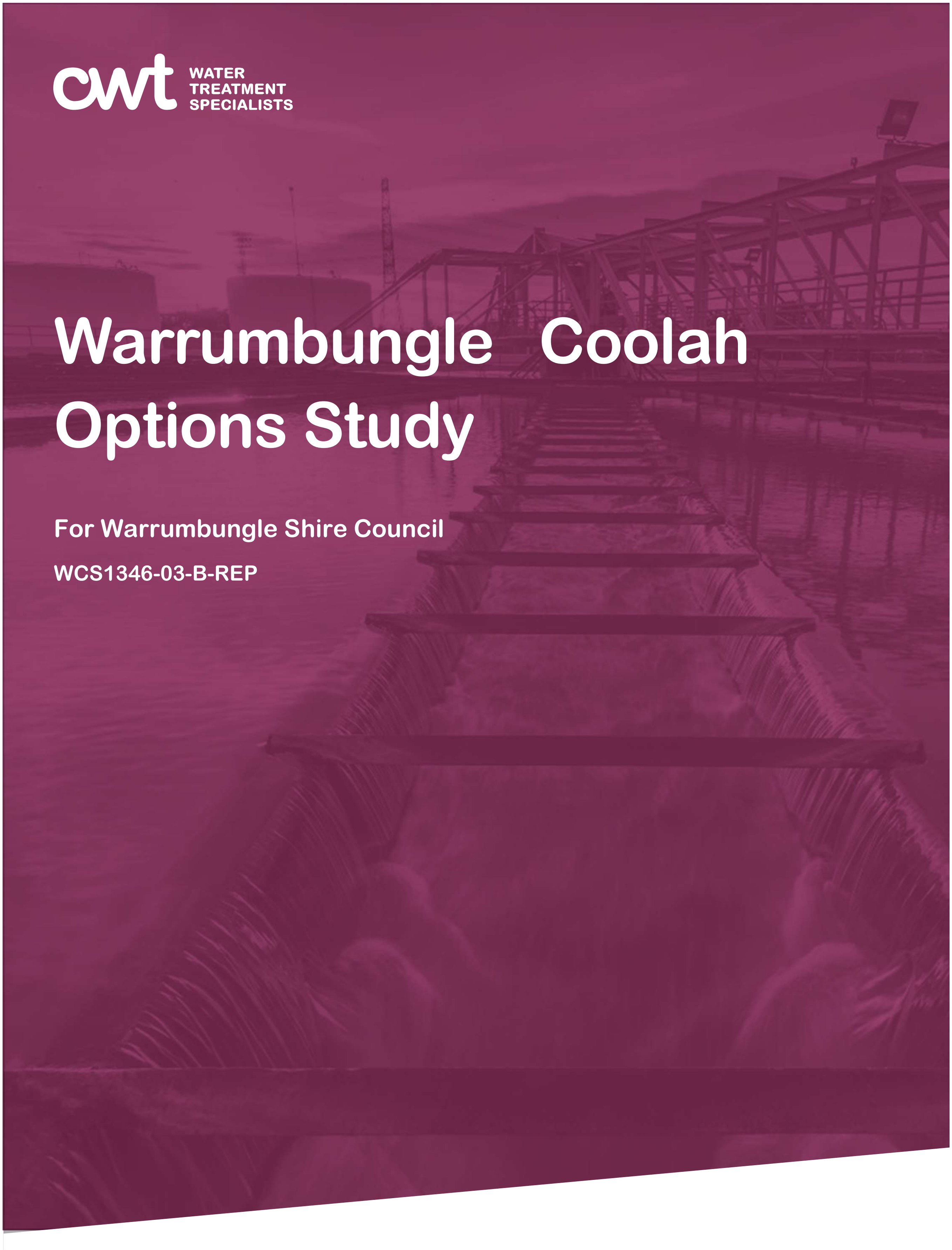

cwt WATER TREATMENT SPECIALISTS

Warrumbungle Coolah Options Study

For Warrumbungle Shire Council

WCS1346-03-B-REP

16 July 2021

Warrumbungle Coolah Options Study

For Warrumbungle Shire Council

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1 Introduction

City Water Technology (CWT) were engaged by Warrumbungle Shire Council (WSC) to conduct an options study for the Coolah Water Supply System. The key objectives of the options study were to improve water stability to minimise corrosion, determine the cause of heavy metals and improve disinfection and reduce water age.

Achieving these objectives would allow WSC to ensure water safety and public health, improve water security, reduce risk of population migration, and increase the potential to attract new residents to the township of Coolah.

This report includes the following:

- A data review of historical samples;
- Summary of the Coolah monitoring program and water stability modelling;
- Site visit observations;
- Design basis for the options assessment;
- Summary of potential treatment options;
- Options assessment; and
- Recommendations.

2 Background

2.1 Existing System

The existing Coolah Water Supply System consists of:

- Main bore field;
- Chlorine gas disinfection;
- Two treated water reservoirs; and
- Existing rising main and the reticulation network.

The main bore field is located along Town Wells Rd and consists of 4 bores: 1) Coolah Town Wells - main supply (also known as Bore 2), 2) Coolah Back-up Well (also known as Bore 1) 3) Coolah - Extra Well, 4) Coolah – Old Bore (decommissioned). The main bore field provides a dedicated supply of bore water, with each bore having a capacity of 15 L/s or 1.3 ML/d, based on 24 h/d operation. According to a recent condition assessment (AEP, 2021), the bores are in good, working order. Located within the main bore site are contained fluoride and chlorine gas dosing systems that facilitate the addition of fluoride (currently not commissioned) and chlorine for disinfection. A backup bore was also built at Neilrex Rd which includes a small chlorine gas dosing system and direct connection to the primary treated water reservoir. The backup bore at Neilrex Rd was never properly commissioned and is currently not in use.

