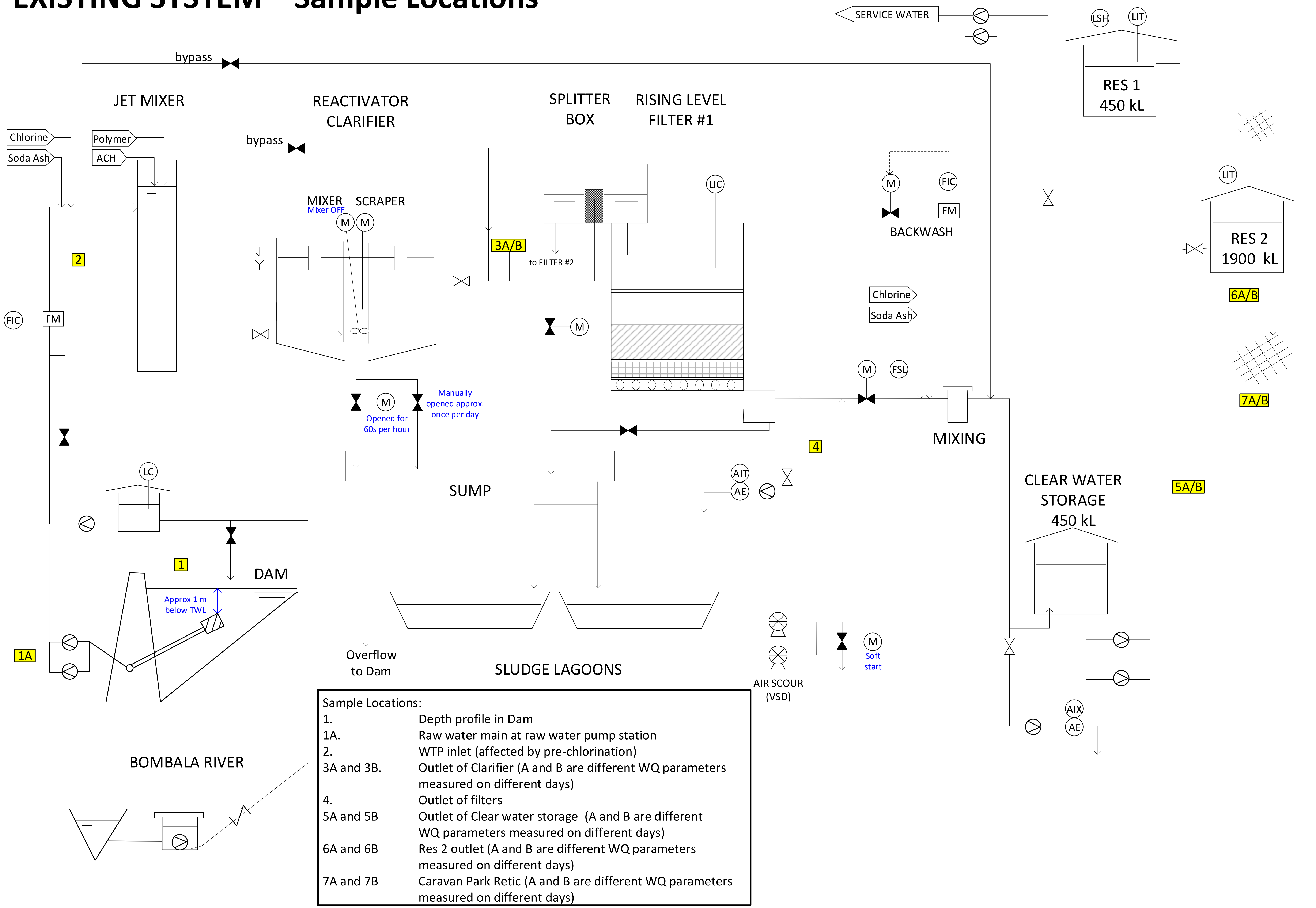
EXISTING SYSTEM – Sample Locations



Sample Locations:

1.	Depth profile in Dam
1A.	Raw water main at raw water pump station
2.	WTP inlet (affected by pre-chlorination)
3A and 3B.	Outlet of Clarifier (A and B are different WQ parameters measured on different days)
4.	Outlet of filters
5A and 5B	Outlet of Clear water storage (A and B are different WQ parameters measured on different days)
6A and 6B	Res 2 outlet (A and B are different WQ parameters measured on different days)
7A and 7B	Caravan Park Retic (A and B are different WQ parameters measured on different days)

Appendix D – Bombala Operational Monitoring Data for recent 2020 wet weather event

Refer following page

			METERED	METERED	METERED						METERED		METERED				METERED										METERED		
																over 8.5	under 0.5										over 1.0		
Process		Raw Water	Raw Water	Raw Water	Raw Water	Raw Water	Raw Water	Raw Water	Clarifier	Clarifier	Clarifier	Clarifier	Clarifier	Clear Water Reservoir	Clear Water Reservoir	Clear Water Reservoir	Clear Water Reservoir	Flash Mixer	Flash Mixer	Flash Mixer	Clarifier Sludge Blanket	Clarifier Sludge Blanket	Reservoir 1	Reservoir 1	Reservoir 1	Reservoir 1	Filters	Filters	Filters
Critical Control Points																CCP2	CCP2										CCP1		
Parameter		Colour	Turbidity	pH	Temperature	Alkalinity	Fluoride	Aluminium	pH	Cl2	Turbidity	Colour	Temperature	Colour	Turbidity	pH	Cl2	Turbidity	pH	Colour	Settling Rate	Settling Rate	Colour	Turbidity	pH	Cl2	Turbidity	pH	Colour
Units		Hu	NTU		°C	mg/l	mg/l	mg/l		mg/L	NTU	Hu	°C	Hu	NTU		mg/L	NTU		Hu	ml	ml	Hu	NTU		mg/L	NTU		Hu
Target (less than)											1.5	5		5	0.3			1.5		15			5	1			0.3		5
Target (greater than)									7	2						7.5	1		7						7.5	1.5		7.5	
Adjustment (less than)																	0.8												
Adjustment (greater than)									7.6	3	2.5	10		10	0.5	8.3	2.5	3	7.6	25			10	3	8.3	2	0.5	7.8	10
Critical (less than)																	0.5									1			
Critical (greater than)		500	50						8.3	5	3.5	15		15	1	8.5	3	5	8.3	35			15	5	8.5		1	8.5	15
Date	Exceedance	Chart 1	Chart 2	Chart 3	Chart 4	Chart 5	Chart 6	Chart 7	Chart 8	Chart 9	Chart 10	Chart 11	Chart 12	Chart 13	Chart 14	Chart 15	Chart 16	Chart 19	Chart 20	Chart 21	Chart 22	Chart 23	Chart 24	Chart 25	Chart 26	Chart 27	Chart 30	Chart 31	Chart 32
1/02/2020		1.00	4.56	7.61	22.50	146.00		15.00	7.35	0.54	0.40	0.01	21.20	0.01	0.26	7.45	2.11	0.71	7.42	0.01	0.00	0.00	0.01	0.58	7.80	1.26	0.05	7.48	0.01
2/02/2020		2.00	2.87	7.92	24.30	137.00		30.00	7.25	0.67	0.48	0.01	24.40	0.01	0.32	7.65	2.09	0.38	7.71	0.01	0.00	0.00	0.01	0.43	7.63	1.18	0.09	7.75	0.01
3/02/2020		1.00	2.55	7.50	21.90	138.00		26.00	7.49	0.45	0.48	0.01	21.20	0.01	0.56	7.66	1.58	0.49	7.46	0.01	0.00	0.00	0.01	0.43	7.67	1.20	0.08	7.69	0.01
4/02/2020		1.00	2.74	7.69	21.40	151.00		28.00	7.34	0.37	0.47	0.01	20.40	0.01	0.48	7.89	2.05	0.72	7.52	0.01	0.00	0.00	0.01	0.61	7.96	1.37	0.07	7.50	0.01
5/02/2020		1.00	2.53	7.59	21.20	136.00		24.00	7.37	0.63	0.59	0.01	20.00	0.01	0.74	7.68	1.19	0.81	7.44	0.01	0.00	0.00	0.01	0.68	7.67	1.58	0.03	7.40	0.01
6/02/2020		1.00	3.27	7.68	22.10	150.00		12.00	7.35	0.68	0.63	0.01	19.10	0.01	0.86	7.65	2.35	0.72	7.48	0.01	0.00	0.00	0.01	0.75	7.51	1.10	0.05	7.08	0.01
7/02/2020		2.00	2.69	7.60	20.50	147.00		18.00	7.25	0.55	0.29	0.01	18.80	0.01	0.23	7.75	2.15	0.39	7.58	0.01	0.00	0.00	0.01	0.57	7.89	1.83	0.13	7.78	0.01
8/02/2020		2.00	2.31	7.63	20.40	144.00		21.00	7.33	0.75	0.54	0.01	19.90	0.01	0.28	7.58	2.21	0.45	7.50	0.01	0.00	0.00	0.01	0.45	7.74	1.55	0.01	7.47	0.01
9/02/2020		1.00	2.74	7.61	18.90	152.00		23.00	7.28	0.68	0.21	0.01	19.60	0.01	0.17	7.76	2.22	0.47	7.58	0.01	0.00	0.00	0.01	0.61	7.86	1.47	0.07	7.32	0.01
10/02/2020		1.00	3.19	7.53	19.50	136.00		6.00	7.32	0.42	0.42	0.01	19.50	0.01	0.34	7.71	2.46	0.38	7.43	0.01	0.00	0.00	0.01	0.23	7.97	1.02	0.07	7.39	0.01
11/02/2020	Exceedance	1.02	19.10	7.11	20.60	0.00		311.00	7.21	0.08	2.48	0.01	18.30	0.01	0.10	7.60	1.88	1.26	7.30	0.01	0.00	0.00	0.01	0.60	7.20	0.48	0.08	7.34	0.01
12/02/2020	Exceedance	47.00	8.04	6.97	21.40	35.00		216.00	6.77	0.06	1.10	0.01	18.60	0.01	0.44	7.33	0.10	0.95	7.38	0.01	0.00	0.00	0.01	0.30	7.58	0.11	0.10	6.98	0.01
13/02/2020	Exceedance	125.00	10.30	6.80	20.40	27.00		215.00	6.68	0.15	1.96	0.01	21.70	0.01	0.74	7.36	0.92	1.77	6.61	0.01	0.00	0.00	0.01	0.41	6.81	0.23	0.16	6.59	0.01
14/02/2020	Exceedance	135.00	12.20	6.84	21.00	46.00		246.00	6.71	0.09	2.46	0.01	20.10	0.01	0.77	7.35	1.29	2.32	6.83	0.01	0.00	0.00	0.01	0.37	7.01	0.58	0.32	6.79	0.01
15/02/2020	Exceedance	46.00	5.27	7.15	21.10	42.00		146.00	6.63	0.20	2.65	0.01	22.90	0.01	0.81	7.04	0.68	2.31	6.72	0.01	0.00	0.00	0.01	0.86	7.33	0.35	0.67	6.91	0.01
16/02/2020	Exceedance	11.00	2.98	6.76	18.50	29.00		44.00	6.59	0.31	2.91	0.01	21.10	0.01	0.50	6.76	0.53	1.82	7.18	0.01	0.00	0.00	0.01	0.42	7.09	0.21	0.24	6.76	0.01
17/02/2020	Exceedance	123.00	3.14	6.84	18.60	44.00		138.00	6.59	0.21	1.83	0.01	21.30	0.01	0.47	7.22	0.95	1.58	6.85	0.01	0.00	0.00	0.01	0.62	7.06	0.22	0.01	6.64	0.01
18/02/2020	Exceedance	144.00	2.11	6.76	19.10	42.00		166.00	6.68	0.44	2.43	0.01	21.40	0.01	0.45	6.60	0.67	1.63	7.06	0.01	0.00	0.00	0.01	0.47	7.09	0.31	0.03	6.80	0.01
19/02/2020	Exceedance	132.00	0.78	6.83	21.80	59.00		149.00	6.80	0.20	1.93	0.01	20.70	0.01	0.86	7.19	1.21	1.51	6.92	0.01	0.00	0.00	0.01	0.63	7.15	0.74	0.28	6.83	0.01
20/02/2020	Exceedance	133.00	1.88	6.74	19.80	46.00		168.00	6.69	0.22	1.21	0.01	19.20	0.01	0.75	6.88	0.61	1.47	7.07	0.01	0.00	0.00	0.01	0.75	6.88	0.61	0.17	7.00	0.01
21/02/2020	Exceedance	111.00	2.42	6.85	19.00	50.00		150.00	6.68	0.90	1.46	0.01	21.10	0.01	0.86	6.87	0.56	1.44	6.58	0.01	0.00	0.00	0.01	0.93	7.08	0.61	0.21	6.67	0.01
22/02/2020	Exceedance	139.00	2.97	7.11	20.00	52.00		184.00	6.79	0.12	1.84	0.01	18.90	0.01	1.00	7.20	0.60	1.70	6.86	0.01	0.00	0.00	8.00	1.12	7.03	0.92	0.14	6.96	0.01
23/02/2020	Exceedance	149.00	2.49	6.78	21.20	44.00		192.00	6.71	0.11	1.60	0.01	20.50	0.01	1.11	7.10	1.06	1.45	6.61	0.01	0.00	0.00	0.01	1.15	7.15	0.77	0.61	7.00	0.01
24/02/2020	Exceedance	115.00	2.41	6.99	20.50	47.00		128.00	6.59	0.12	2.00	0.01	21.20	0.01	0.61	7.13	2.42	1.64	6.96	0.01	0.00	0.00	0.01	0.99	7.41	0.78	0.33	6.96	0.01
25/02/2020	Exceedance	112.00	4.02	6.88	18.70	60.00		176.00	6.64	0.07	1.87	0.01	21.50	0.01	0.64	6.88	1.02	1.51	6.90	0.01	0.00	0.00	0.01	0.69	7.17	0.52	0.19	7.06	0.01
26/02/2020	Exceedance	148.00	2.00	6.95	20.10	58.00		186.00	6.74	0.07	1.43	16.00	21.60	0.01	0.57	7.32	0.67	1.79	6.73	19.00	0.00	0.00	0.01	0.21	7.21	0.29	0.21	6.76	0.01
27/02/2020	Exceedance	149.00	2.32	6.93	18.70	54.00		191.00	6.64	0.12	2.24	13.00	20.70	0.01	0.54	7.31	0.76	1.81	6.78	11.00	0.00	0.00	0.01	0.63	7.35	0.13	0.25	6.66	0.01
28/02/2020	Exceedance	147.00	2.15	6.91	20.60	59.00		190.00	6.74	0.05	1.49	8.00	19.10	0.01	0.84	7.47	0.49	1.91	6.84	11.00	0.00	0.00	0.01	0.62	7.53	0.11	0.23	6.76	0.01
29/02/2020	Exceedance	148.00	2.53	6.96	20.70	59.00		209.00	6.79	0.05	1.29	9.00	20.10	0.01	0.84	7.35	1.83	1.78	6.69	23.00	0.00	0.00	0.01	0.97	7.53	0.47	0.20	7.15	0.01
1/03/2020	Exceedance	0.01	3.20	7.08	18.90	56.00		71.00	6.73	0.06	1.78	0.01	20.50	0.01	0.91	7.46	1.07	1.47	6.70	0.01	0.00	0.00	0.01	0.85	7.38	0.22	0.13	6.87	0.01
2/03/2020	Exceedance	148.00	2.12	6.85	19.70	84.00		196.00	6.76	0.07	1.57	18.00	20.60	0.01	0.69	7.31	0.83	1.96	6.89	14.00	0.00	0.00	4.00	0.81	7.37	0.63	0.22	6.81	0.01
3/03/2020	Exceedance	139.00	2.89	6.69	18.50	62.00		190.00	6.68	0.06	1.24	4.00	20.50	0.01	0.87	7.21	0.59	1.55	7.01	10.00	0.00	0.00	0.01	0.87	7.39	0.51	0.25	6.81	0.01
4/03/2020		134.00	5.57	7.26	20.30	61.00		208.00	6.80	0.08	0.48	0.01	18.90	0.01	0.41	7.71	1.76	1.26	6.78	0.01	0.00	0.00	0.01	0.94	7.35	1.07	0.10	7.02	0.01
5/03/2020		81.00	5.77	6.94	20.40	74.00		209.00	6.70	0.12	0.27	0.01	20.00	0.01	0.42	8.01	1.66	0.62	6.94	0.01	0.00	0.00	0.01	0.54	7.68	1.02	0.01	6.81	0.01
6/03/2020		112.00	3.97	6.83	20.70	68.00		191.00	6.62	0.12	0.34	0.01	20.10	0.01	0.76	7.60	1.93	0.94	7.12	0.01	0.00	0.00	0.01	0.70	7.44	1.03	0.01	6.90	0.01
7/03/2020		123.00	3.01	7.02	20.00	64.00		180.00	6.71	0.14	0.28	0.01	17.20	0.01	0.48	7.90	1.92	0.86	6.80	0.01	0.00	0.00	0.01	0.92	7.61	1.06	0.01	7.01	0.01
8/03/2020		132.00	4.55	7.12	20.40	65.00		194.00	6.71	0.14	0.27	0.01	18.60	0.01	0.92	7.60	1.63	0.68	6.99	0.01	0.00	0.00	0.01	1.04	7.70	1.01	0.02	6.93	0.01
9/03/2020		128.00	5.85	7.02	18.80	67.00		214.00	6.66	0.14	0.35	0.01	18.50	0.01	0.54	7.20	1.49	0.92	6.80	0.01	0.00	0.00	0.01	1.02	7.44	1.10	0.01	6.82	0.01
10/03/2020		130.00	6.93	7.20	17.80	72.00		227.00	6.69	0.15	0.28	0.01	18.30	0.01	0.70	7.47	2.29	0.87	6.92	0.01	0.00	0.00	0.01	0.91	7.46	1.22	0.01	6.95	0.01
11/03/2020		130.00	4.93	6.92	17.90	68.00		203.00	6.65	0.09	0.33	0.01	18.30	0.01	0.78	7.47	1.21	1.21	7.10	0.01	0.00	0.00	0.01	0.88	7.35	1.55	0.05	6.82	0.01
12/03/2020		126.00	5.36	7.21	16.40	67.00		194.00	7.52	0.06	0.49	0.01	18.40	0.01	0.54	7.38	1.96	0.85	7.18	0.01	0.00	0.00	0.01	0.70	7.14	1.44	0.01	6.83	0.01
13/03/2020	Exceedance	114.00	5.53	7.07	16.80	67.00		204.00	6.82	0.04	0.30	0.01	19.50	0.01	0.40	7.08	1.18	0.94	7.10	0.01	0.00	0.00	0.01	0.43	7.33	0.90	0.01	6.93	0.01
14/03/2020		117.00	4.08	7.07	17.50	66.00		186.00	6.90	0.11	0.32	0.01	17.90	0.01	0.39	8.11	2.02	0.67	7.04	0.01	0.00	0.00	0.01	0.50	7.74	1.18	0.01	7.09	0.01
15/03/2020		114.00	4.58	7.11	16.20	76.00		196.00	6.71	0.12	0.26	0.01	17.00	0.01	0.46	7.79	2.11	0.98	6.86	0.01	0.00	0.00	0.01	0.96	7.74	1.02	0.01	6.95	0.01
16/03/2020		138.00	5.18	7.11	17.20	65.00		234.00	6.92	0.10	0.65	0.01	17.10	0.01	0.75	7.29	1.74	0.63	7.00	0.63	0.00	0.00	0.01	1.18	7.32	1.22	0.01	6.85	0.01
17/03/2020		121.00	4.75	7.55	15.20	70.00			6.66	0.10	0.55	0.01	17.40	0.01	0.73	7.22	1.87	1.27	6.88	0.01	0.00	0.00	0.01	1.36	7.38	1.02	0.01	7.00	0.01
18/03/2020		121.00	4.87	7.25	16.90	73.00			6.15	0.12	0.29	0.01	17.60	0.01	0.66	7.66	1.83	1.06	7.04	0.01	0.00	0.00	0.01	1.70	7.48	1.01	0.01	6.91	0.01
19/03/2020		131.00	4.32	7.23	20.50	70.00			6.35	0.16	0.32	0.01	20.20	0.01	0.98	7.47	2.40	0.88	7.12	0.01	0.00	0.00	4.00	1.54	7.35	1.03	0.06	6.93	0.01
20/03/2020		138.00	4.12	7.20	19.00	65.00			6.81	0.12	0.42	0.01	18.60	0.01	0.91	7.41	1.97	0.95	7.01	0.01	0.00	0.00	4.00	1.46	7.26	1.14	0.01	7.03	0.01
21/03/2020	Exceedance	127.00	5.43	7.01	16.80	68.00			6.79	0.10	0.50	0.01	18.20	0.01	0.97	7.27	0.81	1.29	6.92	0.01	0.00	0.00	0.01	1.55	7.25	0.49	0.01	6.80	0.01
22/03/2020	Exceedance	120.00	4.27	7.11	16.90	83.00			6.76	0.04	0.45	0.01	18.20	0.01	1.71	7.86	1.31	1.31	6.98	0.01	0.00	0.00	2.00	2.86	7.50	1.06	0.17	6.89	0.01
23/03/2020	Exceedance	105.00	4.91	7.04	15.60	68.00			6.95	0.05	0.41	0.01	18.50	0.01	1.18	7.60	1.06	1.44	7.08	0.01	0.00	0.00	0.01	2.92	7.86	0.60	0.11	6.77	0.01
24/03/2020	Exceedance	129.00	4.73	6.96	16.00	82.00			6.95	0.09	0.43	0.01	18.10	0.01	2.21	7.58	1.21	1.16	6.88	0.01	0.00	0.00	0.01	2.63	7.60	1.30	0.10	7.11	0.01
25/03/2020	Exceedance	144.00	4.64	6.80	16.50	74.00			6.95	0.09	0.73	0.01	18.20	0.01	1.79	7.32	1.85	1.56	6.83	0.01	0.00	0.00	0.01	1.91	7.48	1.38	0.01	7.14	0.01
26/03/2020	Exceedance	146.00	4.10	7.13	15.40	75.00			6.76	0.03	0.29	0.01	17.50	0.01	1.80	7.23	1.57	1.13	6.85	0.01	0.00	0.00	0.01	2.05	7.26	1.05	0.32	6.92	0.01
27/03/2020	Exceedance	69.00	4.47	6.70	15.60	73.00			6.79	0.11	0.30	0.01	17.50	0.01	1.47	7.25	1.98	1.44	6.77	0.01	0.00	0.00	0.01	2.11	7.41	1.01	0.04	6.79	0.01
28/03/2020	Exceedance	190.00	5.03	7.42	17.20	83.00			6.81	0.09	0.63	4.00	18.20	36.00	1.62	7.38	1.89	1.66	7.04	28.00	0.00	0.00	44.00	2.56	7.28	0.89	0.14	6.93	13.00
29/03/2020	Exceedance	164.00	3.55	6.77	16.40	87.00			6.53	0.04	0.47	22.00	17.80	43.00	1.45	7.20	0.94	1.04	7.02	28.00	0.00	0.00	40.00	1.98	7.38	0.45	0.01	6.90	11.00
30/03/2020	Exceedance	181.00	3.45	6.91	16.50	81.00			6.78	0.03	0.46	15.00	18.70	20.00	1.30	7.05	2.47	1.01	6.88	30.00	0.00	0.00	39.00	2.82	7.53	1.07	0.32	6.75	6.00
31/03/2020	Exceedance	160.00	3.41	6.89	16.80	91.00			6.70	0.07	0.48	8.00	18.90	24.00	1.66	7.56	2.01	1.19	7.02	13.00	0.00	0.00	35.00	2.09	7.44	1.40	0.03	6.89	0.01
1/04/2020	Exceedance	188.00	3.50	6.93	18.20	67.00			6.73	0.06	0.85	13.00	19.20	21.00	1.54	7.34	1.99	1.08	6.92	20.00	0.00	0.00	32.00	1.91	7.55	1.36	0.11	6.83	2.00
2/04/2020	Exceedance	181.00	3.59	7.31	18.70	76.00			6.69	0.07	0.70	5.00	19.00	25.00	1.17	7.36	2.12	0.94	6.94	14.00	0.00	0.00	23.00	2.04	7.50	0.95	0.11	7.08	0.01
3/04/2020	Exceedance	173.00	3.29	7.15	17.10	79.00			6.70	0.09	0.66	2.00	18.20	15.00	1.35	7.36	2.31	1.13	6.98	13.00	0.00	0.00	20.00	1.65	7.29	1.08	0.21	7.33	8.00
4/04/2020	Exceedance	169.00	2.88	7.13	17.30	76.00			6.76	0.08	0.59	7.00	17.80	17.00	1.63	7.33	1.62	0.80	6.85	8.00	0.00	0.00	25.00	1.61	7.40	0.90	0.01	6.94	0.01
5/04/2020	Exceedance	176.00	3.86	6.94	15.40	77.00			6.69	0.08	0.87	11.00	16.50	23.00	1.73	7.29	1.51	0.81	6.94	7.00	0.00	0.00	30.00	2.12	7.47	0.88	0.06	7.05	0.01
6/04/2020	Exceedance	190.00	3.78	7.28	15.70	80.00			6.76	0.08	1.01	14.00	15.90	23.00	1.57	7.39	1.98	0.77	6.99	15.00	0.00	0.00	39.00	1.93	7.31	0.82	0.13	6.90	1.00
7/04/2020	Exceedance	178.00	3.57	7.25	14.60	83.00			6.51	0.09	1.67	24.00	15.10	33.00	1.57	7.34	1.91	0.75	6.71	16.00	0.00	0.00	46.00	2.32	7.50	0.72	0.01	6.97	3.00
8/04/2020																													

Appendix E - Reservoir Aeration/Mixing Systems

Refer to following page.