Treated water from the main bore supply system enters the existing rising main where it can be distributed both directly to consumers, and to the treated water reservoirs. There is a new rising main currently being built that will provide water directly to the Martin St reservoir.

The two treated water reservoirs are located at the end of Martin St and Wentworth Ave. The Martin St reservoir is used as the primary treated water reservoir for the township of Coolah with a capacity of 1.08 ML. The Wentworth Ave reservoir is the secondary treated water reservoir and consists of two hydraulically linked tanks, with a combined capacity of 0.09 ML. There is also a booster pump located upstream of the Wentworth Ave reservoir.

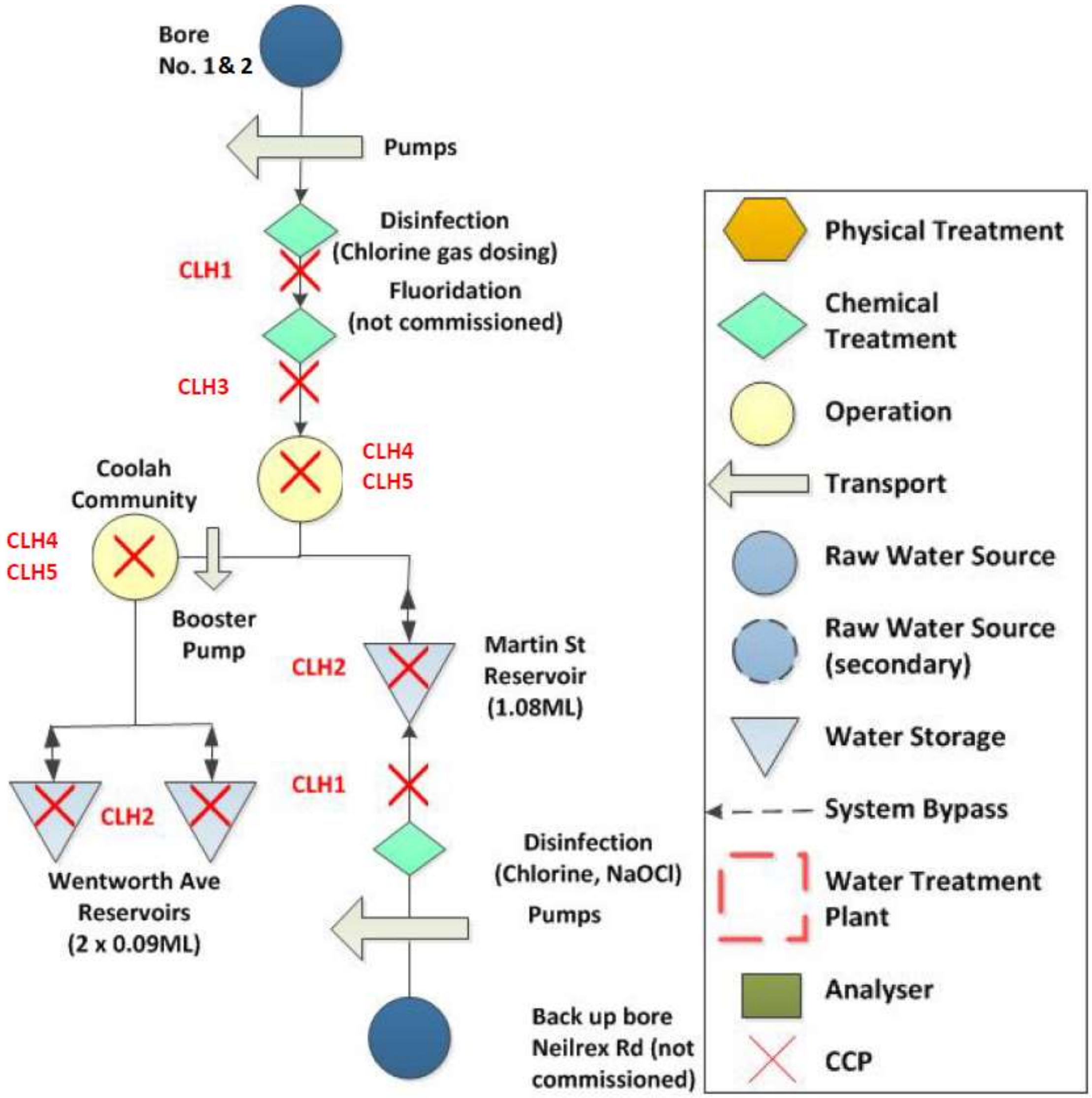

Figure 2-1 Coolah Water Supply flow diagram (Warrumbungle Shire Council DWMS Annual Report, Dec 2019)

2.2 Issues Summary

The main issues of the Coolah Water Supply System are:

- Water stability;
- Heavy metals; and
- Disinfection and water age.

A recent report from Hunter H2O on the water stability of the Coolah Water Supply System indicates the treated water in the reticulation network has a high level of aggressive CO_2. The report indicates the high level of entrained CO_2 is producing corrosive conditions which is contributing to the poor state of the Martin St reservoir. An inspection report of the reservoir developed by Hunter H2O had revealed extensive spalling due to corrosion of the steel reinforcement. There is also a concern that the corrosive conditions in the water will result in an increase of heavy metals such as copper leaching into the water from pipes and fittings.

Water age is another issue that is impacting disinfection and potentially leading to higher levels of corrosion and therefore increased concentrations of heavy metals in the network. As mentioned previously, treated water from the main bore supply system enters the existing rising main where it can be distributed directly to the reticulation network or to the reservoirs. If demand is low this can lead to extended periods with little turnover resulting in long water age, low chlorine residual and potentially a higher concentration of heavy metals in particular locations due to corrosion.

Hunter H2O also reported that the hardness of the treated water was above the Australian Drinking Water Guideline (ADWG) aesthetic limit leading to an increased potential for scaling in the system. Community acceptance on levels of hardness can vary but the aesthetic guideline established in the ADWG is 200 mg/L as $CaCO_3$. Treated water with a hardness above this limit would lead to an increased build-up of scale in water-using appliances, as well as increased detergent use.

3 Data Review and Preliminary Investigations

The purpose of the data review and preliminary investigation is to confirm that the issues presented in previous reports are still relevant and to provide a basis for the proposed additional water monitoring program.

3.1 Coolah Bores

A recent condition assessment of groundwater bores completed by Access Environmental Planning outlined the properties of each of the bores located at the main borefield. Table 3-1 shows a summary of this report. The Town Wells bore is the primary bore used to supply town. According to diagrams presented in the AEP report, the Town Wells bore passes through 3 different aquafers (18.3-20.7m, 33.5-42.6m and 51.8-54.8m). It is unclear as to which aquifer the water is being sourced from and whether they are discrete or interconnected.

AEP recommend that a further detailed condition assessment be conducted by dropping a camera down the bore hole and recording observations. This will aid in further understanding of bore integrity and the risk of surface water ingress.

Table 3-1: Summary of Bores at Coolah (AEP, 2021)

Name	Year	Status	Yield L/s	Depth (m)	Diameter (mm)	Case	Screens (m)	Water table (m)	Operation
Old bore	N/A	Capped	18.9	9.3	300	Concrete cylinder	N/A	N/A	N/A
Town Wells	1996	Main source	15	70	219?	Welded mild steel 0-55.5 m	15-55	6	13m off 4m on
Back up Well	1965	Functional	12.6	10.1	1800	Concrete cylinder	N/A	5	
Extra Well	1963		N/A	11.5	N/A	Welded steel	9.5-11.5	4.5	

3.2 Historical Water Quality Analysis

3.2.1 Treated Water Quality

Table 3-2 shows a summary of the key water quality parameters measured in the Coolah reticulation between April 2018 and April 2020, under the NSW Health Drinking Water Monitoring Program. Hardness remains a concern since all the measurements in this 2-year period are higher than the ADWG guideline. Total dissolved solids (TDS) is also high but still within the ADWG values.

Table 3-2 Treated water quality summary (April 2018 – April 2020)

Parameter	Unit	Minimum	5th %ile	Average	Median	95th %ile	Maximum	ADWG Value
Calcium	mg/L	67.4	67.5	71.7	72.3	75.8	76.1	N/A
Magnesium	mg/L	55.1	55.3	61.7	62.5	68.4	69.0	N/A
Sodium	mg/L	30	31	35	36	39	40	180
Total Dissolved Solids (TDS)	mg/L	321	350	444	465	492	496	600
Total Hardness as $CaCO_3$	mg/L	395	396	433	438	471	474	200

3.2.2 Heavy Metals

Table 3-3 shows a summary of metals concentrations measured in the Coolah reticulation between April 2018 and April 2020, under the NSW Health Drinking Water Monitoring Program. Only the metals that were measured at concentrations above the limit of detection are shown.

Table 3-3 Heavy metals summary (April 2018 – April 2020)

Parameter	Unit	Minimum	5th %ile	Average*	Median	95th %ile	Maximum	ADWG Value
Aluminium	mg/L	<0.01	<0.01	0.010	<0.01	0.018	0.020	0.2
Barium	mg/L	0.015	0.015	0.017	0.017	0.020	0.020	2
Copper	mg/L	0.047	0.050	0.12	0.069	0.28	0.33	1
Iron	mg/L	<0.01	<0.01	<0.01	<0.01	0.017	0.020	0.3
Lead	mg/L	<0.002	<0.002	0.0021	<0.002	0.0041	0.0048	0.01
Zinc	mg/L	0.020	0.022	0.042	0.040	0.066	0.070	3

*** -Samples below the limit of reporting were assumed to hold a value of 'LOR/√2' for the purpose of calculating average**

There have been no exceedances of ADWG limits for metals in this 2-year period. Relatively high (much higher than median) concentrations of Copper and Lead were detected at 23 Binnia St on the 9th of March 2020.

3.2.3 pH

pH is recorded approximately 5 days a week by WSC at the Martin Street reservoir and Wentworth Avenue reservoirs. The measurements from January 2018 to April 2020 have been trended in Figure 3-1. The trend indicates that the water supply at Coolah is not stable and pH can vary significantly.