AWA conference paper 2007/08

The "Do's and the Don'ts" Experience from Design, Installation and Operation of 13 Large Water Supply Reservoir Aeration-Mixing Systems

Mike Chapman, Manager Water Quality and Briony Rogers, Civil Engineer
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ABSTRACT

Over the past 20 years the authors have designed, installed and, in some cases, developed operating histories of thirteen reservoir air diffuser-based aeration-mixing systems. During risk assessments they have also come across a number of other existing systems, which in some cases have not been effective. The reservoirs varied in size from 40 ML to 100,000 ML, with most in the range of 5,000 ML to 30,000 ML. This paper summarises practical experience in aeration-mixing systems for prevention of manganese and iron leaching from sediments and, in some cases, minimising blue green algae blooms. Design, installation and operational "do's" and "don'ts" are discussed and the water quality effects during operation that were observed in some cases are presented. The paper includes discussion of design rules that work, as well as innovative lightweight concepts for the air diffuser pipes in the reservoir. It also also presents the range in installed costs for several recent installations.

INTRODUCTION

Over the past 20 years the authors have designed, installed and, in some cases, developed operating histories of thirteen reservoir air diffuser-based aeration-mixing systems (see Table 1).

Table 1 Recent GHD Experience with Reservoir Aeration-Mixing Systems

Reservoir	State	Capacity (ML)	Design	Installation & Commissioning	Long-term Operation Review
Glenfern	VIC	40	✓	✓	×
Quiet Lakes	VIC	200	✓	✓	×
Kerrie	VIC	200	✓	✓	×
Running Ck	VIC	210	✓	✓	✓
Campaspe	VIC	240	✓	✓	×
White Swan	VIC	5,000	✓	✓	×
Paluma	QLD	11,800	✓(1)	×	×
Tarago	VIC	20,000	✓	✓	✓
Rosslynne	VIC	25,000	✓	✓	×
Merrimu	VIC	30,000	✓	✓	×
Lal Lal	VIC	60,000	✓	✓	×
Sugarloaf	VIC	90,000	✓	✓	✓
Thomson (stage 1 filling)	VIC	180,000	✓	✓	✓
Upper Yarra	VIC	200,000	✓	✓	
Ross River Dam	Qld	200,000	✓	✓	□
Lancefield	Vic	200	✓	✓	
Bundanoon	NSW	2000	✓	✓	

(1) review performance of existing

During risk assessments they have also come across a number of other existing systems, which in some cases have not been effective.

This paper summarises practical experience in aeration-mixing systems for prevention of manganese and iron leaching from sediments and, in some cases, minimising blue green algae blooms. Design, installation and operational "do’s" and "don’ts" are discussed and the water quality effects during operation that were observed in some cases are presented. The paper includes discussion of design rules that work, as well as innovative lightweight concepts for the air diffuser pipes in the reservoir. The range in installed costs for several recent installations is also presented.

BACKGROUND

Mixing-aeration of large reservoirs has been used to destratify reservoirs successfully in a number of locations around Australia and overseas since the 1960s.

The basic concept of the aeration-mixing systems is the use of unconfined air bubble plumes to recreate the natural mixing process that occurs during the colder months in a reservoir. The following are the key features of the system:

- Air is released from long air diffuser pipes located just above the floor of the reservoir.
- The rising air bubbles entrain water, generating a net water flow rate approximately 50 to 300 times the airflow rate, depending on depth.
- Large circulation patterns over the whole of the reservoir are established, which slowly mix the reservoir, breaking down existing stratification of water temperature and increasing the dissolved oxygen (DO) concentration at the bottom of the reservoir.
- Oxygen is transferred into the reservoir water from the air bubbles and, more importantly, by reaeration of water from the atmosphere as it circulates across the surface of the reservoir.
- Best success, in terms of water quality management, depends largely on:
- Delivering enough air in an efficient manner to generate sufficient water movement to raise the DO concentrations at the floor of the reservoir to > 5 to 6 mg/L all year. If this is not achieved manganese and iron are often leached from the bottom sediments especially over periods from January to May.
- Commencing operation of the mixing-aeration system before extensive release of manganese and iron from anaerobic sediments begins, typically in October – December for reservoirs in Victoria. If the aeration system commences operation after this time it may, for a period, "pump" manganese-rich bottom water into the surface well-mixed zone for a while until oxidation occurs. This oxidation process is relatively slow for manganese (months) and relatively rapid for iron (weeks).
- Delaying aeration start up past about February (for reservoirs in Victoria) risks pumping phosphorous into the surface water zone. However, release of phosphorus from bottom sediments is usually only a risk if DO levels at the bottom fall below 1 mg/L for a month or more.

POTENTIAL BENEFITS

GHD's experience with this technology, when properly operated and of the correct size, shows it is effective for:

- Minimising manganese and iron problems by preventing their release from the bottom waters.
- Preventing phosphorus (algae nutrient) and sulphide and ammonia (noxious gas risk in valve houses under a dam) releases from sediments into the water column.
- Minimising the risk of blue-green algae blooms by maintaining a relatively well-mixed environment that is not conducive to the growth of blue-green algae.
- Reduced short-circuiting of flows into the reservoir.
- Allowing the full depth of the reservoir to be withdrawn from for water supply.

- Allowing lower temperature water to be supplied in summer where near-surface draw is required.
- Possibly reducing evaporation by lowering surface water temperature. This has yet to be measured but in theory, may be 5-10% reduction in evaporation loss

DESIGN CONSIDERATIONS

The following factors need to be considered when designing a reservoir aeration-mixing system:

Air Flow Rate

To achieve adequate mixing, air is pumped to the reservoir floor and released at about 0.5 – 2 L/s per hole via small holes (around 1 to 2 mm diameter) in long air diffuser pipes. The small holes size allows a high pressure drop across each hole. Consequently, if the long air diffuser pipes are located on undulating surfaces at the reservoir bottom there is no significant variation in air flow rate out of holes that are nearer the reservoir surface.

As a rule of 'thumb' for reservoirs deeper than about 15 m, the ratio of water flow rate/free air flow rate is around 150-300 to 1 and sufficient air is needed to:

- Overcome the rate of oxygen depletion over say Nov/March in the stratified near bottom water in the reservoir.
- Mix the reservoir contents within 10 to 30 days.

Air Compressor

Rotary screw air compressors have proven to be the best type of unit for these aeration-mixing applications.

Oil-free air is needed to avoid oil-related contamination of the reservoir water. Air filters with capacity to remove down to 0.01 μm particles (Grade C) provide a satisfactory level of control.

Variable speed drives for air compressors are now available. These allow 'fine tuning' of air flow rates.

Construction

Air diffuser pipes of 15 to 20 m in length are typically used, as these permit uniform distribution of air and are relatively easy to manoeuvre into place when installing and pulling out for inspection. It is difficult to install longer aerators in deep reservoirs.

Small air release holes need to be drilled at regular intervals along the diffuser pipe in the horizontal plane on each side to maximise both stability during air diffuser pipe installation and water entrainment.

A flotation pipe attached to each diffuser pipe enables easy removal for inspection and improves the strength of the structure. When inspection and maintenance is required, say once every 5 to 10 years, the flotation pipe is filled with air to allow the aerators to be floated to the surface.

Air hoses are normally connected at the centre of each air diffuser pipe and flotation pipe. A large hose provides the main supply of air to the diffuser pipe and a small hose is utilised to fill the flotation pipe.

Support legs elevate each pipe system approximately 450 to 600 mm from the bottom of the reservoir to avoid entrainment of the bottom sediments.

Photo 1 ; aeration boom placed at floor of reservoir via boats at lal la

Another design for small reservoirs is to run a floating manifold pipe across the sorage with dropper hoses and diffuser heads at the bottom. This approach was used at Glenfern, Lancefield and Campaspe sites.

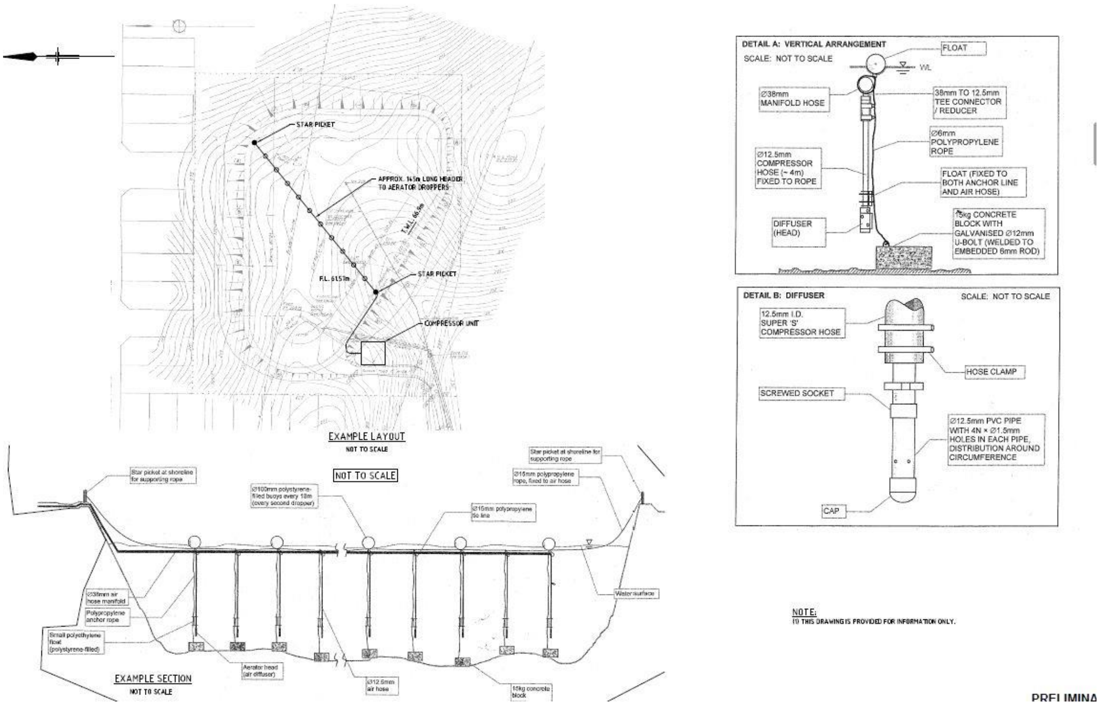

Figure 1; small reservoir aeration/mixing concept

COMMON MISTAKES

GHD's experience has been that mistakes can easily be made in utilising aeration-mixing systems to destratify reservoirs. These errors generally fall into three categories: design, installation and operation.

Design

Incorrect design of an aeration-mixing system will mean the water quality improvements that are expected are not observed.

Air compressor too small

There are a significant number of aeration systems that have not delivered sufficient air to overcome the dissolved oxygen (DO) depletion and raise the DO to > 5 to 6 mg/L at the bottom. This can occur because:

- There was an incorrect understanding of the rate (in kg oxygen/day) of depletion going on in the near bottom water (say > 10m below the surface).
- The aeration started too late in the summer.
- The air diffusers had holes that are too big and all the air came out one end of the long diffuser pipe rather than uniformly along its length.
- The total length of the air diffuser pipes was too short. As a 'rule of thumb' the air flow rate per unit length of air diffuser pipe should be < 0.1 L/s/m.

GHD has had extensive experience in installing aerators to destratify reservoirs of a range of volumes. Examples of the size of compressors recently designed include:

Table 2 Recent GHD aeration-mixing compressor sizes

Reservoir	Design Volume	Compressor Size
Glenfern Reservoir	40 ML	7.5 kW
White Swan Reservoir	10,000 ML	22 kW
Lal Lal Reservoir	36,000 ML	55 kW
Upper Yarra Reservoir	200,000 ML	180 kW (proposed)

Inadequate construction materials

Recent GHD designs have used ABS pipe for the diffusers and flotation pipes (including legs) because of its long life in aquatic environments and its flexibility and impact resistance (minimising the risk of fractures during installation and maintenance).

It should be noted that low DO, sulphides and chlorides in reservoir water can cause rusting of stainless steel that is less than grade 316. Water temperatures >30°C can also result in corrosion of 316 grade stainless steel.

The highest risk element of the aeration system is the connectors holding the air hose to the air diffuser pipe and the straps holding the air diffuser and flotation pipes together. Photo 1 shows the sort of corrosion that can occur to 304 grade stainless steel clips for an aerator installed for only one year.

Photo 1. Corrosion of 304 grade stainless steel

Inappropriate positioning of the diffuser in the water body

The air released from coarse bubble diffuser rises upwards, entraining the water only above the level of the diffuser. There is no mixing of water below the air diffuser pipe. Oxygen transfer below this level is slow, through molecular diffusion.

A common mistake is to locate the diffusers only a few metres below the water surface, resulting in mixing of only the top layers of water, which are naturally well mixed by wind currents and generally high in DO all year around.

It has also been shown on early work that surface aerators are less energy efficient than bottom air diffuser systems.

Installation

The ABS pipes are flexible, so compressed air should be run through the diffuser to reduce weight during installation.

It is also important to minimise the size of air supply hoses, as these can be quite long.

Finally, the ropes connected to the floats and anchors should be carefully designed to avoid tangling during installation.

Operation

The operating strategy for each reservoir varies with experience and climate. Usage tends to increase in hot and low-wind years and decrease in cold and windy years. The critical control is to generate sufficient water circulation to maintain a DO level at the floor of each reservoir of > 5 to 6 mg/L. Installation of a 24 hr/7 day timer to control aerator operating times is essential.

Where manganese and iron control is required, Reservoir aeration-mixing systems in Victorian normally commence operation in October/November to begin mixing before the reservoir begins to stratify. The trigger for starting up the aeration system is typically when the DO level just above the deepest point in the reservoir drops below 5 to 6 mg/L, as measured by fortnightly DO/temperature profile readings.

Where the aeration-mixing system is used for algae control, intermittent operation of the aerator all year in response to detection of high cell counts of blue green algae (say > 1000 to 2000 cells/mL) is required. Normally algae monitoring on a fortnightly to monthly interval is needed to provide sufficient forewarning.

SYSTEM OPERATION AND COSTS

Capital Costs

The capital costs for recent installations ranged from $100,000 for a small system to $500,000 for a large system.

Operating Costs

Annual costs of aeration-mixing systems are directly dependant on the compressor size and the operational hours of the systems.

As an example, a 55 kW compressor was recently installed at Lal Lal Reservoir in Ballarat. The operating strategy presented in Table 3 would result in approximately 2056 hours of usage for the compressor each year.

Table 3 Nominal Operating Strategy for Lal Lal Reservoir (36,000 ML Design Volume)

Month	Nov	Dec	Jan	Feb	Mar	Apr
Days/month	20	31	31	28	31	31
Hours/day	6	12	24	16	6	6

Table 4 Estimated Annual Operating Costs for Lal Lal Reservoir

1	Power consumption of 113,080 kW hrs (55 kW for 2056 hours) per annum @ $0.15 per kW hr	$17,000

1	Power consumption of 113,080 kW hrs (55 kW for 2056 hours) per annum @ $0.15 per kW hr	$17,000
2	Operator visits weekly during operational period @ $70 per hour for 2 hours per week for approximately 20 weeks	$2,800
3	Maintenance, inspections and consumables	$3,000
	Subtotal	$22,800
	TOTAL	Say $22,000 - $24,000 per year

WATER QUALITY

Monitoring for Design

Water quality monitoring before designing a mixing-aeration system is needed to 'fine tune' the design. In particular, the following parameters would ideally be monitored for at least one year:

- Manganese and iron (at say 1 m above the floor of the reservoir) and DO and water temperature profiles, fortnightly over November/March, monthly over October/November and April/June.
- Blue green algae concentration at the surface, every month

The exception is large reservoirs, say > 30,000 ML, where a weather station measures continuous wind speed, air temperature, solar radiation input and thermal/DO patterns in the reservoir. This data is useful, as a more detailed idea of aeration system size can then be determined using DYRESM and/or CADEM hydrodynamic/DO models for deep stratified reservoirs.

Installation of thermistor & DO chains to get continuous monitoring of water temperature and DO profiles is, in the opinion of the authors, unnecessary.

Water Quality Improvements

The aeration-mixing system in Lal Lal Reservoir was installed in December 2006 and started operation at the beginning of January, when the reservoir was already stratified. The purpose of the following discussion is to show how quickly the reservoir was mixed.

Depth Profiles

Figure 2 shows the DO profile of Lal Lal Reservoir. The initial readings showed significant stratification within the reservoir, with bottom DO levels of less than 1 mg/L. Over six weeks of aeration, the reservoir became less and less stratified, until almost uniform DO levels within the water column were achieved.

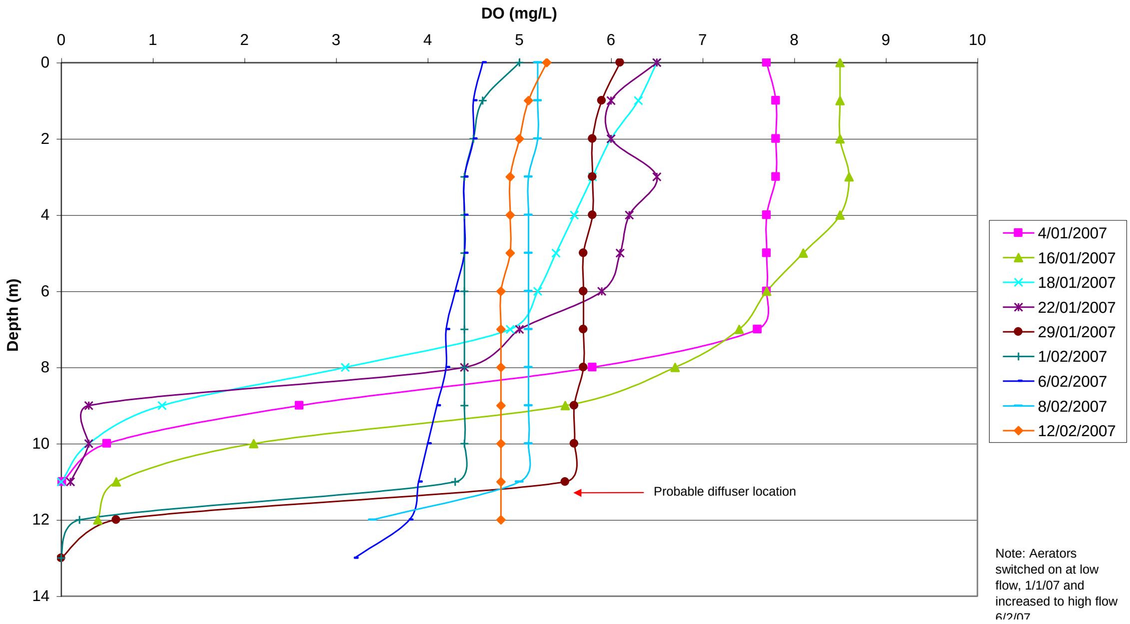

Figure 2. Dissolved oxygen profile

It should be noted that after some time, even the water below the aerator level became oxygenated (i.e. from 1/2/07 to 12/2/07).

Figure 2 shows the changing temperature of the water over time, with representative results at the surface, 5 m depth and 10 m depth.

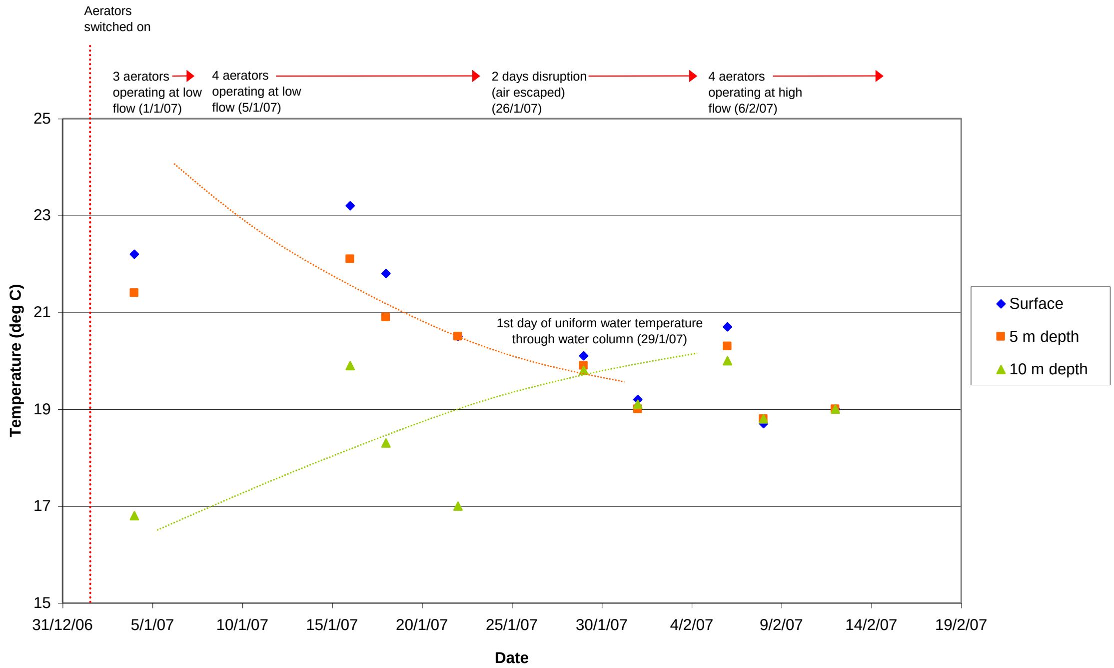

Figure 2. Water temperature over time

The water temperature first became roughly uniform throughout the water column on 29 January, which indicates the time when the reservoir water completed its first turnover. The uniform DO levels on 6 February indicate that by this date the reservoir mixing was complete.

Manganese

Figure 3 illustrates the value of aeration systems in control of manganese.