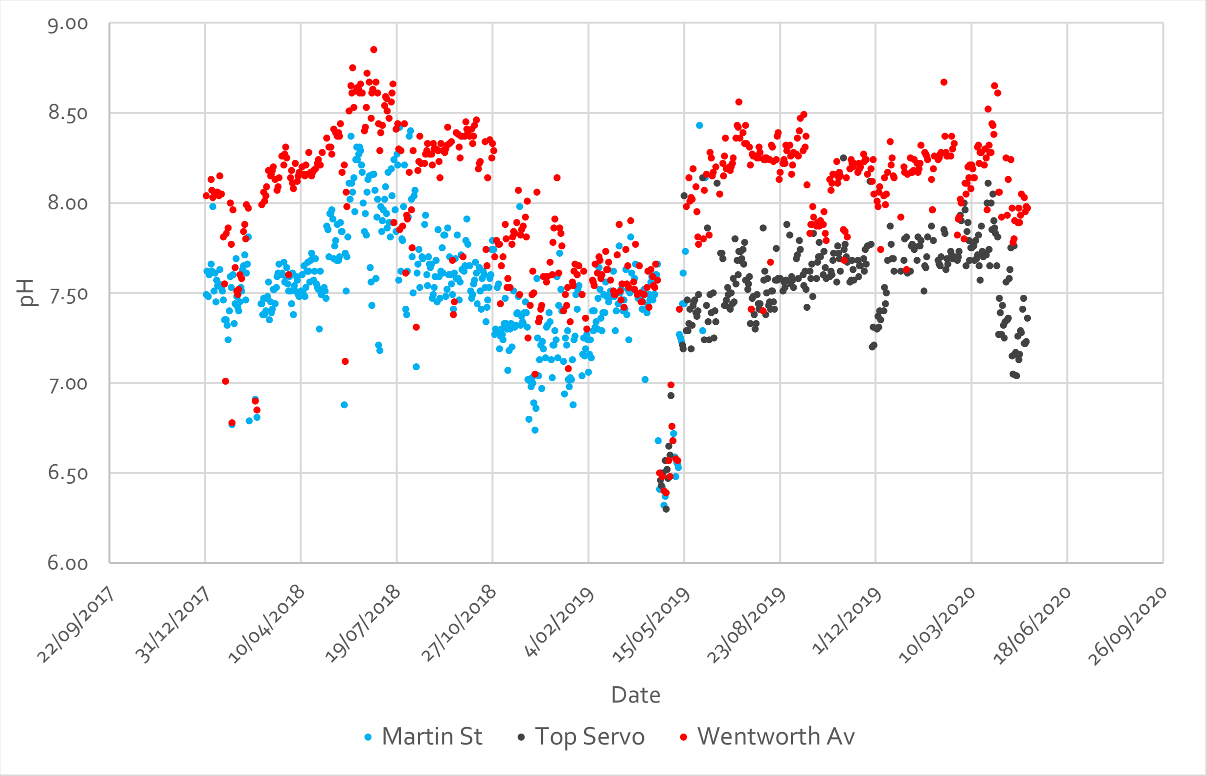

Figure 3-1 pH measurements at Martin St, Top Servo and Wentworth Ave (January 2018 – May 2020)

Previous investigations showed that pH began to deviate between the two reservoirs from April 2016, with the Wentworth Avenue reservoir slightly higher than the Martin St reservoir. This trend continues into the latter part of 2018 and start of 2019. A clear trend between pH and season can also be observed in the two reservoirs. The reason for the unusual dip in pH in April 2019 is not clear with the data and information provided; pH values below 6.6 would indicate corrosive conditions. Following this event, samples were no longer taken at the Martin St Reservoir and taken at the Coolah Top Servo instead. Top Servo represents the point in which the water from the bore enters the town reticulation and should provide a good indication on treated water condition prior to entering the reticulation and/or reservoirs.

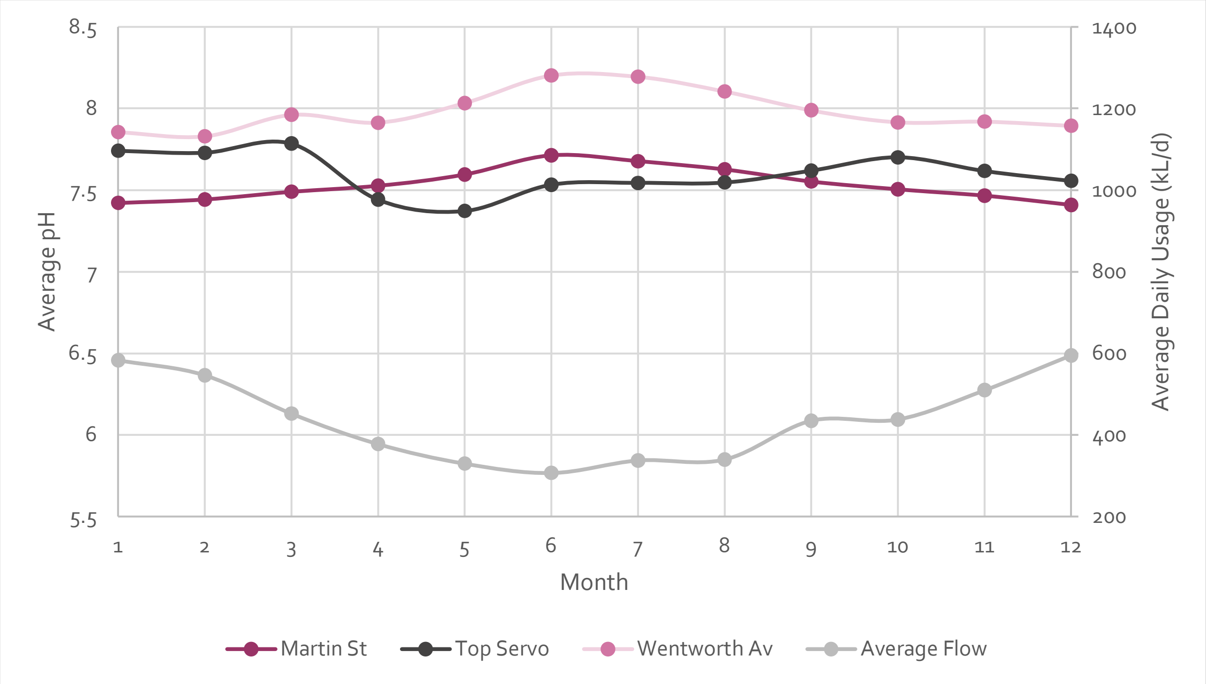

Figure 3-2 Average pH and flow at Martin St, Top Servo and Wentworth Ave for 12 months