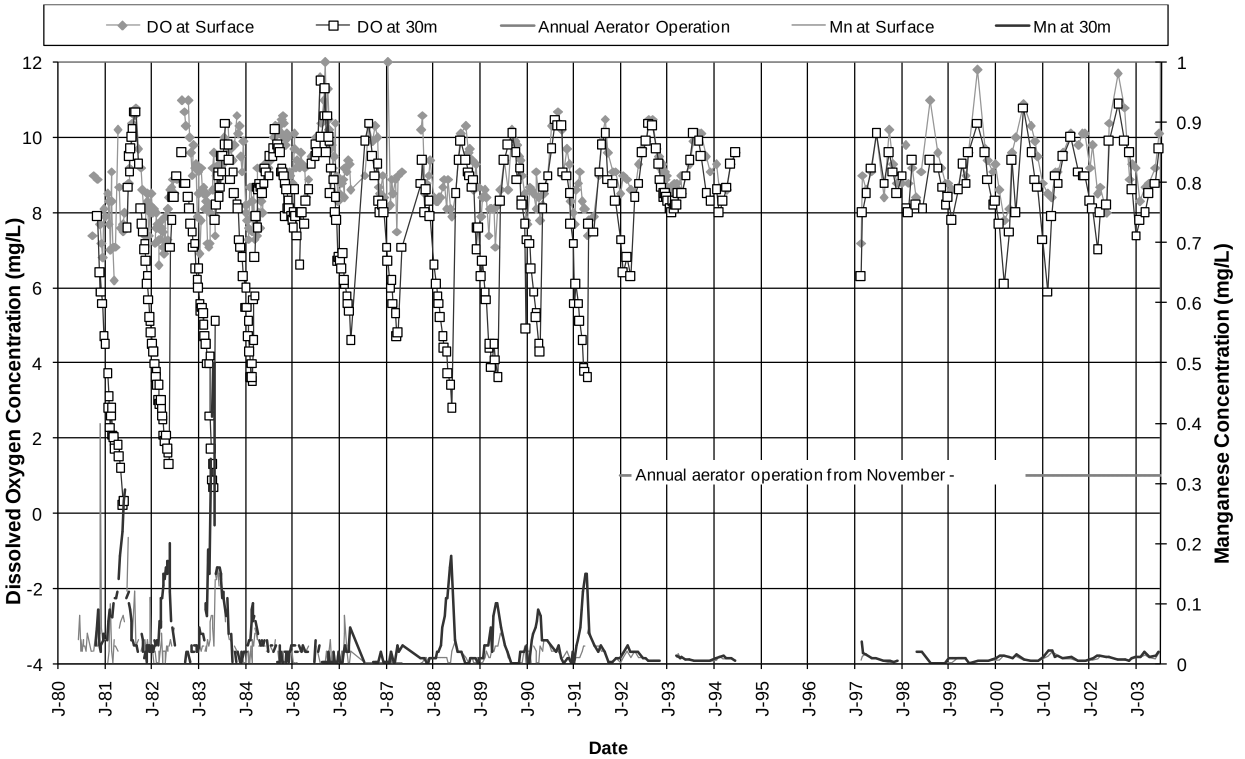

Figure 3. Manganese over time

This time series graph shows the manganese and DO profiles for the 90,000 ML capacity Sugarloaf Reservoir before and after a permanent aeration system was installed at the bottom. The aeration system is operated each year between about November and April/May.

Prior to a permanent aeration system being in place manganese levels routinely exceeded 0.1 mg/L near the bottom (at 30 m depth) and coincided with DO near the bottom (at 30 m depth) falling between 6 mg/L. After installation manganese levels remained < 0.03 mg/L all year.

Blue Green Algae

The example of successful control of blue green algae is at Glenfern reservoirs in the Western water system. Figure 4 shows a time series graph of total blue green algae concentration before and after installation of permanent aeration systems in January 2002.

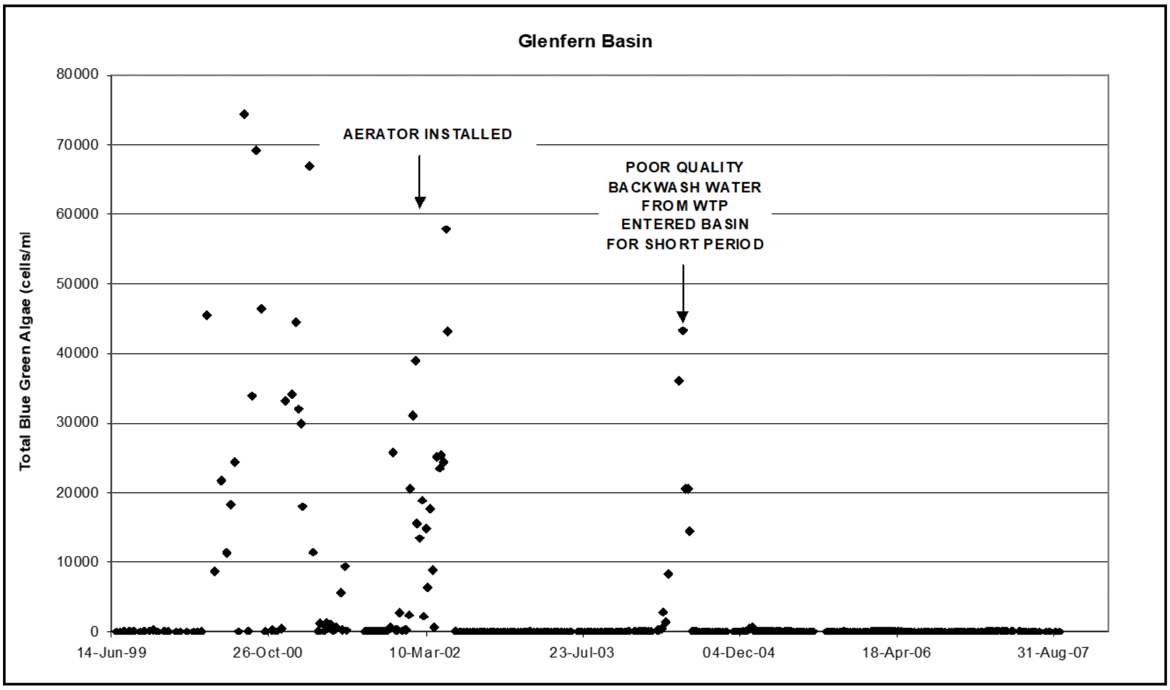

Figure 4. Blue green algae over time

It is, however, important to note that control of blue green algae can be a relatively 'hit and miss' affair. However, the 'rules of thumb' include:

- A significantly larger air compressor than that needed to control manganese is usually needed because more intense mixing is required to produce environmental conditions that discourage the growth of blue-green algae.
- Control in larger reservoirs is more uncertain than smaller ones.
- Control in very shallow reservoirs (say < 3 m deep) is also uncertain.

CONCLUSION

Reservoir stratification over summer often produces water quality problems associated with manganese, iron and blue green algae blooms. In GHD's experience, artificial destratification of such reservoirs through the use of aeration-mixing systems has been an effective way to reduce these water quality risks, provided the systems are sized and located correctly, installed with care and operated with an appropriate strategy.


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Appendix F – Alternative siting location considered for new WTP

Refer to following page

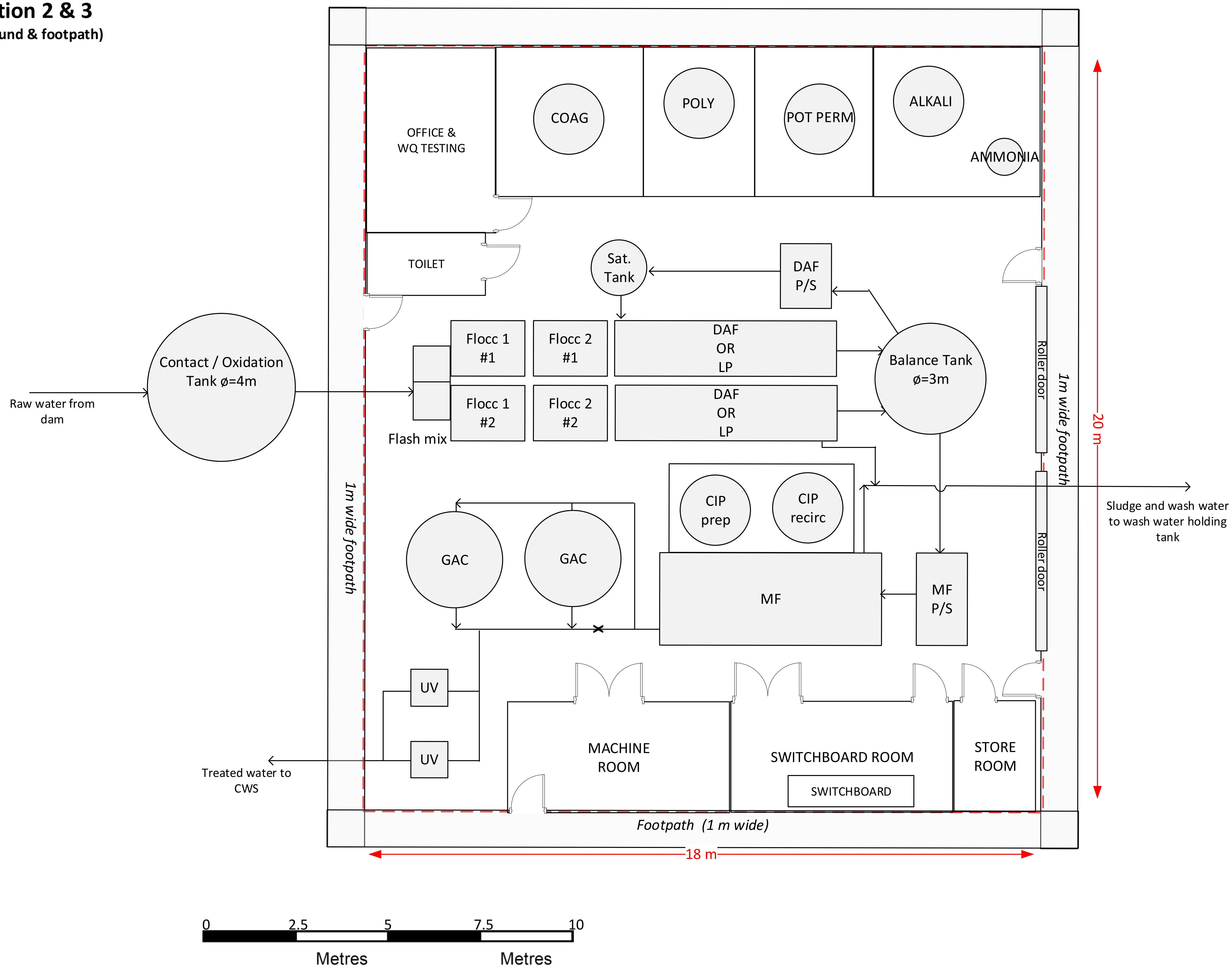
Alternative Siting WTP location

Appendix G – Proposed WTP building layouts

Refer following page

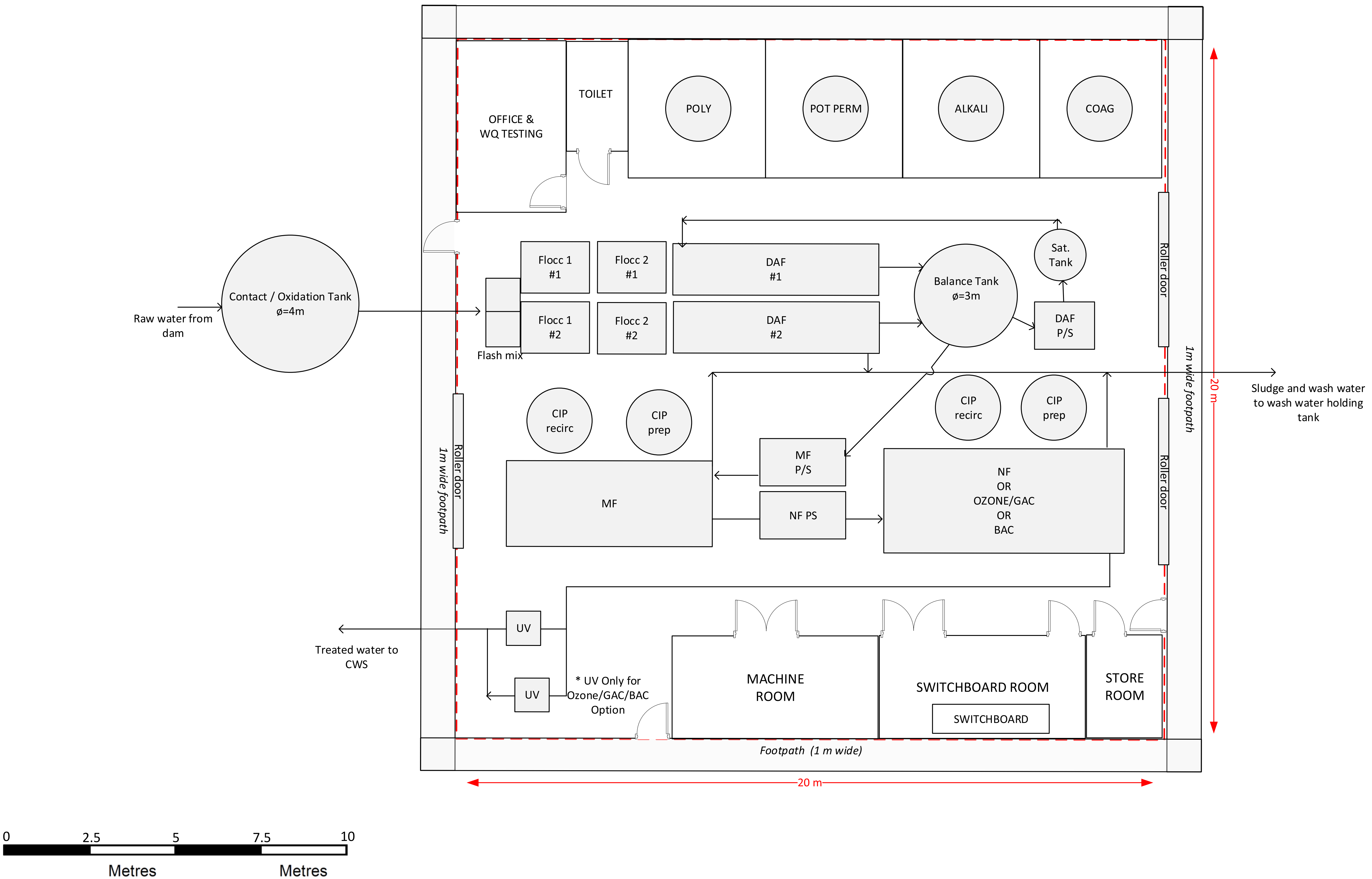
Concept design layout – for preferred site location option 2 & 3

Area: 18 x 20 m (excl. bund & footpath)



Concept design layout – for preferred site location option 4 & 5

Area: 20 x 20 m (excl. bund & footpath)



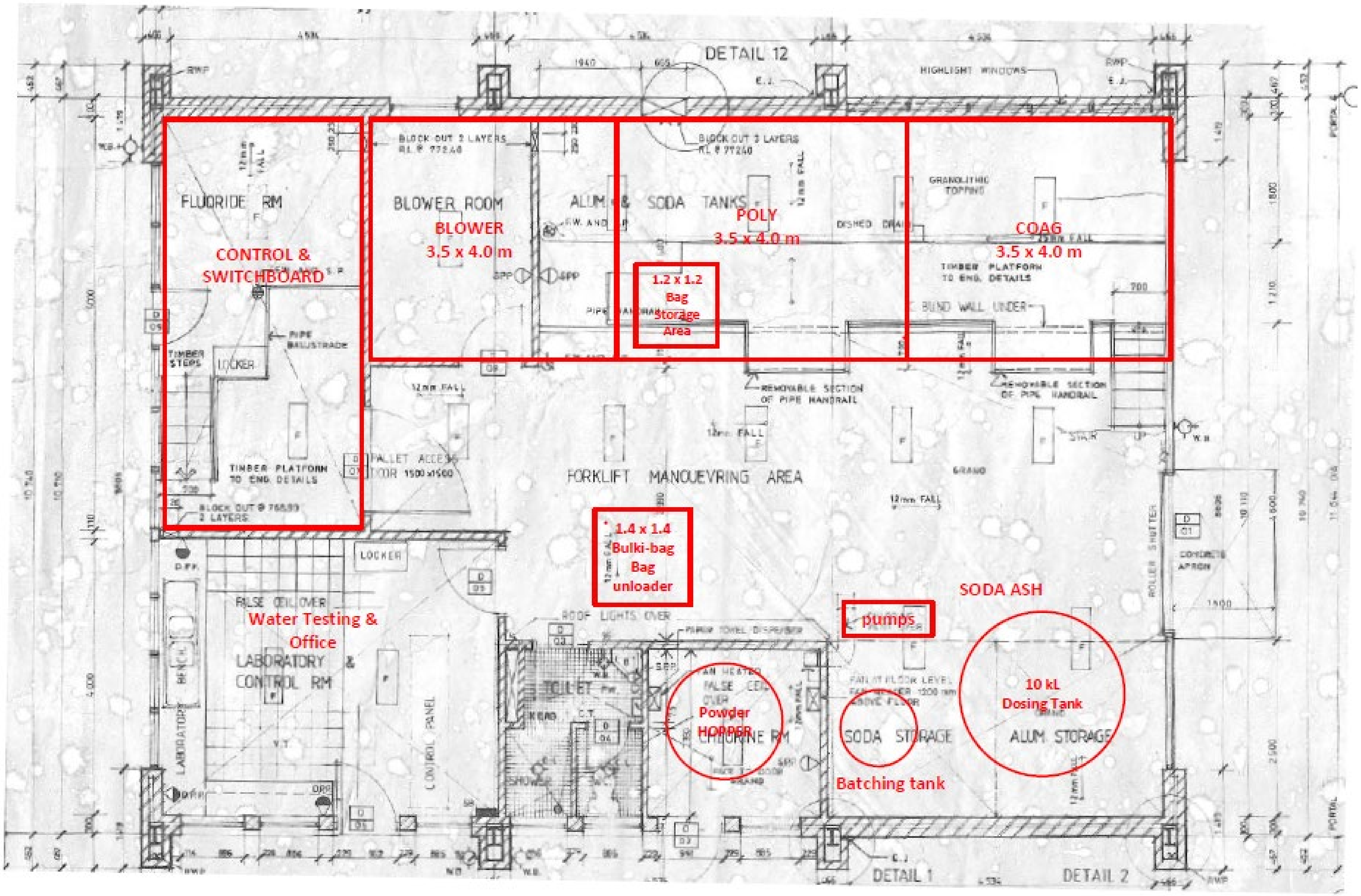


Figure 18 Bombala Control Building Layout for Option 1 (Upgrade existing plant)

Appendix H – Comparison of treatment processes

Refer to following page

Table 13: Comparison of treatment processes based on treatment of contaminants

LEGEND

- preferred process
- optional process

Contaminant Removed	Iron & Manganese	Turbidity and flocc particles	Colour	pH control	Dissolved Organic Carbon	Pesticide chemicals	MIB& Geosmin	Virus	Bacteria	Protozoans	THMs	Algae	Comment
Treatment Process													
Potassium Permanganate	✓✓✓✓												Best at pH >7.5 – 8.5 in high DOC water as if prevents overdose risk
Powder activate carbon					✓		✓✓✓						Best if MIB/Geosmin is intermittent
Alchlor (ACH)		✓✓✓✓	✓✓	✓	✓✓						✓		Not Preferred for high DOC water as does not lower pH and produces poor settling flocc
Alum		✓✓✓✓	✓✓✓✓		✓✓✓						✓✓		Preferred for high DOC water as lowers pH and produces good settling floc
Dissolved Air Floatation (DAF)		✓✓	✓✓✓✓									✓✓✓✓	Best for high colour/low turbidity water and good for confined site
Sedimentation Lamella Plate		✓✓✓✓	✓✓✓										Good for confined site
Sedimentation Reactivator		✓✓✓✓	✓✓										Best for high turbidity water and unconfined site
Gravity Dual Media Filtration	✓✓ (greensand)	✓✓✓								✓			Requires polymer dosing & air scour + water backwash & filter to waste
Microfiltration (MF)		✓✓✓✓	✓							✓✓			Pore size 0.3 – 0.5 µm, lower power
Ultrafiltration (UF)		✓✓✓✓	✓✓							✓✓✓			Pore size 0.1 – 0.2 µm, higher power
Nano Filtration (NF)					✓✓✓✓		✓?			✓✓ ✓(if no bypass)			Get about 50% DOC removal and recovery 85-90%
Nanofiltration (SW)					✓✓✓✓✓		✓?			✓✓ ✓(if no bypass)			Get about 90% DOC removal and recovery 80%
MIEX					✓✓✓✓								Proprietary design & high OPEX risk
Ozone/GAC					✓✓	✓✓✓	✓✓✓✓			✓✓ (if CT correct)	✓✓		ozone mainly for MIB/geosmin & when its present most of the time
GAC/BAC					✓✓	✓✓	✓✓				✓✓		DOC removal drops from 50% to 20-30% over 1 year then drops to 15-25% over 10 year
Chlorine	✓✓							✓✓✓✓	✓✓✓✓		××		Need to have DOC < 4 to 6 mg/L to avoid THMs >250 µg/L
Chloramine								✓	✓✓				Good for avoiding THMs
Caustic Soda				✓✓✓✓									Lower dose required compared to soda ash
Soda Ash				✓✓✓✓									Not a dangerous good
UV Disinfection										✓✓✓✓			Installed power increases a lot as UVT moves from >90% to < 80%
PAX type aeration in Treated water tank											✓✓		Removes about 35% of THM's when water temp <15 deg c

Appendix I – Cost comparison of PAC vs GAC

	PAC	GAC/BAC
CAPEX		
CAPEX	$430,000	$540,000
Site distance	$43,000	$54,000
Subtotal	**$473,000**	**$594**,000
+30%	$142,000	$176,000
CAPEX total	**$635,000**	**$770**,000
O&M		
Power	$700/yr	$1600/yr
PAC Dosing	$7500/yr	-
GAC replacement (every 10 years)	-	$6600/yr
Maintenance (2% MEI&C)	$4000/yr	$3200/yr
Operations	$10,400/yr	$2600/yr
Subtotal	**$26,600/yr**	**$17,200/yr**
+10%	$2660/yr	$1720/yr
O&M Total	**$29,260**	**$18,920**
NPC		
25 years @ 6%	$374,000 $635,000	$242,000 $770,000
NPC	**$1,009,000**	**$1,012,000**

Appendix J – Comparison of DAF and Settling

The following Figure 10.1, based on International Water Treatment experience, shows the normal operating range for a Dissolved Air Floatation (DAF) process. The TOC is related to colour and in turn alum dosage, which adds to the solids load. This figures show that, for water that has a high TOC (or DOC or true colour) and a low turbidity, the preferred treatment process is DAF then filtration. At Bombala the DOC can be up to about 24mg/L and the turbidity is almost all the time <10NTU in all raw water data.

Settling processes, such as the existing reactivator clarifier or lamella Plate clarifier, are not preferred until the raw water turbidity exceeds about 40 NTU (Degremont-Suez). This is consistent with experience by GHD at several plants such as Hamilton in Victoria, where only the combination of high turbidity with high colour caused de-rating of the DAFF process.

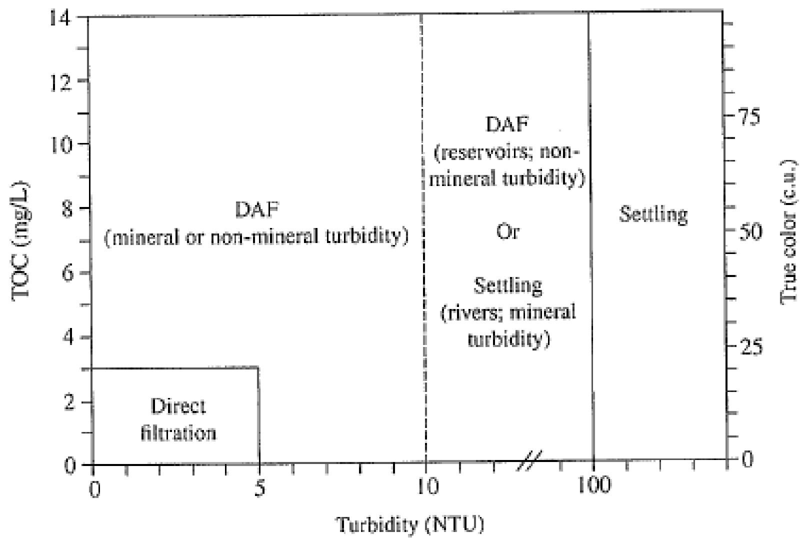


FIGURE 10-1 Process selection diagram based on average raw water quality conditions (*Source: reprinted from Valade et al. (2009), Journal of Water Supply: Research and Technology AQUA, 58 (6), 424–432, with permission from the copyright holder, IWA Publishing).*

Appendix K – THM Stripping System

Refer to following page

CASE STUDY

In-Tank THM Removal System Keeps Water System in Compliance

The Problem

Monterey, California is a seaside town that enjoys cool weather, picturesque beaches and, for the most part, excellent water quality. However, over the last few years, Trihalomethane (THM) levels in the Ryan Ranch part of their system have risen dramatically. Despite aggressively flushing this part of the system and periodically boosting chlorine at the tank to improve residual levels, Monterey was on track to breach their their Total Trihalomethane (TTHM) levels in the summer of 2011.

The Ryan Ranch area is the easternmost part of the Monterey system. While the rest of the Monterey system (closer to the coast) is often shrouded in coastal fog during hot summer days, the Ryan Ranch area is sunny and hot. Furthermore, the 500,000 gallon Ryan Ranch tank receives an average of 100,000 gallons per day of water from three wells in the area. These wells were known to have bromine levels around 70 ppb.

The combination of warmer temperatures and lower turnover had made it difficult to maintain an adequate level of chlorine disinfectant residual. As such, operators had periodically spiked the tank with additional disinfectant and frequently flushed the tank and surrounding system in an attempt to control THMs.

Beginning in 2010, TTHM levels spiked, and the running annual average for the Ryan Ranch system rose dramatically (Figure 1). The dominant THM species was bromoform, “which poses the greatest health risk and is hardest to remove using conventional aeration technologies. Water quality managers calculated that they needed to achieve a TTHM level of less than 50 ppb for the June 2011 measurement for the locational running annual average (LRAA) to remain in compliance. Historical estimates suggested that without a major intervention, TTHM levels were on track to reach 140 ppb by June.

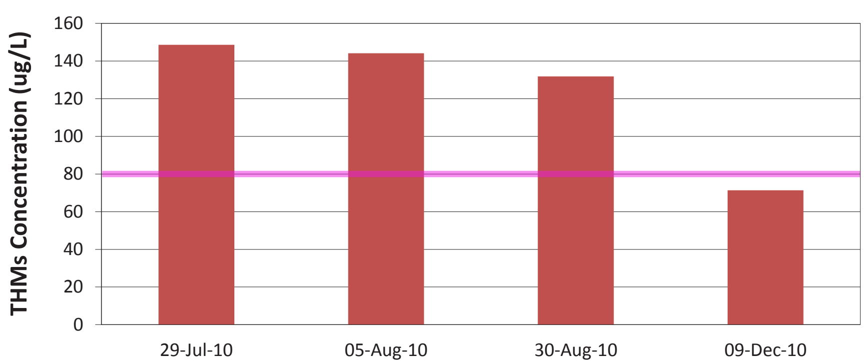


Figure 1. Historic TTHM levels (ppb) per quarter at Ryan Ranch. Locational running annual averages were expected to exceed the Maximum Contaminant Level (MCL) in Q2 2011.

CASE STUDY

In-Tank THM Removal System Keeps Water System in Compliance

The Solution

The precise cause of the dramatic increase in TTHMs in the Ryan Ranch tank were uncertain, but several factors likely contributed to the problem:

1. The combination of high temperatures and low turnover likely led to thermal stratification during some months of the year. Thermal stratification leads to high water age and high rates of residual consumption – both of which can elevate THM levels.
2. The use of source water with high bromine levels likely stimulated the formation of brominated THM species such as bromoform.
3. The tank had been periodically washed out, but it had not been chemically cleaned to remove biofilms. The presence of biofilms and sediment provide additional organic matter that can react with disinfectant to produce DBPs.

Figure 2. The Ryan Ranch tank is a 500,000 gallon steel ground storage tank

Figure 3. Interior conditions of the Ryan Ranch tank prior to TRS.

Operators at Monterey had considered an in-tank aeration system to lower THM levels, but the initial cost estimate they received was not attractive. Complicating the issue was the fact that there was only a limited amount of power available at the Ryan Ranch tank, and a conventional aeration system would have required a substantial electrical service upgrade.

PAX Water Technologies, in partnership with Utility Service Company, proposed a multi-staged approach, using a combination of energy-efficient aeration and mixing, combined with a thorough clean-out of sediment and chemical cleaning of the tank interior. The total system was designed to use less than 30 amps at 120V – and leave power to spare for other systems. The combination of power constraints and the high goal for THM reduction (~60 percent reduction) left no room for error.

In-Tank THM Removal System Keeps Water System in Compliance

The Results

Installation and start-up was completed on June 23rd, 2011, just 5 days before the Q2 compliance sample was to be taken. Figure 4 shows the results of the chemical clean and installation of the PAX mixer.

Figure 4. Interior conditions in the Ryan Ranch after cleanout and installation of the PAX mixer.

On July 11, the staff at Monterey received their results: TTHM levels were measured at 49.2 ppb (~65 percent reduction), which brought their LRAA to just below the Maximum Contaminant Level (MCL). "This result was HUGE", according to Monterey water quality superintendent Leslie Jordan. Subsequent measurements have shown that TTHM levels have remained under control (Figure 4).

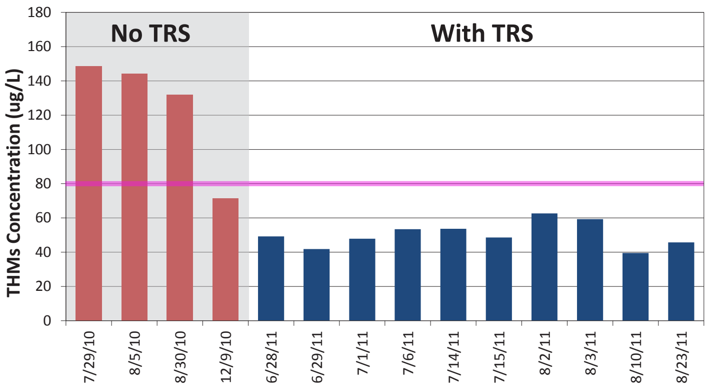


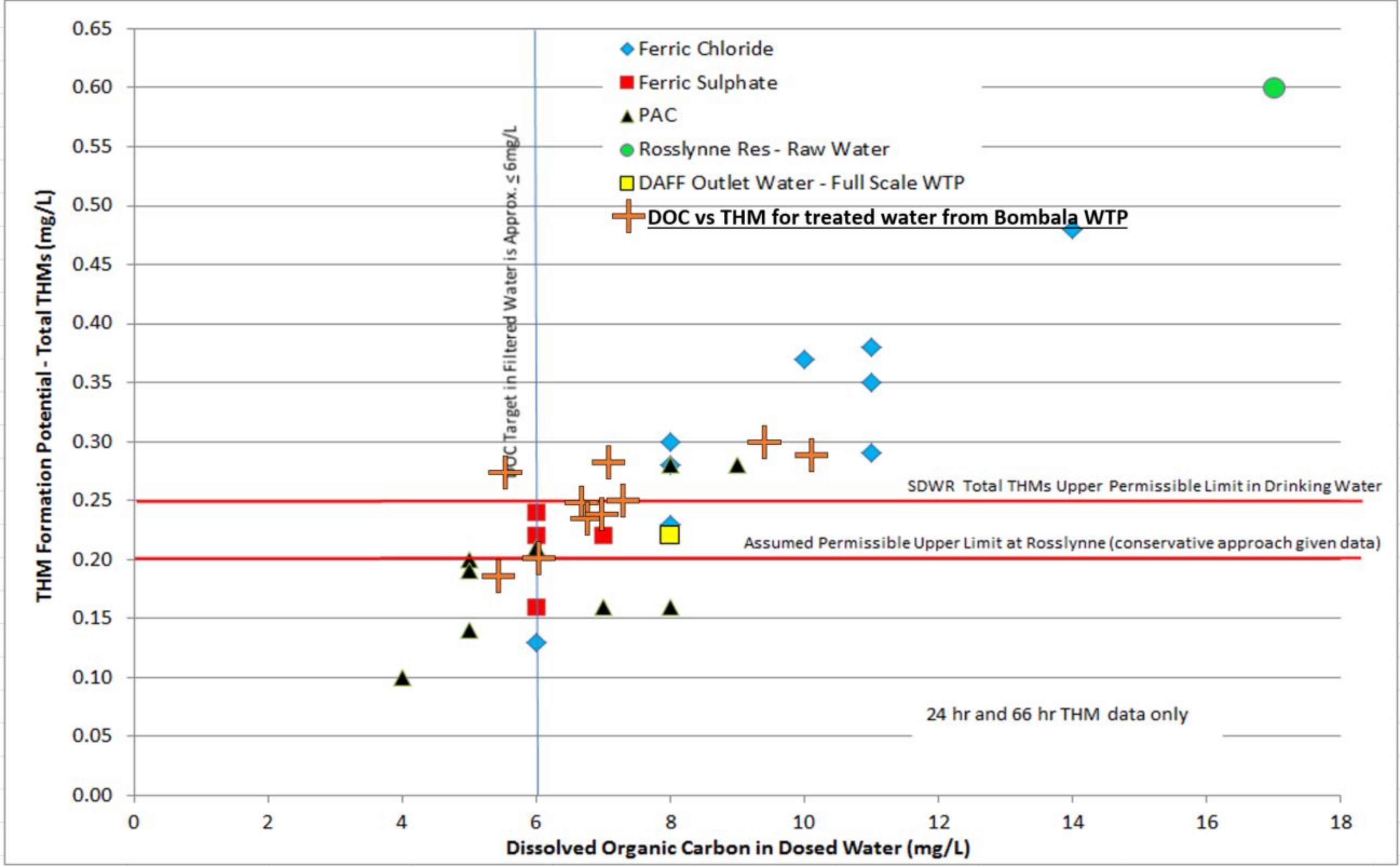
Figure 4. TTHM levels at the Ryan Ranch tank in 2010 (without TRS) and 2011 (after installation of the TRS).

Working Together

It is impossible to know with certainty which parts of the TRS made the greatest contribution to the reduction of THMs at the Ryan Ranch tank. Mixing, aeration and chemical cleaning all likely worked together synergistically to produce the successful results. And, by working together, PAX Water Technologies and Utility Service Company were able to provide a comprehensive and multi-pronged approach to THM reduction that could be implemented quickly.

Appendix L – THM vs DOC relationship

Refer to following page



0.65
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
THM Formation Potential - Total THMs (mg/L)
0
2
4
6
8
10
12
14
16
18
Dissolved Organic Carbon in Dosed Water (mg/L)
Ferric Chloride
Ferric Sulphate
PAC
Rosslynne Res - Raw Water
DAFF Outlet Water - Full Scale WTP
DOC vs THM for treated water from Bombala WTP
DOC Target in Filtered Water is Approx. ≤ 6mg/L
SDWR Total THMs Upper Permissible Limit in Drinking Water
Assumed Permissible Upper Limit at Rosslynne (conservative approach given data)
24 hr and 66 hr THM data only

POWDERED ACTIVATED CARBON USE FOR REDUCING THM RISKS

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INTRODUCTION

For water supply systems that experience periodic high levels of Dissolved Organic Carbon (DOC) associated with pervious storm events or return to average rainfall after extended dry periods the problem of noncompliance with Total Trihalomethanes (TTHM) limits can occur. This paper summarises a recent case study where this has been a problem and how management has been achieved. Pilot scale testing then full scale construction and operation of a new Powdered Activated Carbon (PAC) dosing system at an existing 35ML/d DAFF plant was a successful way to keep DOC levels below the concentration above which excessive levels of THMs are formed following chlorination. For a treatment plant that has enhanced coagulation then DAFF or clarifier/filtration process then PAC dosing can be optimised by use of a online S:CAN or similar multispectral UV monitoring system to enable the correct dose of PAC to be added to maintain treated water DOC below a threshold value above which excessive TTHM levels will emerge after chlorination. Depending on the frequency of high DOC events in the raw water this approach can be a cost-effective option compared to other enhanced DOC removal technologies such as MIEX and Ozone/GAC. This approach also has the added benefit of removal of periodic blue green algae and stagnant water generated Taste/odour chemicals such as MIB and Geomsin.

TRIHALOMETHANE LIMITS IN DRINKING WATER

There is ongoing investigation of disinfection by-products from chlorination of drinking water and there are also different THM limits and components of THMs for drinking water

Table 1. International THM standards and guidelines, adapted from Hrudey (2002). *TTHM = sum of chloroform, bromodichloromethane, dibromochloromethane, bromoform. RAA= rolling annual ave

Country	Guidelines for Disinfection byproduct
Australia	TTHM* (max): 1987: 200 μg/L then 1996: 250 μg/L
USA	TTHM (running annual average) RAA; 1979: 100 μg/L then 1998: 80 μg/L
Canada	TTHM(max);1978: 350 μg/L then TTHM (max), 1996: 100 μg/L TTHM (RAA). Other THM (max)2006: 16 μg/L bromodichloromethane but in 2009 this guideline was withdrawn
WHO	Chloroform (RAA)1984: 30 μg/L, 1993: 200 μg/L, 2008: 300 μg/L .Other THM (RAA)1993: 100 μg/L bromoform then in 1993: 100 μg/L dibromochloromethane and then in 1993: 60 μg/L bromodichloromethane
European Union	TTHM (maximum):1998: 100 μg/L

From this table it is evident that there is a wide range of views around the world on what THM limits and even what species are important. There is also a downward trend in the USA and Canada but a upward trend in Australia and WHO. To achieve compliance with any of these targets would generally require a TTHM level <100ug/L"as a rolling average. This would also tend to mean the maximum TTHM of perhaps <150ug/L.

ENHANCED COAGULATION PLUS PAC DOSING

As part of this study jar test work was also completed to assess what could be done with enhanced coagulation using alum or ferric based coagulants. Optimised DOC removal occurs when the zeta potential is zero. It was found that ferric coagulant operating at a coagulant pH around 4.8 to 5 would achieve this zeta potential. However, DOC removal was still limited. Figure 1 below summarises the findings. It also shows that addition of PAC with enhanced coagulation could further reduce the DOC. The large red dot at the top right hand corner shows the raw water DOC starting point of 18mg/L.

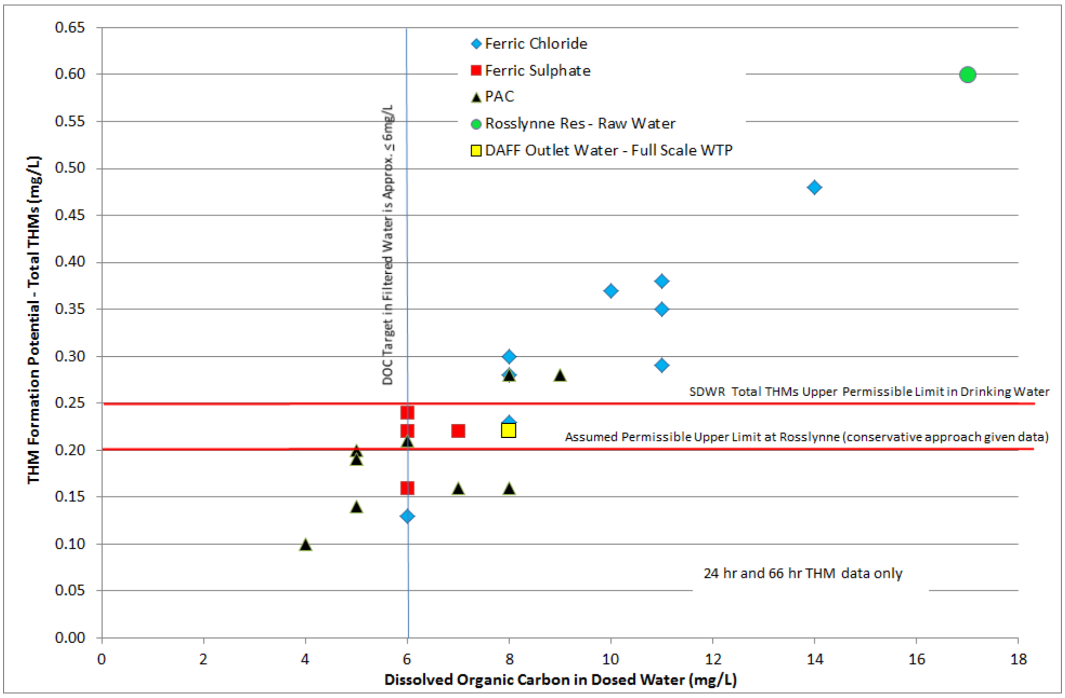


Figure 1: Jar test results for PAC dosing and alternative coagulants

CASE STUDY FOR RETROFITTING PAC DOSING FOR ENHANCED DOC REMOVAL AND TTHM CONTROL

In this case a 35ML/d capacity Dissolved Air Floatation Filtration (DAFF) in Victoria was, after heavy rain flush events following long dry periods, unable to achieve current Safe Drinking Water Act (2005) requirement for TTHM <250ug/L and there was a objective to achieve <150 to 200ug/l in line with the precautionary principle. The problem was that DOC levels in the raw water would rise to >20 mg/L in this soft reservoir water. (see figure 2). With enhanced coagulation using alum at pH6 it was possible to get the DOC down to about 9 to 10mg/L . However, as indicated by the figure below this was not sufficient to achieve TTHM objectives.(refer figure 3)

Figure 2 ; Variation in DOC levels in Supply Reservoir for Case Study No1

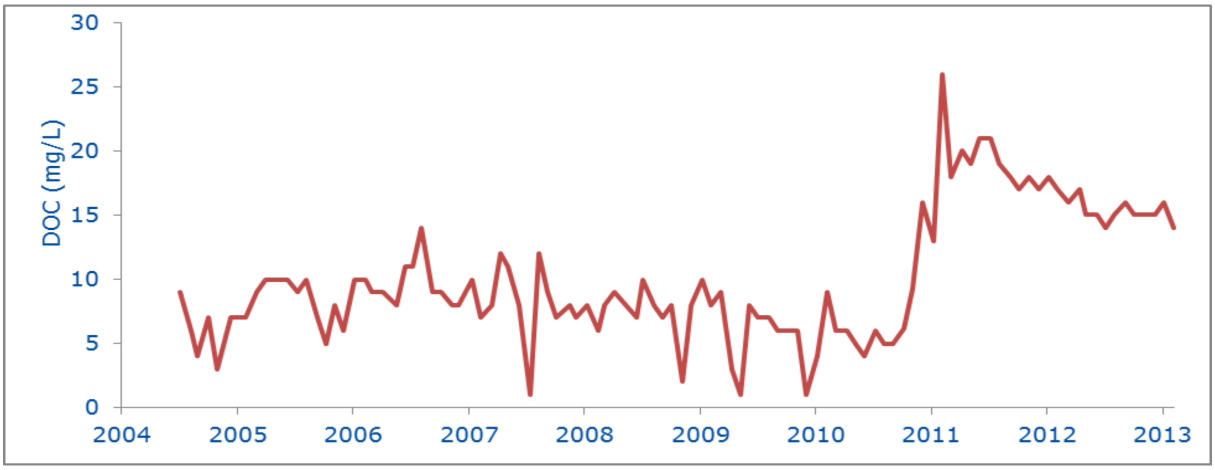
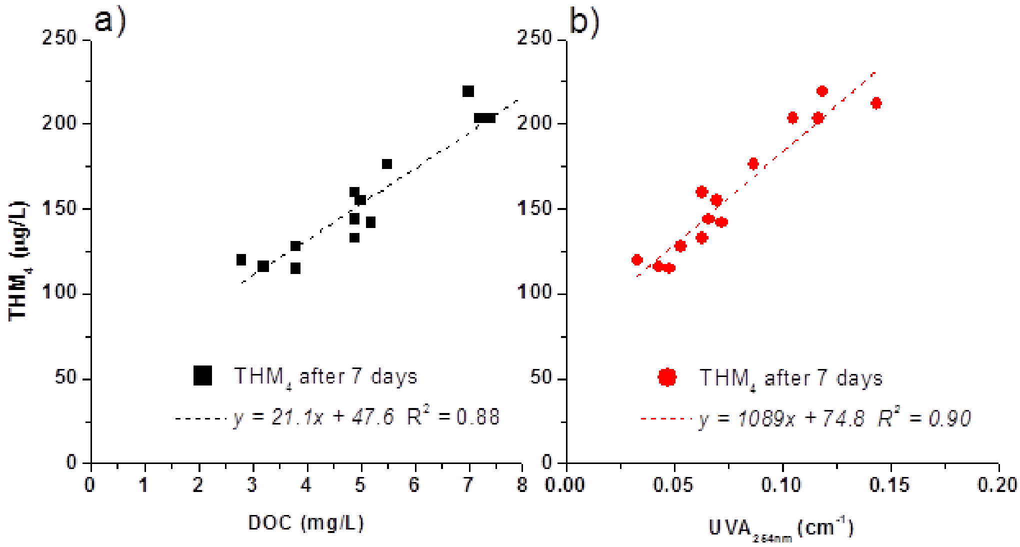
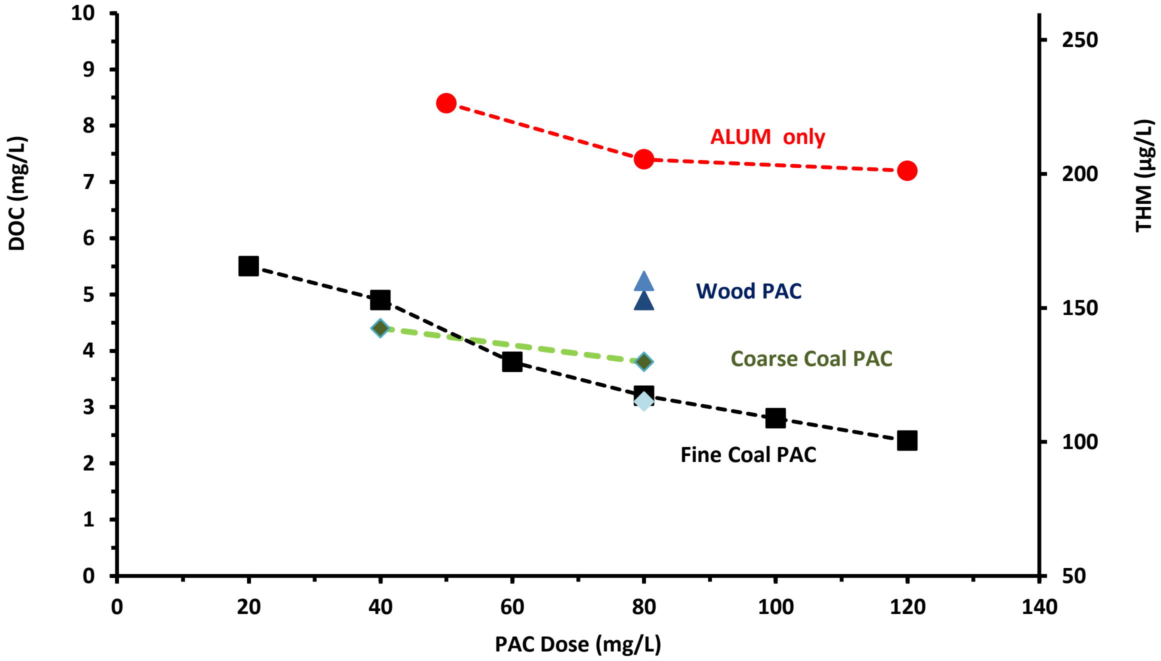


Figure 3 : Relationship between treated water DOC or UVA 254nm on TTHM levels



The next step in this investigation was to determine the relationship between PAC dose and type of PAC product that best suited this water. The raw water DOC was about 18mg/L during the test work. Results of jar tests for this aspect indicated a fine coal based product was best and dose of PAC of about 60 to 80mg/L would be needed to get to TTHM <150ug/L. (refer figure 4).