Figure 3-2 shows monthly average pH for each sample point over a 12-month period following the change in pH data in April 2016. A consistent cycle of pH can be observed in the two reservoirs. This pattern can be directly correlated to the average daily usage of the town. In winter months where the usage is low, the pH in the reservoirs rise. This can likely be attributed to the increased residence time of the water inside the distribution network (including the reservoirs), allowing for more CO_2 to escape. Water will slowly de-gas and equilibrate with the atmosphere without agitation/aeration. The fact that pH is consistently higher in the Wentworth Avenue reservoir suggests a high residence time in that area of the reticulation, or that there is a higher degree of induced aeration at the inlet of the reservoir compared to the Martin Street. These arguments are supported by the fact that there is no clear pattern in the Top Servo pH, although the overall sample size is low at this stage.

3.3 Network Analysis

The Coolah reticulation network was reviewed to determine the location of potential 'dead zones' and identify suitable sampling locations for the proposed additional water monitoring program. Figure 3-3 shows the main sample points around the Coolah reticulation network.

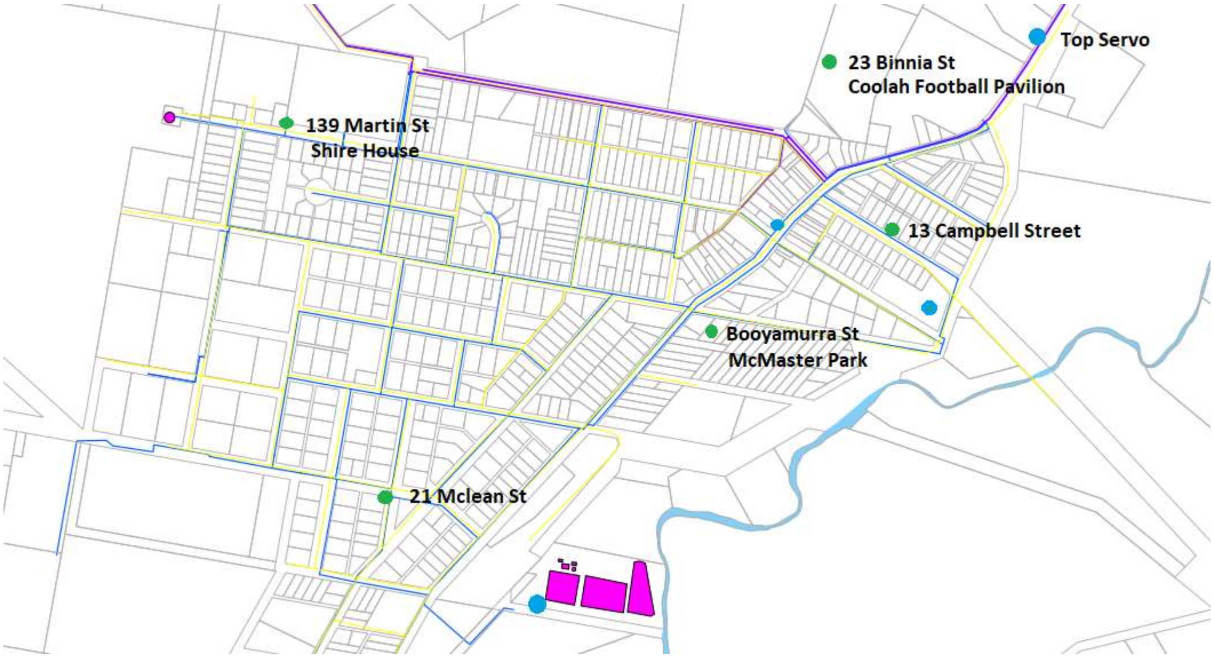

Figure 3-3 Coolah reticulation sample points

Table 3-4 summarises the pH and free chlorine data for each of the sample points since 2016.

Table 3-4 pH and free chlorine summary around Coolah reticulation network (July 2016 – April 2020)

Location	pH				Free Chlorine (mg/L)			
	Count	Min	Avg	Max	Count	Min	Avg	Max
13 Campbell Street	69	6.60	7.42	7.82	75	0.00	1.92	4.40
139 Martin St (Shire House)	66	7.05	7.49	7.93	81	0.38	1.92	5.15
21 McLean Street	85	7.11	7.53	8.00	84	0.27	1.77	4.71
23 Binnia Street Coolah (Coolah Football Pavilion)	70	7.28	7.55	7.96	73	0.05	1.59	4.82
n/a Booyamurra Street Coolah (MacMaster Park)	75	7.15	7.49	8.07	83	0.12	1.60	2.57

The data shows that the pH measured at 13 Campbell Street is lower than other parts of the reticulation. This sample point is in a high usage area at the top end of the town with minimal time for CO2 to escape. A minimum pH value of 6.6 would indicate corrosive conditions. Other pH data is relatively inconclusive and sporadic due to irregular sampling. Seasonal changes in pH are also much less clear in the reticulation compared to the reservoirs. The pH data could also be sporadic due to water supply alternating between directly receiving from the main bore field or older aged water in the reservoirs. Additionally, singular data points are more susceptible to specific factors that may vary from day to day compared to large robust data sets.

Free chlorine data can highlight potential ‘dead spots’ in the reticulation. Similarly to the pH, free chlorine data in Table 3-4 is inconclusive and does not highlight a particular sample point of concern.

There are two cul-de-sacs (Irwin St and Cameron Place) in the Coolah town as seen in Figure 3-4. These types of streets represent possible ‘dead spots’ in the reticulation since water flow is restricted to a single direction. Due to the fire hydrants located in Irwin St, the main may be considerably oversized causing excessive water age. There are also no sample points in the far south-west region of town. A sample on Queensborough St near Walker or Regan St should be taken for pH and Free Chlorine to ensure compliance with ADWG.

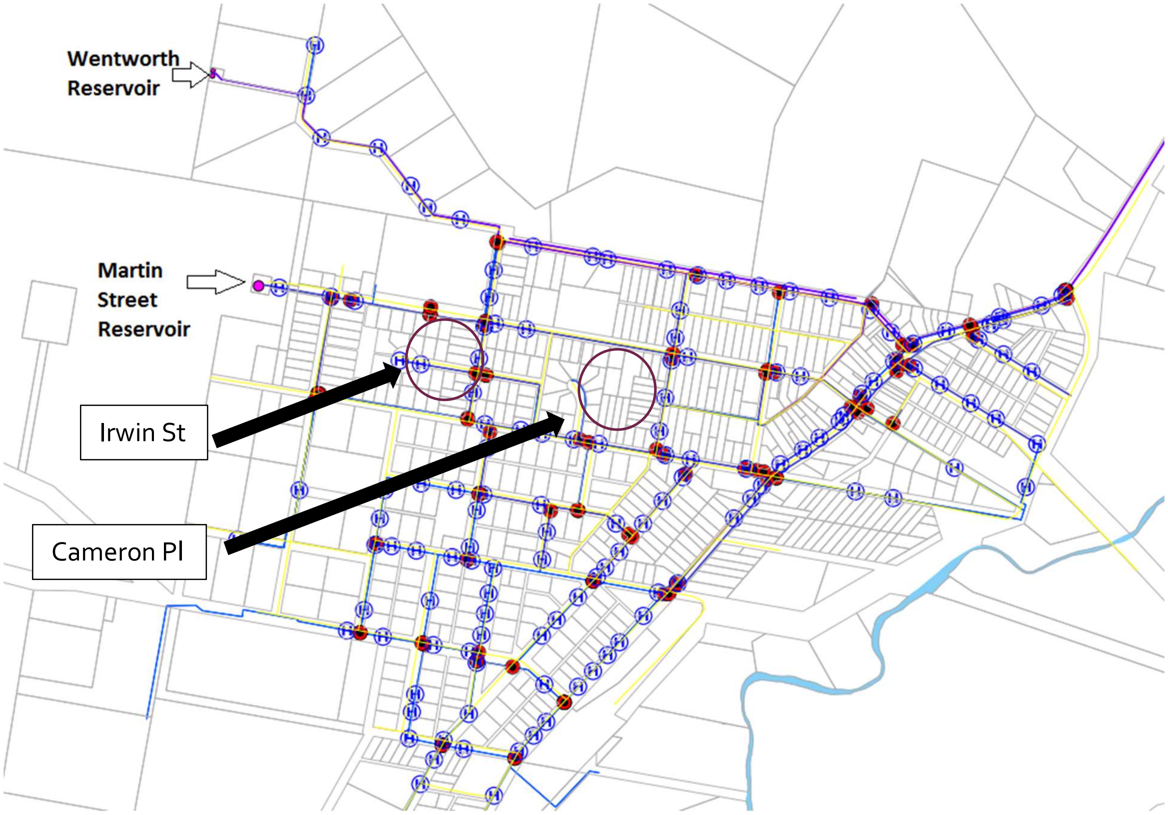

Figure 3-4 Dead spots in Coolah reticulation network

4 Coolah Monitoring Program

A targeted monitoring program was conducted to gain a better understanding of the water quality in the Coolah Water Supply System and to provide a basis for the subsequent treatment options assessment. The goals of the monitoring program were as follows:

- Determine the level of excess CO_2 present in the bore water and around the Martin St reservoir;
- Determine if the corrosivity of the water is increasing the concentration of heavy metals at 'dead spots' in the reticulation network; and
- Gather sufficient data to be able to conduct water stability monitoring and determine the corrosivity and scaling potential of the water.

Sampling was conducted by WSC personnel between 8th July 2020 and 21st July 2020. Additionally, CWT conducted a site visit on 8th July 2020 to observe commencement of sampling and to inspect the Coolah water supply system.

4.1 CO_2 Modelling and Analysis

Additional data was gathered to better understand the level of excess CO_2 present in the bore water and around the Martin St reservoir. The targeted monitoring program for CO_2 involved taking samples from Back-Up Bore, Town Wells Bore, Top Servo and Martin St reservoir. The following parameters were analysed to complete the data set required for CO_2 modelling and analysis:

- Temperature;
- pH; and
- Alkalinity.

The sampling and modelling results are summarised in Table 4-1.