Figure 4 ; Effect of Alum coagulation only and alum plus various types of PAC on DOC and THMs



The last two issues were (1) what minimum detention time for the PAC prior to alum dose was best and (2) can the DAFF process handle the increased suspended solids load of 80mg/L on top of the suspended solids from the 100 to 150mg/l of alum needed for enhanced coagulation.

Jar test work indicated that a contact time of only about 10minutes was sufficient. Full scale pilot testing by dosing PAC to the inlet main of this DAFF plant showed the DAFF process could handle up to about a PAC around 80 to 100mg/L without excessive reduction in filter run time or derating of the plant capacity and also without elevated filtered water turbidity.

PAC DOSE VERSUS ADDITIONAL DOC REMOVAL

A key determining factor for the cost effectiveness calculation for this simple PAC dosing concept is the relationship between PAC dose and reduction in DOC. As a general rule the R&D work carried out by GHD at a number of sites indicates the following general rules;

Raw Water DOC level	Treated water DOC with Enhanced Coagulation only	PAC dose to get more DOC removal than get from EH only (mgPAC /mg extra DOC removed)	Comment
15 to 20mg/L	7 to 10mg/l	15 to 20	Easier to get extra DOC removed as still some big molecular wt species of DOC remaining
10 to 15 mg/L	5 to 8 mg/L	20 to 30	
5 to 10mg/L	3 to 5mg/L	30 to 40	
<5mg/L	2.8 to 3mg/L	>50	

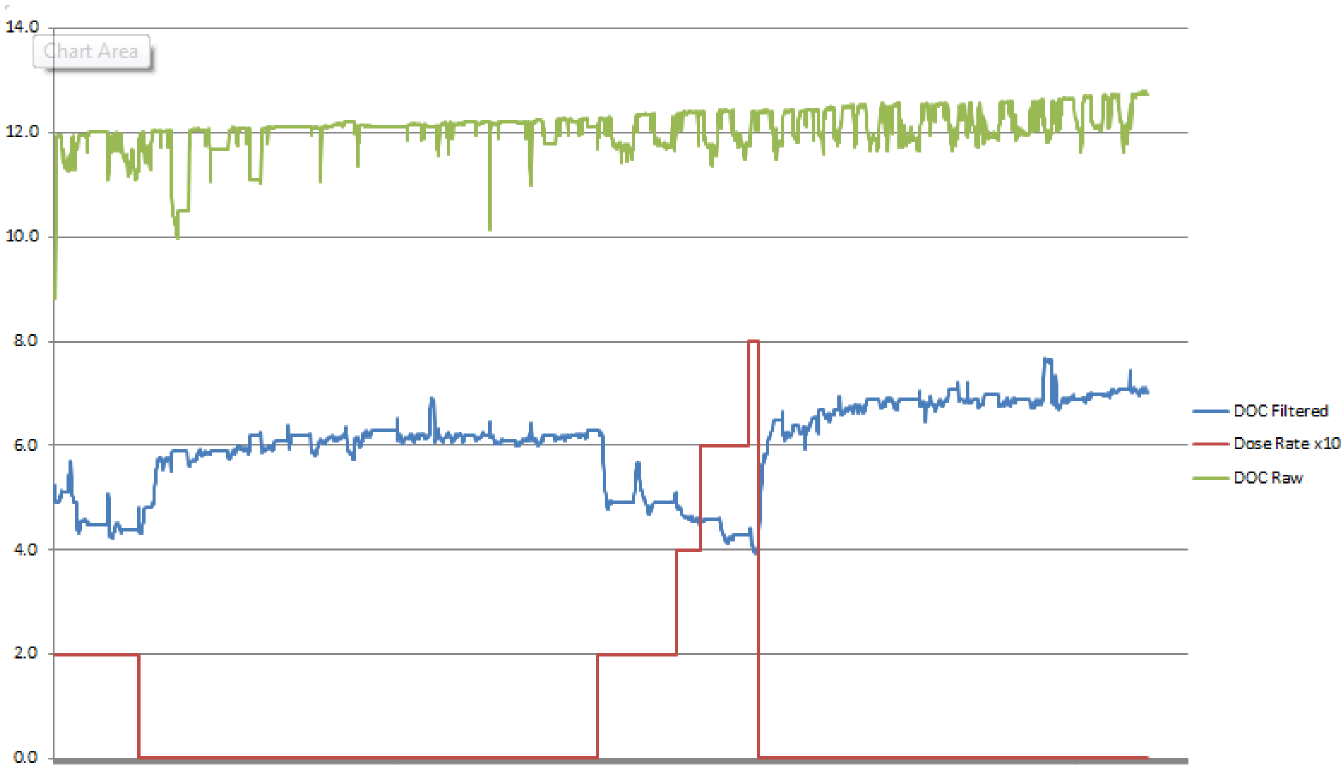
COST

Construction of the PAC dosing system and PAC contact tank for this 35ML/d plant was completed in 2014 at accost of about $1.8m. The supply cost for PAC has been about $2000 to 2500/tonne

Full scale testing at up to PAC dose of 80mg/l with alum dose around 65mg/l has shown ;

- Filter run times >16 to 24 hours running at up to 26ML/d
- A need to raise filter aid polymer dose from about 0.05mg/L to about 0.15mg/L to maintain filtered water turbidity
- The sludge from the process has a poorer drying characteristic probably due to the extra polymer added
- A S:CAN multispectral UV analyser is a reliable operational tool for monitoring raw water DOC and for optimising the PAC dose to achieve the desired final treated water DOC level which is known to maintain TTHM at acceptable level (refer figure 6)..

Figure 6 : Raw and treated water DOC levels and PAC Dose Rate effect on treated water DOC level versus time during 2015 trial at DAFF plant



CONCLUSIONS

For water supply systems with variable raw water DOC levels and traditional treatment including the need for chlorination, there can be conditions that trigger TTHM noncompliance. Installing a suitable size PAC dosing system and reaction tank to dose PAC to the untreated water prior to where coagulant is dosed can be a cost-effective solution. To establish the suitability of a particular water supply system for this solution requires only jar tests, running a temporary PAC dosing system at the full scale plant plus analysis of the long term variation in raw water DOC levels to establish the frequency and duration of high raw water DOC concentration events.

Appendix M — CAPEX and OPEX Estimates

Refer to following page

Bombala WTP Cost Estimate 20/05/2020 Rev0
Options Assessment

					Upgrade existing plant		Clarifier + MF + GAC + Chloramination		DAF + MF + GAC + Chloramination		DAF + MF + Ozone/GAC + Chlorination		DAF + MF + NF + Chlorination		
No.	ITEM	Detail. Note for Existing, Note for New WTP	Rate	Unit	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Qty	Cost	Comment
0.0	**Site Establishment / Preliminaries (10%)**			***Subtotal***		**$ 898,500**		**$ 1,055,000**		**$ 1,027,500**		**$ 1,116,000**		**$ 1,093,500**	
0.1	Mobilisation and demobilisation and contractor margins	Allow 9% of total cost	$ 200,000	No.	2.68	$ 536,000	3.15	$ 630,000	3.05	$ 610,000	3.33	$ 666,000	3.28	$ 656,000	*From Myrniong/Lancefield, Alexandra, Crescent Head, Brogo*
0.2	Design and documentation	Allow 6% of total cost	$ 250,000	No.	1.45	$ 362,500	1.7	$ 425,000	1.67	$ 417,500	1.8	$ 450,000	1.75	$ 437,500	*From Myrniong/Lancefield, Alexandra, Crescent Head, Brogo*
0.3	Planning and approvals			No.	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	*To be undertaken by SMRC*
0.4	Drinking water supply	Drinking water supplied to CWT at a rate of $450/130kL delivered from Cooma	$ 33,000	ML	15	$ 495,000	0	$ -	0	$ -	0	$ -	0	$ -	
1.0	**Site Civil Works**			***Subtotal***		**$ 132,500**		**$ 145,000**		**$ 145,000**		**$ 150,000**		**$ 150,000**	
1.1	Excavation for new treatment plant WTP	Rippable rock assumed	$ 50	m3	350	$ 17,500	400	$ 20,000	400	$ 20,000	500	$ 25,000	500	$ 25,000	*Based on Rawlinsons*
1.2	Removal of existing house		$ 15,000	No.	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	*Crescent head removal of 3 no 30 kL gal tanks was 11k-30k*
1.3	Stormwater drainage works	gutters and pipes	$ 20,000	No.	0.5	$ 10,000	1	$ 20,000	1	$ 20,000	1	$ 20,000	1	$ 20,000	
1.4	New road works to WTP	NEW: 160 m length. EXISTING: bitumen seal on road at steep point where pot holes are to improve truck access to new delivery bund Additional 20 m for access to washwater tank, thickener and supernatant return PS	$ 500	linear m	180	$ 90,000	180	$ 90,000	180	$ 90,000	180	$ 90,000	180	$ 90,000	*Rawlinsons has ~200/m3 (just bitumen) to ~$400/m3 (roadworks). See tab for comparison to Coffs Harbour WTP. Based on single-road concept (Appendix D3)*
1.5	New site security fence and access	Existing fence at site so no works required	$ -	linear m	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	
1.6	Sealed Access Roads	Extended sealed access road beyond site boundary by council	$ -	linear m	0	-	0	-	0	-	0	-	0	-	*Council to provide costing*
2.0	**External Pipelines**			***Subtotal***		**$ 112,000**		**$ 97,500**		**$ 97,500**		**$ 97,500**		**$ 90,500**	
2.1	Sludge pipeline	New sludge pipeline from thickener DN 100 and connection to existing sludge ponds	$ 200	linear m	50	$ 10,000	55	$ 11,000	55	$ 11,000	55	$ 11,000	55	$ 11,000	*Based on Crescent Head + allowance for rock and short length*
2.2	Connection to existing raw water pipeline	DN 200 Supernatant return	$ 600	linear m	15	$ 9,000	35	$ 21,000	35	$ 21,000	35	$ 21,000	35	$ 21,000	*DN 200 since short distance, higher rate /m*
2.3	Connection from the new WTP/ GAC filter to CWS inlet	DN 150	$ 300	linear m	40	$ 12,000	30	$ 9,000	30	$ 9,000	30	$ 9,000	40	$ 12,000	*DN 250; since very short distance, $/m escalated by x3.0*
	Pipeline from CWS to GAC filters	DN 250	$ 500	linear m	30	$ 15,000	0	$ -	0	$ -	0	$ -	0	$ -	
7.4	GAC pipeline from balance tank to CWS	DN 150	$ 500	linear m	40	$ 20,000	20	$ 10,000	20	$ 10,000	20	$ 10,000	0	$ -	*cost per m*
2.4	Isolation valve in sludge pipeline	DN 250	$ 2,000	No.	1	$ 2,000	1	$ 2,000	1	$ 2,000	1	$ 2,000	1	$ 2,000	*Based on Balmoral tenders*
	Washwater tank overflow to sludge pond	DN 200	$ 400	linear m	40	$ 16,000	40	$ 16,000	40	$ 16,000	40	$ 16,000	40	$ 16,000	
2.5	Overflow pipeline from WTP to sludge pond	DN 200	$ 400	linear m	0	$ -	50	$ 20,000	50	$ 20,000	50	$ 20,000	50	$ 20,000	*Existing pipes (old DN100 AC) are not reusable.*
	Pipework from washwater tank to thickener	DN 150	$ 450	linear m	10	$ 4,500	10	$ 4,500	10	$ 4,500	10	$ 4,500	10	$ 4,500	
2.5	Connection to washwater tank	New DN 250 pipe to existing sludge line to new washwater tank	$ 500	linear m	35	$ 17,500	0	$ -	0	$ -	0	$ -	0	$ -	
2.5	Stormwater discharge pipeline from new WTP works	DN100 from building to environment across road	$ 200	linear m	30	$ 6,000	20	$ 4,000	20	$ 4,000	20	$ 4,000	20	$ 4,000	
3.0	**Process Equipment, Tanks and associated pipework in building**			***Subtotal***		**$ 1,450,000**		**$ 2,155,000**		**$ 2,155,000**		**$ 2,155,000**		**$ 2,334,000**	
3.1	Raw water pumps & vsd control	2 no. new 35kw pumps & vsds in existing dry well 2 no. Sump pumps (D/S) Telemetry to WTP & controls 1 no. HLS switch, 2 no. FSL, new Flow meter Switchboard + PLC + lighting for RW pumps	$ 270,000	No.	1	$ 270,000	1	$ 270,000	1	$ 270,000	1	$ 270,000	1.2	$ 324,000	*See other cost estimate for RW pumps*
3.2	UPGRADE TO EXISTING: Clarifier	Replace clarifier internals , add tube settler pack into top of clarifier. Remove everything, prepare surfaces, painting, new internals, rake/draft tube etc, new inlet pipe.	$ 160,000	No.	1	$ 160,000	0	$ -	0	$ -	0	$ -	0	$ -	*scaled from rehabilitation of Charters Towers (150L/s clarifier)*
3.3	UPGRADE TO EXISTING: Clarifier Walkways and roof	New elevated roof and some walkway work to achieve OH&S	$ 50,000	No.	1	$ 50,000	0	$ -	0	$ -	0	$ -	0	$ -	*Allowance.*
3.4	Stabilisation of EXISTING: Filter block	Stabilise Filter Block	$ 100,000	No.	1	$ 100,000	0	$ -	0	$ -	0	$ -	0	$ -	*Allowance. Full structural Assessment required*
3.5	Addition of new slide gates at inlet to each filter	Add motorised modulator to 2no. filter outlet valve MagFlo meter for automated backwash, dP on each Filter, motorised actuated slide gates to each filter inlet to allow individual filter backwashing Turbidity analyser for 2 no. Filter to Waste line .	$ 44,000	No.	1	$ 44,000	0	$ -	0	$ -	0	$ -	0	$ -	
3.6	Filter media	New Media, laterals and nozzles - not included as these were replaced in 2018 (?)	$ 60,000	No.	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	*Bridgewater, Lanacoorie tenders*
3.7	2 No. new air scour blowers on VSD	2 no. air scour blowers in extended new room in existing building	$ 20,000	No.	2	$ 40,000	0	$ -	0	$ -	0	$ -	0	$ -	
3.8	Lamella plate clarifier		$ 550,000	No.	0	$ -	1	$ 550,000	0	$ -	0	$ -	0	$ -	*Based on crescent head and Casterton lamella plate clarifiers*
3.9	DAF tank and recycle system		$ 550,000	No.	0	$ -	0	$ -	1	$ 550,000	1	$ 550,000	1.2	$ 660,000	*Based on Lancefield, Mirani, Myrniong, Alexandria*
3.10	MF/UF and associated equipment/tanks	MF/UF process - feed pumps, pipework, membrane and housing, local controls	$ 550,000	No.	0	$ -	1	$ 550,000	1	$ 550,000	1	$ 550,000	1.2	$ 660,000	*Based on crescent head*
3.11	Air blower for UF		$ 25,000	No.	0	$ -	1	$ 25,000	1	$ 25,000	1	$ 25,000	1.2	$ 30,000	*Rosebury*
3.12	GAC filters	GAC filters and associated pipework	$ 350,000	No.	1	$ 350,000	1	$ 350,000	1	$ 350,000	1	$ 350,000	0	$ -	*Based on Crescent Head, Whitemark, Ringarooma*
3.13	Nanofiltration and associated equipment/tanks	NF feed pumps, pipework, membrane and housing, local controls	$ 450,000	No.	0	$ -	0	$ -	0	$ -	0	$ -	1	$ 450,000	*Based on Whitemark, Ringarooma*
3.14	UV	UV only for options 1,2, and 3	$ 200,000	No.	1	$ 200,000	1	$ 200,000	1	$ 200,000	1	$ 200,000	0	$ -	*Bridgewater, Lanacoorie, Heathcote*
3.15	Additional analysers & sampling systems at existing plant	Raw turbidity+ raw pH ($15k) Coagulation pH ($5k) settled turbidity ($10k) Filtered turbidity ($10k, N/A) Filtered free chlorine ($15k, N/A), filtered pH ($5k, N/A) Post CWS free Chlorine ($15k) Final treated water turbidity, pH, & total chlorine ($30k) + relocate filtered water dosing points to after new GAC filters ($5k)	$ 80,000	No.	1	$ 80,000	0		0		0		0		*GHD estimate & Heathcote tender* *Kahuna*
3.16	Air compressor and aeration pipework into dam	raw water reservoir mixing / aeration system, compressor in existing building	$ 150,000	No.	1	$ 150,000	1	$ 150,000	1	$ 150,000	1	$ 150,000	1	$ 150,000	
3.17	Service Water system	Existing: Service water requires VSD on existing D/S pumps. New WTP options require separate new service water systems	$ 15,000	No.	0.4	$ 6,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	
3.18	Compressed air system	new compressor and pipework and controls from existing plant for service water.	$ 45,000	No.	0	$ -	1	$ 45,000	1	$ 45,000	1	$ 45,000	1	$ 45,000	*Romsey*
4.0	**Building**			***Subtotal***		**$ 403,600**		**$ 849,600**		**$ 849,600**		**$ 909,600**		**$ 989,600**	
4.1	WTP Building	ColourBond; covers all of main WTP process units, chemical storage, control room and electrics	$ 1,500	per sq m.	0	$ -	360	$ 540,000	360	$ 540,000	400	$ 600,000	400	$ 600,000	*Based on Balmoral, Lancefield and Myrniong tenders*
4.2	Chemical Delivery bund	Existing plant has no delivery bund Upgrade of existing plant required new chlorine drum delivery bund	$ 25,000	No.	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	
4.3	Site works	Reinforced concrete pad, bunds etc.	$ 80,000	No.	0	$ -	1	$ 80,000	1	$ 80,000	1	$ 80,000	2	$ 160,000	*Based on Lancefield tenders*
4.4	New Chlorine building	New separate tilt up RC or brick building with all air conditioning and all mechanical ventilation and lining for Chlorine (6 x 8 m) - Allow $2700/m2	$ 2,700	per sq m.	48	$ 129,600	48	$ 129,600	48	$ 129,600	48	$ 129,600	48	$ 129,600	*$2.5k/m2 From Heathcote WTP (2018)- Tender and GHD estimate, 40.32 m2 = 8.4 x 4.8 m building*
4.5	Upgrade to Existing Control Building (for Option 1)	Removal of old equipment, dosing systems, and tanks and redundant electrical switchboards, air blower, chlorination equipment, amenities/sinks etc. ($15k, reference: Crescent Head & Charters towers) Clean out Fluoride Room ($10k, reference Cohuna) **Construction of new walls and bunds as per below:** - Install new switchboard in old Fluoride room and possibly wet rack for equipment on bottom floor ($30k, GHD experience) - When new switchboard installed, remove old switchboard and upgrade office area, including relocation of analysers - Extend wall in blower room ($5k, GHD experience) - New Coagulant dosing bund inside existing building ($25k which includes Epoxy coating, reference Charters towers) - Removal of Chlorine walls for new soda ash area ($5k, GHD experience) - large bund for Soda Ash ($40k, Reference: Charters towers)	$ 130,000	no.	1	$ 130,000	0	$ -	0	$ -	0	$ -	0	$ -	*Reference: refer to comment* *Apollo Bay WTP upgrade*
4.6	Raw water pump station building	Remove old building, new colourbond building, new monorail with hoist for pumps (5x6m)	$ 2,500	per sqm	30	$ 75,000	30	$ 75,000	30	$ 75,000	30	$ 75,000	30	$ 75,000	
4.7	Carport structure over GAC filters	GAC carport over filters and GAC return pumps (11 m x 5 m = 55m2)	$ 800	per sqm	55	$ 44,000	0	$ -	0	$ -	0	$ -	0	$ -	*Cost based on Avoca Tender (2011) Carport over chemical dosing tender*
5.0	**Electrical, instrumentation and control (EI&C)**			***Subtotal***		**$ 1,203,500**		**$ 1,052,000**		**$ 1,032,000**		**$ 1,120,000**		**$ 1,096,000**	
5.1	New WTP Electrical, instrumentation and control (EI&C)	Allow 15% of total cost, excluding all items for Raw Water pump station as the EIC for this is considered separately (below)	$ 1,000,000.00	No.	0	$ -	0.96	$ 960,000	0.94	$ 940,000	1.04	$ 1,040,000	1	$ 1,000,000	*Around 15% of contract value based Laanecoorie, Bridgewater Crescent Heathcote, and Tassie plants*
5.2	EI&C for Existing Plant	Allow 20% of total cost, excluding all items for Raw Water pump station as the EIC for this is considered separately (below) PLC Control & SCADA upgrade ($50k) Replacement of existing MCC Main WTP Electrical switchboards, control panels and electrical cables New Chemical dosing switchboard, control and electrical works ($140k) Electrical Isolation works Distribution Board Standby generator connection	$ 650,000.00	No.	1.71	$ 1,111,500	0	$ -	0	$ -	0	$ -	0	$ -	*Refer to SMRC Summary*
5.3	Raw Water Pump Station Electrical, instrumentation and control (EI&C) (20%)	Including upgrade of telemetry and diesel generator power connection point, including flowmeter and pressure gauges and building lighting	$ 80,000.00	No.	1	$ 80,000	1	$ 80,000	1	$ 80,000	1	$ 80,000	1.2	$ 96,000	
	Total chlorine residual analyser	for Chloramination. New analyser + sampling system	$ 12,000.00	No.	1	$ 12,000	1	$ 12,000	1	$ 12,000	0	$ -	0	$ -	*Bridgewater, Lanacoorie tenders*
6.0	**Chemical Systems**			***Subtotal***		**$ 640,000**		**$ 845,000**		**$ 725,000**		**$ 1,035,000**		**$ 591,500**	
6.1	Coagulant	New Alum dosing system and bulk storage (for new WTP) For existing, no need for storage tank - Existing assumed ok	$ 45,000	No.	0	$ -	1	$ 45,000	1	$ 45,000	1	$ 45,000	1.2	$ 54,000	*Based on Crescent Head, Casterton, and Tassie (small plants)*
6.2	Polymer	Poly only for clarifier. Only new pumps are required for BAU option	$ 120,000	No.	1	$ 120,000	1	$ 120,000	0	$ -	0	$ -	0	$ -	*Based on Charters Towers*
6.3	Potassium permanganate	Automated with hot water supply	$ 65,000	No.	1	$ 65,000	1	$ 65,000	1	$ 65,000	1	$ 65,000	1.2	$ 78,000	*Based on Lancefield WTP*
6.4	Caustic soda	Dosing system + bulk storage and dosing lines	$ 50,000	No.	0	$ -	0	$ -	0	$ -	0	$ -	0	$ -	*Based on Tassie (small plants)*
6.5	Ozone		$ 350,000	No.	0	$ -	0	$ -	0	$ -	1	$ 350,000	0	$ -	*Based on Hamilton Island & Rochester*
6.6	Soda Ash	Bulki Bag Soda Ash dosing system & pumps (new pumps required for BAU option as well)	$ 150,000	No.	1	$ 150,000	1	$ 150,000	1	$ 150,000	1	$ 150,000	1.1	$ 165,000	*Based on Proserpine and Bowan*
6.7	Chlorine gas	New D/S Gas chlorinator with 2x 72kg cylinders in new building	$ 95,000	No.	1	$ 95,000	1	$ 95,000	1	$ 95,000	1	$ 95,000	1.1	$ 104,500	*Based on Crescent Head*
6.8	Ammonia	Dosing system including storage tank, pipework, pump systems and controls	$ 40,000	No.	1	$ 40,000	1	$ 40,000	1	$ 40,000	0	$ -	0	$ -	*Balmoral, $30k in 2003.*
6.11	Flow meter on line from GAC back to CWS		$ 10,000		1	$ 10,000	1	$ 10,000	1	$ 10,000	1	$ 10,000	1	$ 10,000	*Cohuna*
6.12	CIP systems for MF/UF and NF (where applicable)	Includes pipework and CIP preparation tanks, controls, dosing system, bunds	$ 160,000	No.	0	$ -	1	$ 160,000	1	$ 160,000	1	$ 160,000	1.125	$ 180,000	*Based on Crescent Head*
6.13	THM Stripping (PAX system)	Will be installed onsite at Reservoir 1.	$ 160,000	No.	1	$ 160,000	1	$ 160,000	1	$ 160,000	1	$ 160,000	0	$ -	*Scale down from Rosslynne (from 10ML to 0.5ML tank)* *Remove electrical works (20%). Awaiting Budget price from Metaval*
7.0	**Pumps and pipework**			***Subtotal***		**$ 110,000**		**$ 110,000**		**$ 110,000**		**$ 110,000**		**$ 105,000**	
7.1	Washwater to thickener pumps	includes VDS control and reinforced concrete pad, pipework and carport structure	$ 35,000	No.	1	$ 35,000	1	$ 35,000	1	$ 35,000	1	$ 35,000	1.5	$ 52,500	*Based on Mole Creek, Heathcote ($48-60k)*
7.2	Supernatant return pumps	includes VDS control and reinforced concrete pad, pipework and carport structure	$ 35,000	No.	1	$ 35,000	1	$ 35,000	1	$ 35,000	1	$ 35,000	1.5	$ 52,500	*Based on Mole Creek, Heathcote ($32-36k)*
7.3	GAC filter backwash system	system same as filter backwash which is a connection off treated water pump main, with control valve and flow meter to allow gravity backwash.	$ 25,000	No.	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	0	$ -	*Based on Mole Creek, similar to supernatant return pipework for Heathcote, plus FM and control valve.*
7.5	GAC pump station	From balance tank after GAC filters, back to existing CWS. Under GAC carport.	$ 15,000	No.	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	0	$ -	*Based on Crescent head, Heathcote and Laanacoorie*
8.0	**Other Tanks**			***Subtotal***		**$ 295,000**		**$ 335,000**		**$ 335,000**		**$ 335,000**		**$ 416,000**	
8.1	Raw water balance/oxidation tank	10kL stainless steel tank with mixer	$ 50,000	No.	1	$ 50,000	1	$ 50,000	1	$ 50,000	1	$ 50,000	1.2	$ 60,000	*Based on Lancefield WTP, and Heathcote PAC tank at ($90-100k)*
8.2	MF/UF feed pump balance tank	Between clarifier / daf and MF/UF - 20 kL, includes connecting pipework	$ 25,000	No.	0	$ -	1	$ 25,000	1	$ 25,000	1	$ 25,000	0	$ -	*Based on estimate for Brogo (2020)*
8.3	UF/NF feed pump balance tank	between MF/UF and NF - 30kL	$ 35,000	No.	0	$ -	0	$ -	0	$ -	0	$ -	1	$ 35,000	*Based on estimate for Brogo (2020)*
8.4	Balance tank after GAC filters	20kL tank	$ 15,000	No.	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	0	$ -	*Rosebury & Ringarooma*
8.5	Washwater holding tank MF/UF and GAC	45kL tank, includes $20,000 for mixer	$ 60,000	No.	1	$ 60,000	1	$ 60,000	1	$ 60,000	1	$ 60,000	0	$ -	*Based on Crescent Head, Rosebury and Brogo (2020)*
8.6	Washwater holding tank for UF and NF	100kL tank, includes mixer	$ 100,000	No.	0	$ -	0	$ -	0	$ -	0	$ -	1	$ 100,000	*Based on Crescent Head and Rosebury*
8.7	Supernatant return tank	15 kL (not mixed)	$ 25,000	No.	1	$ 25,000	1	$ 25,000	1	$ 25,000	1	$ 25,000	1.2	$ 30,000	*based on Heathcote ($67-85k)*
8.8	Thickener	2.5L/s lamella plate clarifier	$ 130,000	No.	1	$ 130,000	1	$ 130,000	1	$ 130,000	1	$ 130,000	1.2	$ 156,000	*Based on Forsyth, and Heathcote (5.6L/s at $140-288k)*
8.9	CIP waste tank for MF/UF	Tank has connection for pump out by contractor to waste tank on truck. 5kL	$ 15,000	No.	0	$ -	1	$ 15,000	1	$ 15,000	1	$ 15,000	0	$ -	*Based on Tassie (small plants)*
8.10	CIP waste tank for UF/NF	Tank has connection for pump out by contractor to waste tank on truck. 10 kL	$ 20,000	No.	0	$ -	0	$ -	0	$ -	0	$ -	1	$ 20,000	*Based on Tassie (small plants)*
8.11	Chemical spill tank for delivery bund	9 kL (minimum) tank	$ 15,000	No.	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	1	$ 15,000	*Based on Avoca (2011) ($11k)*
9.0	**Other Requirements for BAU: upgrade Existing plant**			***Subtotal***		**$ 10,500**		**$ 10,500**		**$ 10,500**		**$ 10,500**		**$ 10,500**	
9.1	New Safety shower	Existing is only standard Bathroom shower, not approved Safety shower	$ 3,500	No.	3	$ 10,500	3	$ 10,500	3	$ 10,500	3	$ 10,500	3	$ 10,500	*based on Charters Towers*
10.0	**Commissioning & Proof of performance**			***Subtotal***		**$ 240,000**		**$ 366,000**		**$ 366,000**		**$ 396,000**		**$ 387,000**	
10.1		Allow 4% of total cost	$ 300,000	No.	0.8	$ 240,000	1.22	$ 366,000	1.22	$ 366,000	1.32	$ 396,000	1.29	$ 387,000	*~4% at Lancefield, Myrniong, Balmoral and 5% at Brogo (2020)*
	Sub-total					**$ 5,991,000**		**$ 7,021,000**		**$ 6,854,000**		**$ 7,435,000**		**$ 7,264,000**	
	Remote location factor	(% based on subtotal)	10%			$ 599,100		$ 702,100		$ 685,400		$ 743,500		$ 726,400	*Rawlinsons*
	Contingency	% based on subtotal & location factor)	20%		1.5	$1,977,030.00	1.00	$1,544,620.00	1.00	$1,507,880.00	1.00	$1,635,700.00	1.00	$1,598,080.00	
	Sub-total (Indirect Job Costs)					**$ 2,580,000**		**$ 2,250,000**		**$ 2,200,000**		**$ 2,380,000**		**$ 2,330,000**	
	TOTAL					**$ 8,580,000**		**$ 9,280,000**		**$ 9,060,000**		**$ 9,820,000**		**$ 9,600,000**	
	PROVISIONAL ITEM														
11.0	**Fluoride System**			***Subtotal***		**$ 650,000**		**$ 650,000**		**$ 650,000**		**$ 650,000**		**$ 650,000**	
11.1	Fluoride	Separate contract including building and all civil, structural, mech and EI&C dosing, sampling and service water to allow separate funding arrangement by DHS. Based on a sodium fluoride saturator system. In a 40 m2 building (5 x 8 m)	$ 650,000	No.	1	$ 650,000	1	$ 650,000	1	$ 650,000	1	$ 650,000	1	$ 650,000	*Cost based on Camperdown, Cahoona and independent estimates for Brogo.*

Cost Estimates have been developed based on supplier budget quotes and a concept design for the purposes of comparing options . These estimates are typically developed based on cost curves, budget quotes for some equipment items, extrapolation of recent similar project pricing and GHD experience. It should be noted that at this level of design, the scope and quality of the works has not yet been fully identified and some items may not be included. Therefore the estimates are not warranted by GHD and the accuracy of the estimates is typically not expected to be better than about ± 40%.

Operating Cost Estimates - Bombala WTP Options Assessment

Base Assumptions			
Electricity Price	$ 0.23	per kWhr	*From SW Rocks estimate*
Annual treated water production	180	ML/yr	*Based on treated Water demand - WTP flows in 2019*
Max flowrate	24	L/s	

Chemicals (as supplied)	Cost		% concentration		SG	
Coagulant (Alum)	$0.45	per kg as pure Alum			1	Dose as pure alum (which is 16% Al2O3)
Potassium permanganate	$8.0	per kg			1	
pH adjustment (Soda Ash)	$0.8	per kg			1	
Pre Chlorine gas as 100% Cl2	$4.5	per kg	100%	w/w (as pure cl2)	1	*Updated to gas with new cost*
post Chlorine gas as 100% Cl2	$4.5	per kg	200%	w/w (as pure cl2)	1	
Polymer - settled water	$8.0	per kg	100%	w/w (powder)	1	
Ozone					1	*based on 3mg/L dose, refer to Electricity usage table*
Ammonia	$10.0	per kg				
						UP CIP every month. Based on Romsey CIP and Upper Yarra CIP.
CIP for MF/UF	$4,000	per year				*Hypo, citirc acid, SMBM, Caustic Soda*
CIP for NF	$2,000	per year				*CIP on NF every 2 months. Caustic Soda, Citric acid*
Antiscalant for NF	$1,170	per year				*based on 2 mg/L = 2kg/ML * $6.5/kg *ML/year*

UV replacement items			
UV lamps	$8,000	per year	*4 lamps at $1000 each, twice a year*
UV Ballast	$400	per year	*$500 * 4, replaced every 5 years*
UV sleeves	$400	per year	*4 UV sleeves replaced every 5 years*
UV wiper	$200	per year	*$750 each, replaced every 5 years*
UVI sensors	$2,200	per year	*4 at $5400 each, replaced every 10 years*

Membrane Replacement			
UF Membrane cost	$2,500	per element	*From TasWater plants - Laurie Curran tenders. Replace every 5 years*
NF Membrane cost	$1,000	per element	*From TasWater plants - Laurie Curran tenders. Replace every 3 years*
UF Membrane elements	64	elements	*64 units at Ringarooma (20.8 L/s), $2100 per element, 5 year life, quote from 2015*
NF Membrane elements	96	elements	
UF Membrane life	5	years	*According to tenders*
NF Membrane life	3	years	

Operating cost estimate

	Upgrade Existing Plant	Clarifier + MF + GAC + Chloramination	DAF + MF + GAC + Chloramination	DAF + MF + Ozone/GAC + Chlorination	DAF + MF + NF + Chlorination	basis of dose	
Annual treated water production	180	180	180	180	180		ML/year
Raw water for dosing	189	189	189	189	216		ML/yr
Chemical Doses (mg/L)							
Coagulant (Alum)	120	120	120	120	120	raw water	*as supplied material (16%w/w Al2O3)*
Potassium permanganate	0.8	0.8	0.8	0.8	0.8	raw water	*1.5mg/L for 3 months, 0.5mg/L for 3 months*
pre pH adjustment (soda)	3	3	3	3	3	raw water	*5mg/L for half the year*
Pre Chlorine gas as 100% Cl2	1	1	1	1	1	raw water	*2mg/L for half the year*
post Chlorine gas as 100% Cl2	4	4	4	3	2	treated	
Polymer - settled water	0.1	0.1	0	0	0	raw water	*polymer only for Clarifier*
Ozone	0	0	0	3	0	treated	Electricity cost only
Ammonia	1.3	1.3	1.3	0.0	0.0	treated	a third of post chlorine dose
post pH adjustment (soda) - if alum	45	45	45	45	45	treated	
Coagulant dose to washwater	100	100	100	100	100	raw water	dose for 5% of raw water (options 1-3) and 20% of raw water for option 4

Variable Costs ($ k/yr)

Chemicals ($k/year)	Upgrade Existing Plant	Clarifier + MF + GAC + Chloramination	DAF + MF + GAC + Chloramination	DAF + MF + Ozone/GAC + Chlorination	DAF + MF + NF + Chlorination		
Coagulant (Alum)	$ 10,206	$ 10,206	$ 10,206	$ 10,206	$ 11,664	raw water	
Potassium permanganate	$ 1,210	$ 1,210	$ 1,210	$ 1,210	$ 1,382	raw water	
pre pH adjustment (soda)	$ 454	$ 454	$ 454	$ 454	$ 518	raw water	
Pre Chlorine gas as 100% Cl2	$ 851	$ 851	$ 851	$ 851	$ 972	raw water	
post Chlorine gas as 100% Cl2	$ 3,240	$ 3,240	$ 3,240	$ 2,430	$ 1,620	treated	
Polymer - settled water	$ 151	$ 151				raw water	
Ozone						treated	electricity only - calculated below
Ammonia	$ 2,400	$ 2,400	$ 2,400	$ -	$ -	treated	
post pH adjustment (soda) - if alum	$ 6,480	$ 6,480	$ 6,480	$ 6,480	$ 6,480	treated	
Coagulant dose to washwater	$ 1,058	$ 1,058	$ 1,058	$ 1,058	$ 1,209		dose for 5% of raw water
CIP for MF/UF		$ 4,000	$ 4,000	$ 4,000	$ 4,000		
CIP for NF					$ 2,000		
Antiscalant for NF					$ 1,170		
TOTAL CHEMICALS	**$26,049**	**$30,049**	**$29,898**	**$26,688**	**$31,016**		

Energy ($k/year)	Upgrade Existing Plant	Clarifier + MF + GAC + Chloramination	DAF + MF + GAC + Chloramination	DAF + MF + Ozone/GAC + Chlorination	DAF + MF + NF + Chlorination	
Raw Water pumping	$ 11,737	$ 11,737	$ 11,737	$ 11,737	$ 11,737	*See calculations below*
Flash mixer	$ 504	$ 504	$ 504	$ 504	$ 504	*See calculations below*
Flocc mixers	$ 604	$ 604	$ 604	$ 604	$ 604	*See calculations below*
DAF & sludge roller			$ 2,351	$ 2,351	$ 2,351	*See calculations below*
UF		$ 4,701	$ 4,701	$ 4,701	$ 4,701	*See calculations below*
NF					$ 6,716	*See calculations below*
UV	$ 2,686	$ 2,686	$ 2,686	$ 2,686		*See calculations below*
Ozone				$ 3,105		Ozone cost is electricity only
Air compressors - Clarifier	$ 504	$ 504				*See calculations below*
Air compressors - DAF			$ 2,519	$ 2,519	$ 2,519	*See calculations below*
Supernatant	$ 504	$ 504	$ 504	$ 504	$ 1,007.40	*option 5 has double flowrate hence double suprnatant*
Washwater pumping	$ 504	$ 504	$ 504	$ 504	$ 1,007	
Miscellaneous	$ 3,022	$ 3,022	$ 3,022	$ 3,022	$ 3,022	
TOTAL ENERGY	**$20,065**	**$24,766**	**$29,131**	**$32,236**	**$34,168**	

	Upgrade Existing Plant	Clarifier + MF + GAC + Chloramination	DAF + MF + GAC + Chloramination	DAF + MF + Ozone/GAC + Chlorination	DAF + MF + NF + Chlorination
Total Variable Costs ($ k/yr)	$ 46,113	$ 54,815	$ 59,029	$ 58,924	$ 65,184
Total Variable Costs ($ / ML)	$ 256	$ 305	$ 328	$ 327	$ 362

Fixed Costs ($ k/yr)

	Upgrade Existing Plant	Clarifier + MF + GAC + Chloramination	DAF + MF + GAC + Chloramination	DAF + MF + Ozone/GAC + Chlorination	DAF + MF + NF + Chlorination	
Operations labour	$ 100,000	$ 100,000	$ 100,000	$ 100,000	$ 100,000	*based on other plants of similar size and complexity, the operations labour and associated transport and wq testing costs is set at $100,000/yr*
Maintance (Labour & equipment)	$ 68,070	$ 83,240	$ 80,440	$ 88,400	$ 82,530	*2% of M&E CAPEX cost - linked to CAPEX calculation page*
GAC media replacement	$ 6,000	$ 6,000	$ 6,000	$ 6,000	$ 6,000	*$2000/m3 * 30m3 replaced every 10 years*
UV total	$ 11,200	$ 11,200	$ 11,200	$ 11,200		
UF Membrane replacement cost		$ 32,000	$ 32,000	$ 32,000		*Annualised cost*
NF membrane replacement cost					$ 32,000	*Annualised cost*
CIP waste removal for MF		$ 2,000	$ 2,000	$ 2,000	$ 2,000	*2 removals by truck each year*
CIP waste removal for NF					$ 1,000	*1 removal by truck each year*
NF reject					$ 225,000	*approx 8% of total produced water over the year = 15ML/year. Trucked to STP @$300/20kL*
Sludge Removal	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	*Assumption*
Total Fixed Costs ($ k/yr)	$ 195,270	$ 244,440	$ 241,640	$ 249,600	$ 458,530	

Totals

	Upgrade Existing Plant	Clarifier + MF + GAC + Chloramination	DAF + MF + GAC + Chloramination	DAF + MF + Ozone/GAC + Chlorination	DAF + MF + NF + Chlorination	
Total Operating Costs	$ 241,000	$ 299,000	$ 301,000	$ 309,000	$ 524,000	
Contingency (10%)	$ 24,100	$ 29,900	$ 30,100	$ 30,900	$ 52,400	
TOTAL OPEX ($/year)	**$ 265,100**	**$ 328,900**	**$ 331,100**	**$ 339,900**	**$ 576,400**	10 % contingency

Electricity estimates							
Type of operation	**Power (kW)**	**Hours per day**	**kWh/day**	**Annual cost**	**kWhr/ML**		
Raw Water pumping				$ 11,737	270	kWh/ML raw water	
Flash mixer	0.75	8	6	$ 504	12.2	kWh/ML treated water	
Flocc mixers	0.3	24	7	$ 604	14.6	kWh/ML treated water	
DAF & sludge roller	3.5	8	28	$ 2,351	56.8	kWh/ML treated water	
UF	7	8	56	$ 4,701	113.6	kWh/ML treated water	
NF	10	8	80	$ 6,716	162.2	kWh/ML treated water	
UV	4	8	32	$ 2,686	64.9	kWh/ML treated water	
Ozone			0	$ 3,105	75	kWh/ML raw water	based on 3kg/ML * 25 kWh/kg
Air compressors - Clarifier	3	2	6	$ 504	12.2	kWh/ML treated water	
Air compressors - DAF	3	10	30	$ 2,519	60.8	kWh/ML treated water	
Supernatant	0.75	8	6	$ 504	12.2	kWh/ML treated water	
Washwater pumping	0.75	8	6	$ 504	12.2	kWh/ML treated water	
Miscellaneous	3	12	36	$ 3,022	73.0	kWh/ML treated water	

Growth rate	Discount rate
0%	6%

Year		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Annual treated water demand (ML)		180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
UPGRADE EXISTING																										
CAPEX	8,580,000																									
OPEX		265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100
Cash flow	8,580,000	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100	265,100
Cash flow NPV		250,094	235,938	222,583	209,984	198,098	186,885	176,307	166,327	156,912	148,030	139,651	131,747	124,289	117,254	110,617	104,356	98,449	92,876	87,619	82,659	77,981	73,567	69,402	65,474	61,768
Cumulative Cash flow NPV	**8,580,000**	8,830,094	9,066,032	9,288,615	9,498,599	9,696,698	9,883,583	10,059,889	10,226,216	10,383,129	10,531,159	10,670,810	10,802,557	10,926,846	11,044,100	11,154,717	11,259,073	11,357,522	11,450,398	11,538,017	11,620,676	11,698,657	11,772,223	11,841,626	11,907,100	11,968,868
Clarifier + MF + Chloramination																										
CAPEX	9,280,000																									
OPEX		328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900
Cash flow	9,280,000	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900	328,900
Cash flow NPV		328,900	292,720	276,151	260,520	245,773	231,862	218,737	206,356	194,675	183,656	173,260	163,453	154,201	145,473	137,238	129,470	122,142	115,228	108,706	102,553	96,748	91,271	86,105	81,231	76,633
Cumulative Cash flow NPV	**9,280,000**	9,608,900	9,901,620	10,177,771	10,438,290	10,684,063	10,915,925	11,134,662	11,341,018	11,535,694	11,719,350	11,892,610	12,056,063	12,210,264	12,355,737	12,492,976	12,622,446	12,744,588	12,859,816	12,968,521	13,071,074	13,167,822	13,259,093	13,345,198	13,426,430	13,503,063
DAF + MF + Chloramination																										
CAPEX	9,060,000																									
OPEX		331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100
Cash flow	9,060,000	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100	331,100
Cash flow NPV		312,358	294,678	277,998	262,262	247,417	233,412	220,200	207,736	195,978	184,885	174,419	164,547	155,233	146,446	138,156	130,336	122,959	115,999	109,433	103,239	97,395	91,882	86,681	81,775	77,146
Cumulative Cash flow NPV	**9,060,000**	9,372,358	9,667,036	9,945,034	10,207,296	10,454,714	10,688,126	10,908,326	11,116,063	11,312,040	11,496,925	11,671,344	11,835,891	11,991,123	12,137,569	12,275,726	12,406,062	12,529,021	12,645,020	12,754,452	12,857,691	12,955,086	13,046,968	13,133,649	13,215,423	13,292,569
DAF + MF + Ozone/GAC + Chlorination																										
CAPEX	9,820,000																									
OPEX		339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900
Cash flow	9,820,000	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900	339,900
Cash flow NPV		320,660	302,510	285,387	269,233	253,993	239,616	226,053	213,257	201,186	189,798	179,055	168,920	159,358	150,338	141,828	133,800	126,227	119,082	112,341	105,982	99,983	94,324	88,985	83,948	79,196
Cumulative Cash flow NPV	**9,820,000**	10,140,660	10,443,170	10,728,557	10,997,789	11,251,782	11,491,399	11,717,451	11,930,709	12,131,895	12,321,694	12,500,749	12,669,669	12,829,027	12,979,365	13,121,193	13,254,994	13,381,221	13,500,302	13,612,644	13,718,626	13,818,610	13,912,934	14,001,919	14,085,867	14,165,063
DAF + MF + NF + Chlorination																										
CAPEX	9,600,000																									
OPEX		576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400
Cash flow	9,600,000	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400	576,400
Cash flow NPV		543,774	512,994	483,957	456,563	430,720	406,339	383,339	361,640	341,170	321,859	303,640	286,453	270,239	254,942	240,512	226,898	214,054	201,938	190,508	179,724	169,551	159,954	150,900	142,358	134,300
Cumulative Cash flow NPV	**9,600,000**	10,143,774	10,656,768	11,140,724	11,597,287	12,028,006	12,434,346	12,817,685	13,179,325	13,520,495	13,842,354	14,145,995	14,432,448	14,702,686	14,957,629	15,198,140	15,425,038	15,639,092	15,841,031	16,031,538	16,211,263	16,380,814	16,540,768	16,691,668	16,834,026	16,968,326

Upgrade existing:

CAPEX	$	8,580,000	
OPEX	$	265,100	per year
NPC (25 years)	**$**	**11,970,000**	

Clarifier + MF + Chloramination:

CAPEX	$	9,280,000	
OPEX - fixed	$	328,900	per year
NPC (25 years)	**$**	**13,505,000**	

DAF + MF + Chloramination:

CAPEX	$	9,060,000	
OPEX - fixed	$	331,100	per year
OPEX - variable			per ML
NPC (25 years)	**$**	**13,295,000**	

DAF + MF + Ozone/GAC + Chlorination:

CAPEX	$	9,820,000	
OPEX - fixed	$	339,900	per year
NPC (25 years)	**$**	**14,165,000**	

DAF + MF + NF + Chlorination:

CAPEX	$	9,600,000	
OPEX - fixed	$	576,400	per year
NPC (25 years)	**$**	**16,970,000**	

Appendix N — Weir proposal correspondence

Refer to following page.