Table 4-1 Field measurements to confirm presence of aggressive CO_2

Location	Flow Direction	Temperature (°C) *	pH *	Total Alkalinity as $CaCO_3$ (mg/L)	Equilibrium CO_2 Conc. (mg/L)	Excess CO_2 (mg/L) – estimated
Town Wells	Out	10.3	7.25	490	61.6	6.36 (+10%)
Back-up Bore	Out	17.5	7.26	480	58.7	-1.09 (-2%)
Top Servo	-	13.5	7.33	471	49.0	3.03 (+6%)
Martin St Reservoir	In	13.1	7.42	N/A	N/A	N/A
Martin St Reservoir	Out	13.1	7.42	463	38.7	1.75 (+4%)

***pH and temperature were analysed immediately at the time of sampling**

The positive level of excess CO_2 in the Town Wells bore indicates there is an increased potential for CO_2 induced corrosion within the Coolah Water Supply System. The Back-up Bore has a negative level of excess CO_2 indicating there is no aggressive CO_2 present from this source. The difference in excess CO_2 levels could be due to the difference in temperature between the two bores. The solubility of CO_2 in water increases with cooler temperatures resulting in a higher concentration of dissolved CO_2.

The data also shows there is a pH and temperature increase from the Town Wells bore as the water travels through the network to Top Servo and Martin St reservoir. This could indicate that CO_2 is gradually being liberated through the network.

4.2 Heavy Metals Analysis

Samples were taken to confirm if the corrosive conditions in the water and water age were resulting in an increase of heavy metals such as copper leaching into the water from pipes and fittings. Identified 'dead spots' include the cul-de-sac on Irwin St, the corner of Queensborough St and Regan St, and the outlet of Martin St reservoir. The main bores were also tested for heavy metals to provide a standard baseline for analysis. Significant increases in the reticulation samples would indicate leaching and subsequent accumulation. Table 4-2 shows select heavy metal results at the bores and identified potential 'dead spots'.

Table 4-2 Heavy metal results by ICP-MS

Parameter	Unit	Sample 1	Sample 2	Sample 3	ADWG Value
Back-up Bore					
Total Copper	mg/L	0.009	0.069	0.047	1
Total Lead	mg/L	0.001	0.003	0.001	0.01
Total Zinc	mg/L	0.018	0.058	0.022	3
Total Iron	mg/L	<0.05	<0.05	<0.05	0.3
Town Wells Bore					
Total Copper	mg/L	1.21	0.372	0.116	1
Total Lead	mg/L	0.011	0.01	0.03	0.01
Total Zinc	mg/L	0.633	0.199	0.074	3
Total Iron	mg/L	0.46	0.32	0.05	0.3
Martin Street Reservoir					
Total Copper	mg/L	0.02	0.011	0.011	1
Total Lead	mg/L	<0.001	<0.001	<0.001	0.01
Total Zinc	mg/L	0.011	0.011	0.012	3
Total Iron	mg/L	<0.05	<0.05	<0.05	0.3
Irwin St					
Total Copper	mg/L	0.098	0.083	0.092	1
Total Lead	mg/L	0.019	0.004	0.018	0.01

Parameter	Unit	Sample 1	Sample 2	Sample 3	ADWG Value
Total Zinc	mg/L	0.061	0.065	0.074	3
Total Iron	mg/L	0.98	0.27	1.02	0.3
Queensborough St					
Total Copper	mg/L	0.018	0.024	0.02	1
Total Lead	mg/L	0.004	0.003	0.002	0.01
Total Zinc	mg/L	0.014	0.022	0.027	3
Total Iron*	mg/L	<0.05	<0.05	<0.05	0.3

***Aluminium, Beryllium and Manganese were measured below the limit of detection**

High copper and iron in the first sample at the Town Wells bore indicate that the sample line was possibly not flushed properly prior to collecting the sample. Despite this, the data indicates that water from the Town Wells bore can be corrosive and water age in the reticulation is an issue. This is especially highlighted in the data from Irwin St with both Iron and Lead concentrations exceeding ADWG limits which would suggest that the main in the cul-de-sac at Irwin St is considerably oversized causing excessive water age.

4.3 Water Stability Modelling and Analysis

Water stability modelling for the Coolah water supply was conducted using the Rothberg, Tamburini & Winsor (RTW) corrosivity model. This model will be used to calculate the corrosivity indices, Calcium Carbonate Precipitation Potential (CCPP) and Langelier Index (LI).

If the CCPP is zero, then the water is saturated in terms of calcium carbonate. If the CCPP is positive then the water is over-saturated and likely to precipitate a film, predominantly of $CaCO_3$, onto pipes and other water supply infrastructure in contact with the water. If the CCPP is negative, then the water is under-saturated and is likely to be corrosive. Various studies have shown CCPP to be an accurate indicator of corrosiveness of concrete and cement linings.

The Langelier Index (LI) has also been found to be an accurate indicator of water scaling and hence corrosivity under most circumstances. It is the difference between the saturated pH and the water's actual pH and is therefore on a logarithmic scale. Again, a negative value indicates that the water is likely to be corrosive and a positive value shows it to be over-saturated and therefore likely to be scale forming.

Based on industry experience, the water quality targets outlined in Table 4-3 below are generally recommended to minimise potential corrosivity in treated waters.