NSW GOVERNMENT | Department of Primary Industries

OUT17/21143

The General Manager
Snowy Monaro Regional Council
PO Box 714
COOMA NSW 2630
Council@snowymonaro.nsw.gov.au

Dear Sir/Madam,

Planning Proposal: PP 2017 SMONA 001 00. Amend Bombala Local Environmental Plan 2012

Thank you for your referral of 18 April 2017, received on 27 April 2017, seeking comment on the proposal from DPI Fisheries, a division of NSW Department of Primary Industries.

DPI Fisheries is responsible for ensuring that fish stocks are conserved and that there is no net loss of key fish habitats upon which they depend. To achieve this, DPI Fisheries ensures that developments comply with the requirements of the *Fisheries Management Act 1994* (FM Act) (namely the aquatic habitat protection and threatened species conservation provisions in Parts 7 and 7A of the Act, respectively), and the associated *Policy and Guidelines for Fish Habitat Conservation and Management (2013)*. In addition, DPI Fisheries is responsible for ensuring the sustainable management of commercial, recreational and Aboriginal cultural fishing, aquaculture and marine protected areas within NSW.

The Department understands that the 'Planning Proposal' is to enable the construction of a new weir (approximately 2m high) on the Bombala River between Caveat and Young Streets Bombala. The resulting weir pool/lake is expected to inundate the beds of the Bombala River and the Coolumbooka River to beyond the confluence of the two rivers and up to the existing Coolumbooka Weir.

Please note that the Department's assessment does not concur with the way the project has been characterised as "an extension of the existing weir pool". The proposal involves the construction of a new weir which will create a new weir pool and inundate a previously un-impacted section of river channel. The Department considers that the footprint of the proposal, as shown in the Planning Proposal (Zenith) and Biodiversity Assessment (Envirokey), is likely to be incorrect. The diagrams show the weir pool/lake extending up the Coolumbooka River from the Bombala/Coolumbooka confluence but do not show the weir pool/lake extending up the Bombala River from the Bombala/Coolumbooka confluence. The weir pool is likely to extend further up the Bombala River than shown and is therefore likely to affect additional properties.

Both the Bombala and Coolumbooka Rivers are considered by the Department to be Type 1 (highly sensitive), Class 1 (major) key fish habitats under the *Policy and*

Guidelines for Fish Habitat Conservation and Management (2013). Both are also highly valued as recreational fishing areas.

As identified by both the Planning Proposal (prepared by Zenith) and Biodiversity Assessment (prepared by Envirokey), the Bombala and Coolumbooka Rivers are included as part of the Endangered Ecological Community (EEC) of the Snowy River Catchment in NSW under Schedule 4 of the FM Act. The proposal for amending the Bombala LEP 2017 to permit the construction of a new weir and creation of a water storage facility on the Bombala River and to rezone land associated with the existing Coolumbooka weir pool/lake is therefore of significant interest to the Department. It should also be noted that the provisions of section 34A of the *Environmental Planning and Assessment Act 1979* are applicable to this proposal.

A new weir across the Bombala River would obstruct fish passage to in excess of 50km of the upper reaches of the river. The Department would require a high quality fishway to be included in the design of the weir in accordance with section 218 of the FM Act. Significant offsets to compensate for the loss of flowing river habitat, likely impacts on the EEC and recreational fishing would also be required. Additionally, the “installation and operation of instream structures and other mechanisms that alter natural flow regimes of rivers and streams” is listed as a key threatening process under the FM Act. Construction and operation of the proposed weir would fall within this classification. It should be noted that approval to construct a weir (i.e. undertake a Key Threatening Process) within a core area of a listed EEC will require a Species Impact Statement to be prepared under the FM Act.

While the Department acknowledges the need to rezone the land to enable a weir to be constructed, we note that “the planning proposal has not resulted from a strategic study or report”. The Department’s view is that Council needs to consider completing an Integrated Water Cycle Management Study to:

1. demonstrate that additional Town Water Supply is required to meet future demand,
2. canvass the full range of options for supplying additional demand and
3. settle on a preferred option which balances economic, social and environmental considerations.

In light of the fact that the main purpose of the proposal is to allow for the construction of a new weir for town water supply, the Department recommends the issues raised above should be adequately addressed by the planning proposal.

If you require any further information, please contact Senior Fisheries Manager, Allan Lugg, on (02) 4428 3401.

Yours sincerely

Dr Geoff Allan
Deputy Director General DPI Fisheries

Date: 30 May 2017

Department of Primary Industries
Water

Contact: Bob Britten
Phone: 02 6491 7809
Email: bob.britten@dpi.nsw.gov.au

Our ref: V15/3876#69,
File No:
Your Ref:

16 May 2017

General Manager
Snowy Monaro Regional Council
PO Box 714
COOMA NSW 2630

Attention: Grantley Ingram

Dear Grantley,

Re: DPI Water Consultation – Planning Proposal (PP_2017_SMONA_001_00) to amend Bombala LEP

Thank you for seeking comments on the proposed amendment to Bombala Local Environmental Plan 2012 – to permit the expansion of a water storage facility on a section of the Bombala River to facilitate town water supply.

DPI Water has reviewed the information and reports provided. The proposed rezoning of the Bombala River (Lot 7018 DP 94005) component is not supported, on the basis of significant reservation with regard to the suitability of the intended purpose of the rezoning, which is to enable the construction of a storage weir on the Bombala River. The proposed development of the Bombala River channel within the town precinct as a town water supply storage is not adequately justified or supported. The submitted information does not adequately demonstrate that the proposed use of the site and intended works are likely to be within the objectives and principles of the Water Management Act 2000 (WMA).

The Department recognises issues which have arisen with regard to meeting Bombala's town water supply requirements during serious drought periods. Advice has been provided in line with future water supply development should be based on both a justified water requirement and development within a framework of water use efficiency and best management practice for TWS. It is to be noted that the NSW Government's Best-Practice Management of Water Supply and Sewerage Framework (PDF, 23.9 KB) requires local water utilities to prepare and implement a sound 30-year Integrated Water Cycle Management (IWCM) Strategy.
Key elements which should be addressed include:

- The proposed rezoning should sit within a broader strategy for the sustainable water use in Bombala, consistent with the principles of the Water Management Act 2000 and DWE guidelines including NSW Best- Practice Management (BPM) of Water Supply and Sewerage Framework incorporating:
    - Integrated Water Cycle Management Planning (IWCM) recommended as an appropriate planning mechanism to manage the urban water services in an integrated manner. Council's overall water requirements and the best integrated solutions will not be fully realised until the IWCM is

underway or completed. At this stage the overall economics / benefits / costs of proposals remains unclear.

- Environmental Assessment is considered preliminary with a number of issues identified, but not effectively addressed at this stage. Identified issues include "Loss of vegetation and Habitat", impacts to Threatened Ecological Communities (*Tablelands Snow Gum Grassy Woodland* and the "*Aquatic Ecological Community in the Catchment of the Snowy River in NSW*"), Connectivity of habitat within the Bombala River and dispersal potential of immature platypus. Mitigation measures discussed are brief and considered non-specific with regard to environmental outcomes. Viable outcomes should align with the objectives of the WMA.
- The NSW Weirs Policy is a key document for consideration in the future development of the site. The goal of the State Weirs Policy is to halt and, where possible, reduce and remediate the environmental impact of weirs. The Principles of this policy should be addressed and incorporated at this early stage of development planning. A copy of this policy is attached.

For further information please contact Bob Britten, Water Regulation Officer at DPI Water (Bega office) on **t:** (02) 6491 7809; **e:** bob.britten@dpi.nsw.gov.au

Yours sincerely

for :

Vickie Chatfield
Regional Manager
Water Regulation

NSW Weirs Policy

NSW Weirs Policy

CONTEXT

In 1994 the Council of Australian Governments recognised that widespread natural resource degradation has occurred in Australia that has impacted on the quality and/or quantity of the nation's water resources. It adopted a framework for the efficient and sustainable reform of the water industry that included making formal allocations to the environment, based on the best scientific information available.

In September 1995, the Minister for Land and Water Conservation announced that a State-wide review of weirs would take place as part of the water industry reforms. The State Weirs Policy provides the framework for that review and establishes the goals and principles for the ongoing approval and management of weirs.

The State Weirs Policy is a further component of the *State Rivers and Estuaries Policy*, which was approved by the NSW Government in 1991. The *State Rivers and Estuaries Policy* establishes the framework for the management of rivers and estuaries of NSW and related ecosystems, such as wetlands. It is based on the Total Catchment Management philosophy, defined in the Catchment Management Act 1989 as "the coordinated and sustainable use and management of land, water, vegetation and other natural resources on a catchment basis so as to balance resource utilisation and conservation". Other policies under this framework include the State Wetlands Policy, Estuaries Policy and the Sand and Gravel Extraction Policy.

BACKGROUND

WHAT IS A WEIR ?

A weir is a structure (including a dam, lock, regulator, barrage or causeway) across a defined watercourse that will pond water, restrict flow or hinder the movement of fish along natural flow paths, in normal flow conditions.

THE ROLE OF WEIRS

There are estimated to be over 3,000 weirs on rivers in New South Wales. In some rivers significant lengths of stream are impounded behind weirs. For example 40% of the Barwon-Darling River is in weir pools.

Most weirs were originally built to provide a reserve of water for towns or properties to carry them through dry periods. Others were built to facilitate diversion of water into effluent streams or onto floodplains to spread the productive benefits of water over a wider area. In more recent years, weirs have been built to help river operators manage releases from dams or to increase water depth for pumps and diversion channels in major irrigation developments. In a few cases weirs have been built for purely recreational or aesthetic purposes. Some weirs in the Murray River were built to improve navigation.

WHY ARE WEIRS A PROBLEM ?

Weirs have served an important role in the amenity of the towns and properties they serve, but in recent years it has become apparent that this has been at a significant environmental cost. For example:

- the still waters in weir pools are less biologically productive than natural river channels, as native species adapted to diverse and free-flowing stream conditions are disadvantaged;
- riparian vegetation is drowned in the weir pool or killed by water-logging in low-lying areas of adjoining floodplains;
- weirs act as a trap for sediments, nutrients and pollutants;

- invertebrate and detrital drift is reduced, reducing biological productivity and diversity below weirs;
- weir conditions favour water stratification in summer and the growth of algae and development of algal blooms;
- weirs obstruct native fish migration and reduce native fish populations;
- the relatively stable conditions in weir pools give alien species, such as carp, an advantage over native species;
- weir pools may affect groundwater systems by maintaining artificially high water levels, resulting in groundwater mounding;
- inundation of surrounding areas destroys flora and fauna habitat, including that of threatened species;
- weirs accumulate sediments and prevent their downstream flow, resulting in erosion and scouring downstream of the weir;
- a constant level of discharge from weirs can result in geomorphological changes to rivers, tending to make them wider and shallower; and
- weirs can alter temperature regimes down stream, resulting in an adverse impact on native flora and fauna.

Another issue is that circumstances and community needs may have changed over the years since a weir was constructed. For example, an alternative water supply may now be available and an old weir may no longer serve its original purpose. Some of these, particularly those near towns, may have developed secondary uses as recreational and visual amenities for local communities, but others are now redundant and could be removed.

A number of older weirs need major maintenance or refurbishment. Before significant expenditure is incurred, the owners and the community should consider if the cost would be better spent on an alternative supply, or significant design changes, which will reduce the environmental impact of the weir.

Because of changing circumstances and the growing awareness of the adverse impacts most weirs have on the environment, it is time to evaluate the need for existing weirs, to remove redundant weirs, to devise ways to minimise the impact of weirs retained and to critically consider any proposals for new construction.

GOAL AND PRINCIPLES

GOAL

The goal of the State Weirs Policy is to halt and, where possible, reduce and remediate the environmental impact of weirs.

PRINCIPLES

The goal is to be supported by the adoption of the following management principles:

1. *The construction of new weirs, or enlargement of existing weirs, shall be discouraged.*

2. *Weirs that are no longer providing significant benefits to the owner or user shall be removed, taking into consideration the environmental impact of removal.*

3. *Where retained, owners shall be encouraged to undertake structural changes to weirs to reduce their environmental impact on the environment.* For example:

- reducing the crest level and pool storage volume to the minimum necessary to satisfy the purposes for which the weir is required;
- modification of the weir to reduce its impact. For example, installing a larger outlet to permit the release of environmental flows or water level variation, or installing a dropboard or gated opening to allow free flow when the weir is not needed; and
- constructing a fishway or modifying an existing fishway to reduce the weir's impact on fish passage.

4. *Where retained, owners of weirs with regulatory works shall prepare and adhere to operational plans to reduce the environmental impact of those weirs.*

For example:

- achieving water level variations;
- setting minimum rates of change for discharge and storage draw-down to mimic natural changes of water level within and downstream of the weir;
- raising gates fully during any portion of the year when a weir is not needed, such as in the non-irrigation season or during significant unregulated flows; and
- raising gates at times critical to maintenance of river health, wetlands, fish etc.

5. *Where retained, gates, offtake structures and fishways on all weirs shall be maintained in good working order.*

6. *Wetlands and riparian vegetation adjacent to weirs should be protected from permanent inundation.*

7. *Areas of environmental degradation caused by the impacts of weirs upstream and downstream of weir pools, should where possible be rehabilitated.*

8. *A respect for the environmental impact of weirs should be encouraged in all agencies and individuals who own, manage or derive benefits from weirs.*

The State Weirs Policy will have three components. The first relates to the approval to build a new, or expand an existing weir. The second is a review of all existing weirs (Weir Review Program). The third addresses the provision of fishways.

APPROVALS FOR NEW OR EXPANDED WEIRS

For the purposes of this part of the policy, weir means a licensable "work" as described under the Water Act 1912, and could include any dam, lock, weir, regulator, barrage or causeway which effects the quantity or flow of water in a river or lake. This part of the policy applies to privately owned and publicly owned weirs. This does not, however, include off-river storages or farm dams on small, ephemeral streams.

Note that the State Weirs Policy does not act to the exclusion of any applicable EIA or heritage protection legislation, notably the *Environmental Planning and Assessment Act 1979*.

A proposal to build a new weir or enlarge an existing weir should not be approved unless it can be demonstrated that the primary component of the proposal is necessary to maintaining the essential social and economic needs of the affected community.

In determining the need for a new or expanded weir, the following general principles apply:

- Provision for fish passage cannot be used as a sole justification to approve a proposal to enlarge an existing weir.
- An increase in town water supply for the purposes of meeting projected population demand cannot be used as a justification to approve a proposal to build a new, or expand an existing weir, if environmentally friendlier alternatives to meeting that demand exist, which are also economically feasible.
- Provision for future industrial expansion (such as, but not limited to, tourism) cannot be used as a justification to build a new, or expand an existing weir.
- Subject to the usual EIA process, a proposal for the construction of new, or expansion of an existing weir, that will result in a net environmental benefit may be approved

(eg. this may include options to offset the impact of new or enlarged structures by the removal of existing ones).

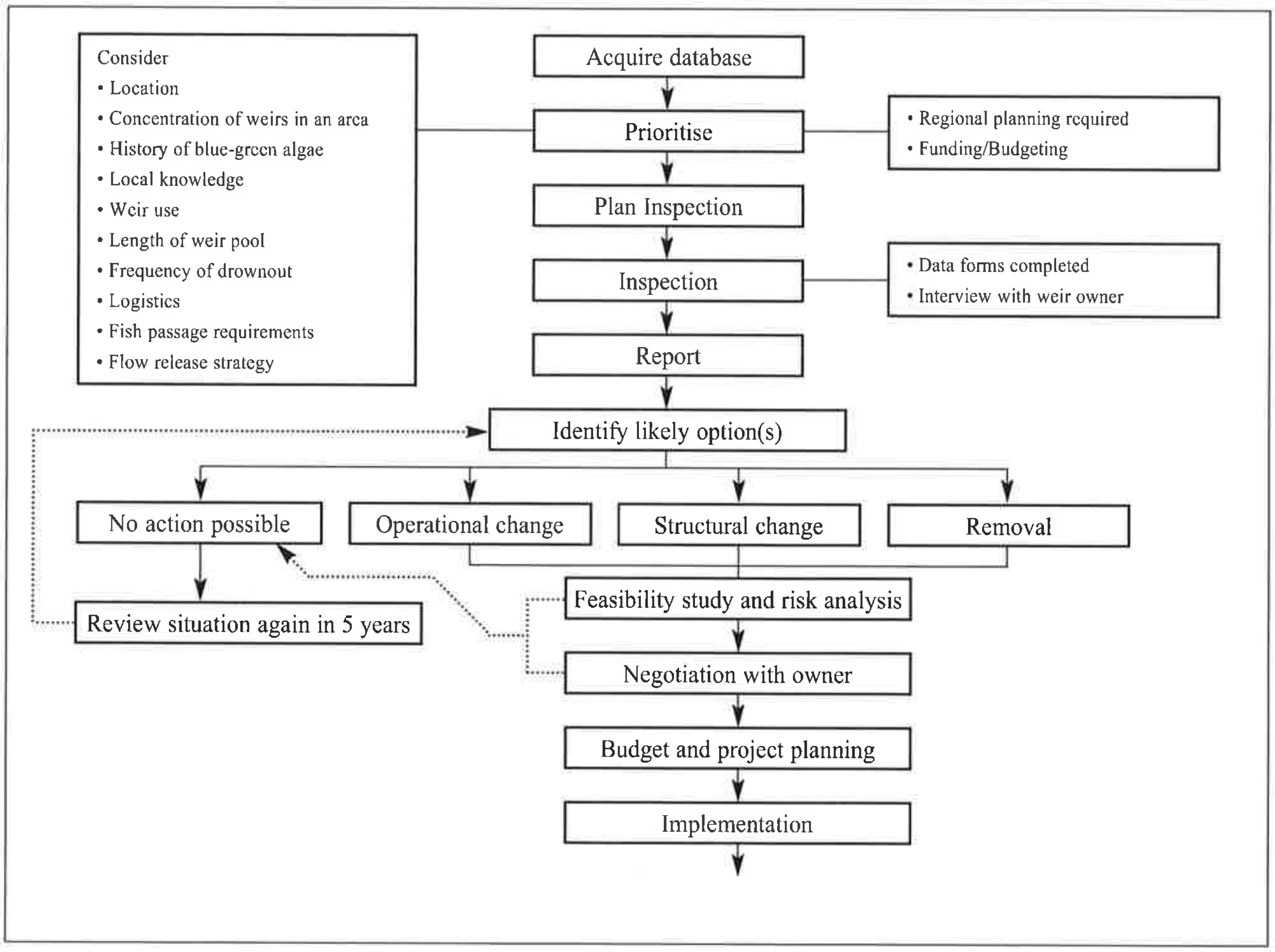
WEIR REVIEW PROGRAM

The aim of the Weir Review program is to examine the impacts of existing works and to develop a strategy which would lead to an enhanced environmental outcome. It will be achieved through undertaking an environmental audit of all weirs throughout the State, and assessing the appropriateness of the existence and/or operation of each weir, against a set of established criteria.

The review process will also cover all publicly and privately owned licensed weirs, and unlicensed weirs, including riparian rights weirs (ie those weirs not requiring to be licensed under the *Water Act 1912*) and other in-stream structures such as road crossings, which have the hydraulic effect of a weir. Information about some of these weirs and structures, especially riparian rights weirs and road crossings, will be acquired through local knowledge.

The program will be implemented in two stages - an inventory and a review stage. The inventory will provide a comprehensive database on the weirs in each region. The review stage will evaluate the environmental impact of each weir against its socio-economic value.

From the results of the review, options for modifications to a weir will be explored. These might include structural changes, changes in weir operation rules or even removal of the weir. However, weirs will not be removed or changes made without consideration of the needs of the communities they serve and the socio-economic impact of removal. Following is the process of weir review. See Figure 1 below.



WEIR IDENTIFICATION

The first step in the weir review process will be to identify the number, location, purpose and size of the weirs in each region. A Weir Inventory Database has been adapted by the Department of Land and Water Conservation (DLWC) from a database developed by the Murray-Darling Basin Commission.

The database will record information on weir ownership, mode of operation, purpose, licensing and weir type, location, structural characteristics, some hydrological characteristics and environmental data.

TRIGGERS FOR REVIEW

A review of a weir may be triggered by any of the following:

- license renewal;
- consideration of a weir for modification under the Algal Management Program;
- consideration of a weir for inclusion of a fishway;
- weirs identified as having a serious environmental impact eg. groundwater, wetlands, water quality, etc.;
- weirs whose purpose is now redundant; and
- DLWC operational structures.

LICENCE RENEWAL

Licences for weirs are renewed every five years, or ten years for town water supplies. This gives the DLWC an opportunity to ask the owner to show cause why the licence for the structure should be renewed and for additional conditions to be imposed. The process would be:

- When the renewal notice is issued, the licensee will be forwarded background information on the environmental impact of weirs and the review process, and a pro-forma requesting updated information on the weir's structure, its current use, operating rules and justification for its retention. It will be the owner's responsibility to provide this information to the satisfaction of the DLWC.
- The information will be used to update the database on weirs, and for a review of the weir by DLWC regional staff, who may also draw on expertise from other government agencies.
- If a clear need for the weir can be established and no significant adverse impacts are identified, the licence will be renewed, subject to normal licensing procedures.
- If a significant impact is apparent or no clear and strong need for the weir is identified, follow up field inspection and discussion with the owners and other interested parties will occur. This will aim to determine if:

  – the weir can be removed,
  – the weir should be modified, or
  – additional conditions should be imposed on its use.

  Where there is significant public use or interest in a weir, wider community consultation should be included in the investigation.
- On the basis of this investigation the DLWC may either refuse to renew the licence, or issue the renewal with conditions prescribing modifications or changed operating rules, or renew with existing conditions.

Weirs which are subject to licensing under the Water Act but not licensed, should be the subject of ongoing action to bring them into line with the Act's requirements. Before any licence is issued to authorise a structure, it should be subject to the same review process outlined above for renewal of existing licences.

ALGAL MANAGEMENT PROGRAM

Weirs being identified as structures of concern under the Algal Management Program shall be subject to a full review before a decision is made about an appropriate algal management strategy.

FISHWAYS

Once a weir is being seriously considered for inclusion of a fishway, a comprehensive review shall be included in the initial evaluation of the site before any significant expenditure on design or construction of a fishway is incurred.

WEIR ASSESSMENT

Each weir should be evaluated to determine the options for modification. Options may include doing nothing, weir removal, operational modifications or structural modifications such as lowering the crest height, constructing a larger diameter flow through pipe or installation of syphons, or fitting a fishway.

Consideration must be given to whether or not there is a realistic chance of effecting some change, either operational or structural on the weir. The likelihood of any action being taken must be assessed within the context of the current dependence and importance of the weir.

If it is likely that an operational or structural change, or removal may occur, a more detailed feasibility study should be undertaken and should include:

- socio-economic impact assessment of options;
- negotiation with owners/users;
- considerations regarding cumulative impacts of weirs in a locality; and
- environmental impact assessment of options including:
  - continuous impact of "do nothing" option
  - environmental benefits of options
  - environmental risks of options.

PROVISION OF FISHWAYS

Where necessary, weirs considered to have a significant impact on the movement of fish shall be formally considered for inclusion of a fishway.

The Fisheries Management Act 1994 requires that NSW Fisheries must be notified whenever a weir or any barrier to fish movement is constructed, altered or modified. If the Minister for Fisheries requests it, a fishway must be included in the design. Where the DLWC or NSW Fisheries identifies a weir as having a significant impact on the movement of fish, licensees should be advised and the weir review process commenced without waiting for the normal renewal process.

A State Government program has been established, coordinated by the DLWC and NSW Fisheries to provide adequate fish passage in rivers to ensure the maintenance of native fish stocks for species conservation, ecosystem maintenance, and economic and cultural uses. The Fishways program seeks to identify weirs which are a significant barrier to fish passage. It will also design and trial a range of structural and operational solutions for fish passage.

The fishways program is strongly linked to the Weir Review program through the Weir Inventory, which is currently being developed by DLWC. Weirs targeted by either program will automatically trigger a broader review of options, as well as specific consideration of fishway requirements.

STATE WEIR REVIEW COMMITTEE

Progress on the weir review will be reported through the existing *State of the Rivers and Estuaries* Reports, and the proposed State of the Catchment Reports. A State Weir Review Committee will be established to further develop the weir review program and to give feedback on the approval process for new or expanded weirs. This committee will be comprised of representatives of:

- DLWC Resource Management;
- DLWC Water Business;
- EPA;
- NSW Fisheries;
- NSW Agriculture;
- Local Government Association;
- Catchment Management Committees;
- NSW Farmers Association;

- NSW Irrigators Council; and
- NSW Conservation interests (eg, Australian Conservation Foundation, Nature Conservation Council).

The role of the Committee will be, amongst other things:

- to review and refine criteria for weir review;
- to review and refine criteria for approval to construct new or expanded weirs;
- to provide advice on State priorities for weir management;
- to recommend on funding priorities;
- to promote the goal and principles of the State Weirs Policy; and
- to conduct an annual audit over the implementation and performance of the State Weirs Policy.

WHOLE OF GOVERNMENT APPROACH

DEPARTMENT OF LAND AND WATER CONSERVATION

The Department of Land and Water Conservation is the agency responsible for coordinating the implementation of the water reforms. The department will work closely with the community and other government agencies to define the mix of environmental, economic and social outcomes it wants, then manage the development, use and protection of our natural resources to achieve these outcomes.

ENVIRONMENT PROTECTION AUTHORITY

The Environment Protection Authority (EPA) is leading the process for recommending to the Government interim environmental (river flow and water quality) objectives for New South Wales intrastate rivers.

The EPA will audit the achievement of environmental objectives.

NSW AGRICULTURE

NSW Agriculture is committed to helping NSW food and fibre industries and our rural communities to be economically viable and environmentally sustainable.

NATIONAL PARKS AND WILDLIFE SERVICE

The National Parks and Wildlife Service is concerned with ensuring healthy and sustainable water resources in the future, including an equitable share of water for the environment.

NSW FISHERIES

NSW Fisheries will use the findings of its NSW Rivers Survey to pinpoint areas where there are problems - especially with carp - and seek remedial action to improve conditions for native fish and fish habitat, e.g. better water quality, increased water flows and removal of impediments to flow.

HEALTHY RIVERS COMMISSION

The Healthy Rivers Commission is holding independent public inquiries into individual rivers. The Commission will recommend longer term environmental objectives for each river and strategies to achieve them.

NSW GOVERNMENT | Office of Environment & Heritage

PP_2017_SMONA_001_00
DOC17/250451

Grantley Ingram
Deputy Director Service Planning
Snowy Monaro Regional Council
PO Box 714
COOMA NSW 2630
via email: council@snowymonaro.nsw.gov.au

Dear Mr Ingram

RE: Planning Proposal to Permit Water Storage Facility at Bombala

Thank you for referring the above planning proposal to permit a water storage facility at Bombala to the Office of Environment and Heritage (OEH) for our review and advice. We have reviewed the biodiversity, Aboriginal cultural heritage and flooding potential impacts of the proposed plan amendment.

The proposal is for Snowy Monaro Regional Council to construct a water storage weir on the Bombala River to augment the existing town water supply storage capacity. The weir is to be located on top of a natural sandbar at central point in town and would most likely incorporate a gabion rock basket and fish ladder. The structure would raise the level of the existing pool by about 1.5 metres, which would extend upriver to the existing weir on Coolumbooka River, where the elevation of the water level is not expected to exceed about 10 centimetres.

It is recognised that proposal has only currently a concept design at the LEP amendment stage to enable it to be made a permissible use in the zone. That final design will be confirmed and detailed assessment carried out as part of the Review of Environmental Factors for the project.

Biodiversity

OEH has reviewed the *Terrestrial and Aquatic Biodiversity Assessment Bombala Weir and Low-level Bridge* February 2016 by Envirokey and supports its recommendations and conclusions.

EnviroKey report concludes that the proposal is unlikely to have a 'significant effect' on any listed threatened species, communities, populations and their habitats and the current rezoning proposal should proceed. Also that the mitigation measures detailed within Chapter 5 should be adopted and implemented.

Of particular importance is the recommendations in regard to the area as platypus habitat. Two individuals were observed utilising the area during the site survey. This is going to require carefully planning and design in the detailed assessment at the REF stage.

OEH support the recommendation that a qualified ecologist would inspect the banks of the river where proposed bridge and weir construction would be undertaken prior to works beginning to ensure no platypus burrows are present. That a contingency plan would be formulated if so. Also that a Platypus management plan would be created following the management guides set out by the Australian Platypus Conservancy (http://www.platypus.asn.au) and Platypus Spot (www.platypusspot.org). This should be resolved before the detailed design is finalised as it would provide an opportunity to incorporate platypus friendly measures into the project.

In this regard *Queanbeyan Platypus Awareness and Conservation Strategy 2012* prepared by Australian Platypus Conservancy has many relevant design considerations for urban friendly riparian environment for the species. This document and other sources of information can be found at www.qcc.nsw.gov.au/Environment/Sustainability/Platypus-Awareness-and-Conservation/Platypus-Awareness-and-Conservation

Aboriginal cultural heritage

In relation to Aboriginal cultural heritage matters; OEH advises that several Aboriginal sites are known to occur around the Bombala township and within the general locality of both the existing and proposed impoundments of the Coolumbooka Weir. These sites were recorded during previous archaeological assessments which concluded that there is potential for further evidence of Aboriginal heritage values to occur across the current subject area. As the planning proposal itself indicates, while no Aboriginal objects are recorded on AHIMS in the immediate area this may be because no Aboriginal cultural heritage survey has been conducted rather than reflecting an actual absence of Aboriginal objects. The Bombala River itself is a significant landscape feature that is often associated with Aboriginal people's traditional use of an area.

As such, OEH advises that while the current planning proposal may not specifically impact any Aboriginal objects at this time, any future development in this area will require a comprehensive Aboriginal cultural heritage assessment to be undertaken. Details regarding specific requirements for the preparation of Aboriginal cultural heritage assessments and AHIP applications can be found within the guidance material listed below;

OEH Guidelines

- Guide to investigating, assessing and reporting on Aboriginal cultural heritage in NSW. OEH 2011. Available online at: http://www.environment.nsw.gov.au/resources/cultureheritage/20110263ACHguide.pdf
- Code of practice for archaeological investigation of Aboriginal objects in New South Wales, DECCW 2010. Available online at: http://www.environment.nsw.gov.au/resources/cultureheritage/10783FinalArchCoP.pdf
- Aboriginal cultural heritage consultation requirements for proponents 2010. DECCW 2010. Available online at: http://www.environment.nsw.gov.au/resources/cultureheritage/commconsultation/09781ACHconsultreq.pdf
- Applying for an Aboriginal Heritage Impact Permit guide for applicants, OEH (2011). Available online at: http://www.environment.nsw.gov.au/resources/cultureheritage/20110280AHIPguideforapplicants.pdf

Flooding

The planning proposal makes reference to hydraulic assessment of the weir being in the FRMS. OEH has reviewed both the flood study and floodplain risk management study for Bombala and can't find any explicit reference to any proposed water supply weir in the Bombala River or potential impacts.

Could Council please forward a copy of the report in this regard.

Please contact Miles Boak on (02) 62297095 or by email miles.boak@environment.nsw.gov.au if you have any further questions regarding this development application.

Yours sincerely

24/5/17

ALLISON TREWEEK
Senior Team Leader - South East Planning
Regional Operation Division

Our Ref: STH12/00088/02
Contact: Andrew Lissenden 4221 2769
Your Ref: PP_2017_SMONA_001_00

NSW GOVERNMENT | Transport Roads & Maritime Services

6 June 2017

Grantley Ingham
Snowy Monaro Regional Council
BY EMAIL: council@snowymonaro.nsw.gov.au

PLANNING PROPOSAL – TO AMEND BOMBALA LOCAL ENVIRONMENTAL PLAN 2012 TO PERMIT A WATER STORAGE FACILITY ALONG SECTIONS OF THE BOMBALA RIVER (PP_2017_SMONA_001_00)

Dear Grantley

Roads and Maritime Services (RMS) refers to your email to Transport for NSW dated 18 April 2017 regarding the above planning proposal (PP) and subsequent email from Transport for NSW dated 15 May 2017 seeking RMS comment.

RMS has reviewed the information provided and wishes to seek clarification of the following in order to provide an informed comment:

- *SP2 Infrastructure Zoning:* The proposal seeks to rezone land inclusive of the lot that contains the Classified Road and associated bridge that crosses the Bombala River to SP2 Infrastructure (refer to Attachment 1). This bridge as well as a separate bridge over the Coolumbooka River at Bombala/Crankkies Plains, which adjoins the PP area (refer to Attachment 2) are controlled, inspected and maintained by the RMS.

  RMS acknowledges the intent of the proposed rezoning so as to allow water supply systems and permit the expansion of a water storage facility on the affected land which, based on the submitted PP, includes the above lot on which the bridge that crosses the Bombala River is located. It is also acknowledged that the rezoning will allow a range of works in the proposed SP2 zone as 'development permitted without consent' or as 'exempt development'.

  Concern is therefore raised that works could occur within close proximity to the existing bridges without any consultation with RMS. A review of the submitted PP and the provisions of *State Environmental Planning Policy (Infrastructure) 2007* has failed to locate any requirement for consultation to occur with RMS. Noting this concern, RMS seeks advice on what measures will be put in place to ensure that consultation with RMS is undertaken prior to the commencement of any works that may impact on the Classified Road and associated bridge structures that cross the Bombala River and Coolumbooka River (i.e. no works shall be carried out within either bridges footprint unless it is authorised by RMS – refer to comments below under the heading 'Existing Bridges' for details on each bridges footprint).

- *Flooding Impacts/assessment:* Noting the above comments and the general comments provided below in relation to each of the bridge structures that may be impacted upon, RMS at this time is unclear as to what impacts the PP will have on each structure. The main concern relates to the existing bridge over Bombala River at Bombala (RMS Bridge No. 7585). The RMS drawings for this bridge do not contain Australia Height Datum (AHD) details. As such, the levels provided can't be correlated with the proposed weir structure and resultant maximum water level. As this bridge has not been designed to be submerged, additional flood information is required to satisfy RMS that the bridge will not be impacted upon.

In addition to the above, RMS provides the following general comments for Council's consideration:

- *Existing Bridges:* There are currently two bridges that are controlled, inspected and maintained by RMS that may be affected by the PP (refer to Attachment 2). Additional details on each is provided below:
  - Bridge over Bombala River at Bombala (RMS Bridge No. 7585):
    - This is a plank concrete bridge with eight spans with a total bridge length of 121m and overall width of 13m. The bridge was built in 1986;
    - The bridge is suitable for Higher Mass Limit (HML) loading;
    - No works should be carried out within the bridge footprint unless is authorised by RMS. The total bridge footprint is defined by its length and width that is 121 m and 15m;
    - The bridge drawings that RMS have do not have Australia Height Datum (AHD). As such, the levels can't be correlated with the proposed weir structure. A survey will be required.
    - The latest inspection conducted on the bridge in March 2107 noted a flood level on Pier 1 which was one metre down from the soffit of the headstock. The river level was 6.5m during the inspection; and
    - The bridge hasn't been designed to submerged, so a flood study/assessment required for the proposed area so as to clearly identify any impacts of the proposal on the bridge.
  - Timber Truss Bridge over Coolumbooka River at Bombala (RMS Bridge No. 6129):
    - It has a two timber-truss span and four timber girder span. The total length and width of the bridge are 87m and 6m. The bridge was built in 1893 and under the timber truss strategic the bridge has been identified for replacement within 10 years.
    - The bridge is suitable only for General Access (ST42.5 and TDT50T);
    - No works shall be carried out within the bridge footprint unless is authorised by RMS. The total bridge footprint is defined by its length and width that is 87m and 10m;
    - The bridge drawings doesn't have Australia Height Datum (AHD) so the levels can't be correlated with the proposed weir structure; and
    - Flood in 2011 reported water level 300mmover the top of the bridge deck.

RMS will reconsider the PP once the above issues/clarification is provided. Please ensure all future correspondence relating to this matter is sent to development.southern@rms.nsw.gov.au and quote RMS reference STH12/00088/02.

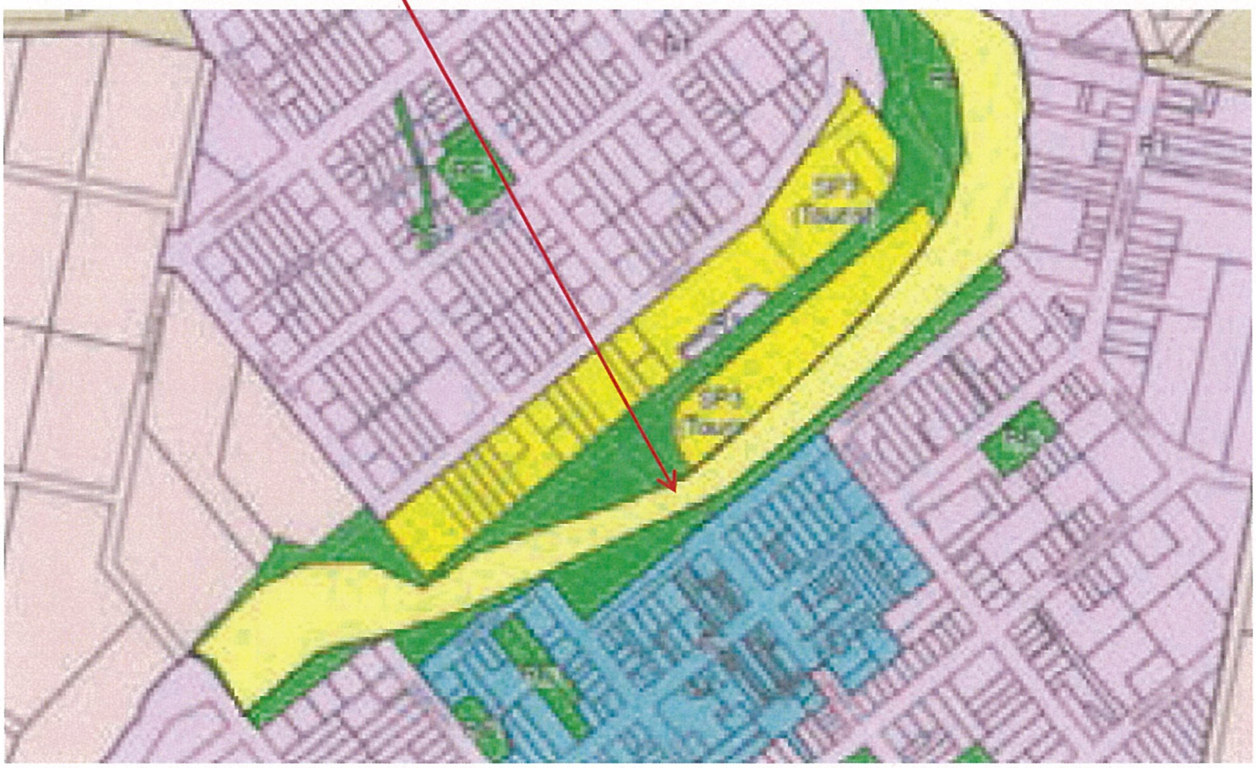
If you have any questions please contact Andrew Lissenden on 4221 2769.

Yours faithfully

Andrew Lissenden
A/Manager Land Use
Southern Region

Attachment 1

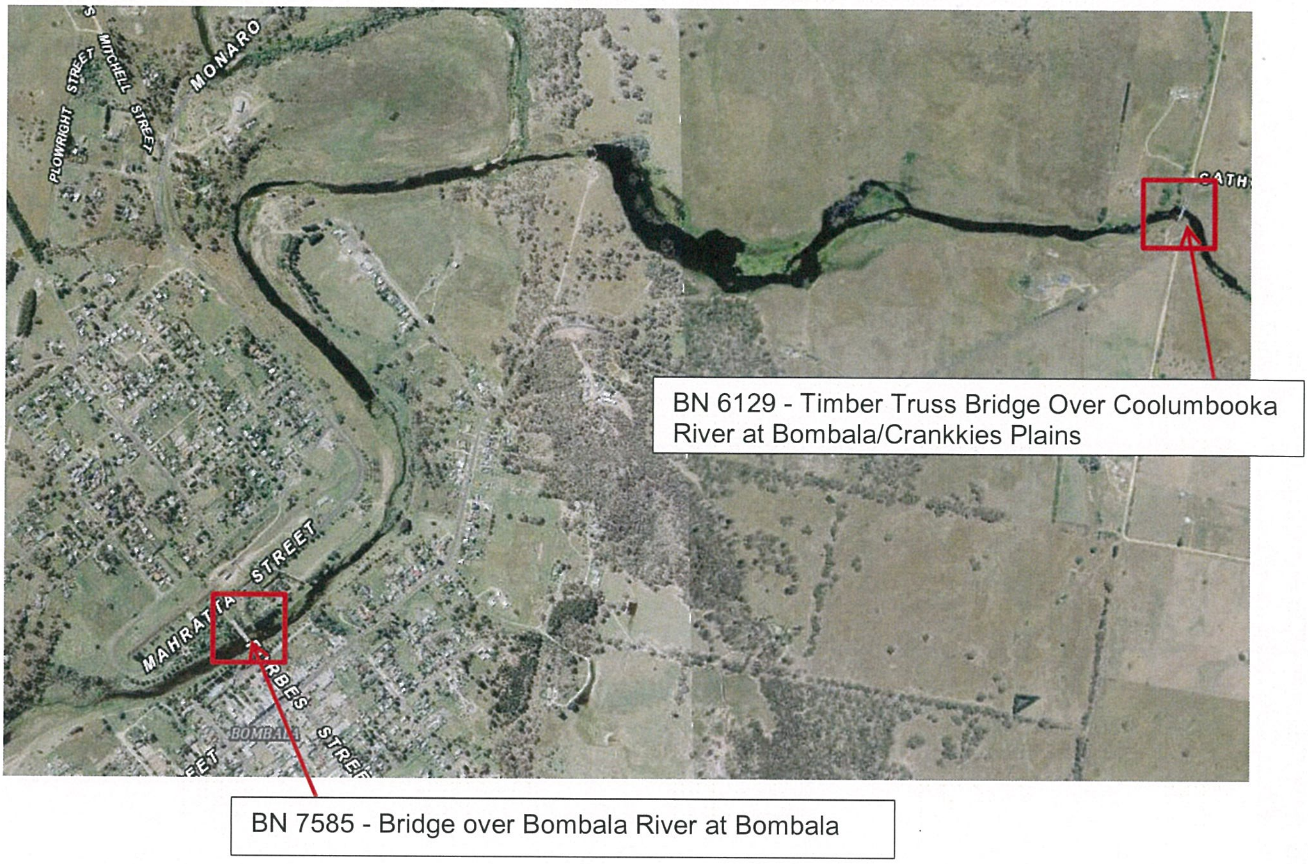
RMS bridge/asset that it is proposed to rezone SP2 – Water Storage Facility – Bridge No. 7585



Roads & Maritime Services

Level 4, Southern Regional Office, 90 Crown Street, Wollongong NSW 2500 | PO Box 477 Wollongong East NSW 2520
T 02 4221 2460 | **F** 02 4221 2777 | **www.rmservices.nsw.gov.au** |

Attachment 2



NSW EPA

Our reference: DOC17/280501-01
Contact: Carlie Armstrong (02) 6229 7002

The General Manager
Snowy Monaro Regional Council
PO Box 714
Cooma NSW 2630
Attention: Mr Grantley Ingram

Dear Mr Ingram,

Planning Proposal (PP_2017_SMONA_001_00) to Amend Bombala Local Environmental Plan 2012

Thank you for your referral to the NSW Environment Protection Authority (EPA) of the above planning proposal on 01 May 2017. The EPA understands that the proposed amendment will permit the expansion of a water storage facility on a section of the Bombala River and rezoning of land associated with the existing Coolumbooka River storage for the purposes of securing town water supply.

The EPA is not an approval body in the assessment of the proposed amendment of the LEP. Accordingly the EPA does not have any comments on the proposed amendment of the LEP. However, the EPA is the Appropriate Regulatory Authority (ARA) pursuant to Section 6 of the *Protection of the Environment Operations Act 1997* (POEO Act) for activities carried on by a State of Public Authority. Accordingly, EPA is the ARA for activities carried on by Snowy Monaro Regional Council (Council), including works to expand water storage on Bombala River. In this regard, pending approval of the amendment to the LEP and prior to any works to construct the proposed weir, the EPA provides the following comments for consideration:

Water (Sediment and Erosion Control – Construction Phase)

Activities at the site must be carried out to ensure that any discharge from the premises complies with Section 120 of the POEO Act. Stormwater management and sediment and erosion control should be managed in a manner consistent with the guidelines "Managing Urban Stormwater: Soils and Construction" (*Landcom, 2004*). Sediment and erosion control measures must consider clean water diversion around the construction site in order to reduce the volume of "clean" water to be controlled.

During construction of the weir, particular care must be taken to avoid pollution of waters and to ensure that stormwater discharge criteria and work plans are developed in consideration of the general framework outlined in the NSW Water Quality Objectives and Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000).

Noise

Noise generated during the construction phase of the project must be managed in a manner consistent with the principles stated in the "Industrial Noise Policy" (*NSW EPA, 2000*). The amenity of any residents adjacent to the proposal must be considered.

Air

Council must ensure that dust is managed on site to reduce the potential for pollution of waters or impact on amenity of adjacent residents.

General

The EPA emphasise that all activities must be carried out with due diligence, duty of care, and in accordance with best management practices. All staff associated with operations at the site of the proposed works must be aware of the strict liability provisions of the POEO Act, particularly section 120 of the Act which prohibits the pollution of waters. In this regard, all personnel involved in the works for the proposal should be aware of the details of the works plans, legislation and associated pollution controls, and the environmental sensitivity of the receiving waters before any works commence.

The EPA would appreciate the opportunity to provide further comments once the environmental assessment for construction of the weir has been developed.

Thank you for discussing this matter with the EPA. If you have any queries or wish to discuss this matter further, please contact Carlie Armstrong or myself on (02) 6229 7002.

Yours sincerely

17-5-2017

Mr Matthew Rizzuto
Unit Head - South East Region
Environment Protection Authority

Transport for NSW

The General Manager
Snowy Monaro Regional Council
PO Box 714
COOMA NSW 2630

Attention: Grantley Ingram

Exhibition of Planning Proposal (PP_2017_SMONA_001_00) to Amend Bombala Local Environmental Plan 2012

Dear Mr Sir/Madam

Thank you for your letter 18 April 2017 requesting Transport for NSW (TfNSW) review and comment on the amendments to the Bombala Local Environmental Plan 2012.

TfNSW have reviewed the documentation supplied in support of the above proposal and have no comment at this stage of the planning process. Please note that Roads and Maritime Services (RMS) will be providing a separate submission.

Thank you again for requesting TfNSW comment on this proposal. If you have any further questions, Mr Lee Farrell, Transport Planner at TfNSW, would be pleased to take your call on (02) 8202 2944. I hope this has been of assistance.

Yours sincerely

6/6/17

Mark Ozinga
Principle Manager, Land Use Planning and Development
Freight, Strategy and Planning Division

CD17/04706

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Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
A	L. De Rango M. Chapman B.Jackson	M. Chapman	*M.Chapman*			7/5/2020
0	L. De Rango M. Chapman B.Jackson	M. Chapman	*M.Chapman*	John Wearne	*John Wearne*	21/5/2020
1	J Wearne	M Chapman	*M.Chapman*	John Wearne	*John Wearne*	12/6/2020

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