Table 4-3 Treated water targets for corrosion indices

Parameter	Units	Target	Guideline Range
pH	pH units	7.8 to 8	7.6 to 8.2
Alkalinity	mg/L as $CaCO_3$	45 to 55	> 40
Ca Hardness	mg/L as $CaCO_3$	> 40	> 40
CCPP	mg/L	- 3	- 6 to 0
Langelier Index	pH units	- 0.3	- 0.6 to 0

The pH of the water should be above 7.6 for waters leaving the WTP but should not exceed 8.3 as dezincification can occur at pH values of around 8.5 and above. At pH values above 7.0, the effectiveness of chlorine disinfection is reduced.

The RTW model requires accurately determining the following parameters:

- Temperature, °C
- pH
- TDS, mg/L
- Calcium, mg/L as $CaCO_3$
- Magnesium, mg/L
- Alkalinity, mg/L as $CaCO_3$ (determine used the titration method)

Important points regarding the data used to determine the corrosivity indices with the RTW model are listed below:

- All data, except for total dissolved solids, is based on results from Coolah Monitoring Program conducted between 8th July 2020 and 21st July 2020;
- Total dissolved solids for all locations is assumed to be an average of 444 mg/L and is based on measurements made around the Coolah reticulation network by NSW health between April 2018 and April 2020;
- No data was available from the Coolah Monitoring Program for the concentration of dissolved calcium and magnesium at the Top Servo so the values for the Town Wells bore were used;
- Dissolved concentrations of calcium and magnesium were converted to mg/L $CaCO_3$ equivalent values; and
- Total hardness is based on the sum of the dissolved calcium and magnesium concentrations as mg/L $CaCO_3$.

The results from the RTW model are summarised in Table 4-4 below.

Table 4-4 Corrosivity modelling results

Location	Temperature (°C)	pH *	Calcium Hardness (mg/L as $CaCO_3$)	Magnesium Hardness (mg/L as $CaCO_3$)	Total Hardness (mg/L as $CaCO_3$)	Total Alkalinity (mg/L as $CaCO_3$)	CCPP (mg/L as $CaCO_3$)	LI
Town Wells	10.3	7.25	185	269.23	454.23	489.67	34.67	0.26
Back-up Bore	17.5	7.26	180	263.77	443.77	480.33	44.04	0.36
Top Servo	13.5	7.40	185	269.23	454.23	471.00	50.21	0.44
Martin St Reservoir	13.1	7.42	188.33	266.5	454.83	462.67	50.79	0.45

*** Average pH based on 1st and 3rd sample of Coolah Monitoring Program as there were no results available for the 2nd pH sample**

Based on the results above and the typical water quality targets to minimise corrosion, water from Back-up Bore, Town Wells Bore and within the Coolah reticulation network has a high tendency to form calcium carbonate scale as indicated by the positive CCPP and LI values. The CCPP and LI values exceed their respective target and guideline values indicating the raw water from Back-up Bore and Town Wells bore will need additional treatment to ensure the potential for corrosion and scaling is minimised.

5 Site Visit Observations

A site visit was undertaken by CWT on 8th July 2020 to inspect the Coolah Water Supply Scheme, identify potential locations for the proposed treatment options, and observe the commencement of the Coolah Monitoring Program.

CWT inspected the following locations of the Coolah Water Supply Scheme:

- Main bore field including Back-up Bore, the Town Wells Bore, fluoride dosing system and chlorine gas dosing systems;
- Martin St reservoir;
- Wentworth Ave reservoir and booster pumps; and
- Backup bore on Neilrex Rd.

The main bore field and Martin St reservoir are being considered as potential locations for future treatment options.

5.1 Main Bore Field

The main bore field contains Back-up Bore, Town Wells Bore, the fluoride dosing system and the chlorine gas dosing system. The site is securely fenced off from the public and is accessible via an unsealed dirt road. Power is supplied to the site via power poles and has 3-phase power. Telemetry and communications are available onsite via an antenna and 4G is also available.

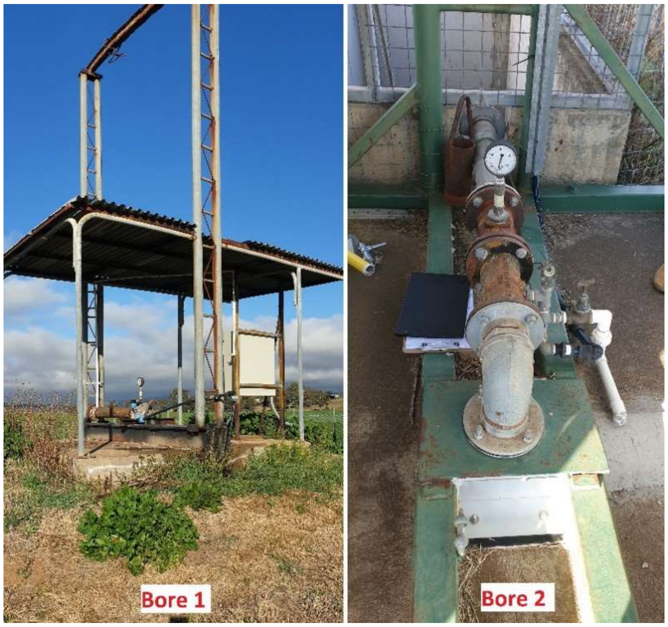

Figure 5-1 Back-up Bore and 2 at the main bore field

Town Wells Bore is the primary bore used to feed the Coolah Water Supply Scheme and can be controlled either from a local control panel or remotely. Back-up Bore is the secondary bore and can only be controlled from a local control panel. Back-up Bore is only operated once a month to check the operation of the bore. Each bore has a capacity of 15 L/s.

According to discussions with WSC and as indicated in the flood map below; access to the bore field can sometimes be cut off due to flooding.

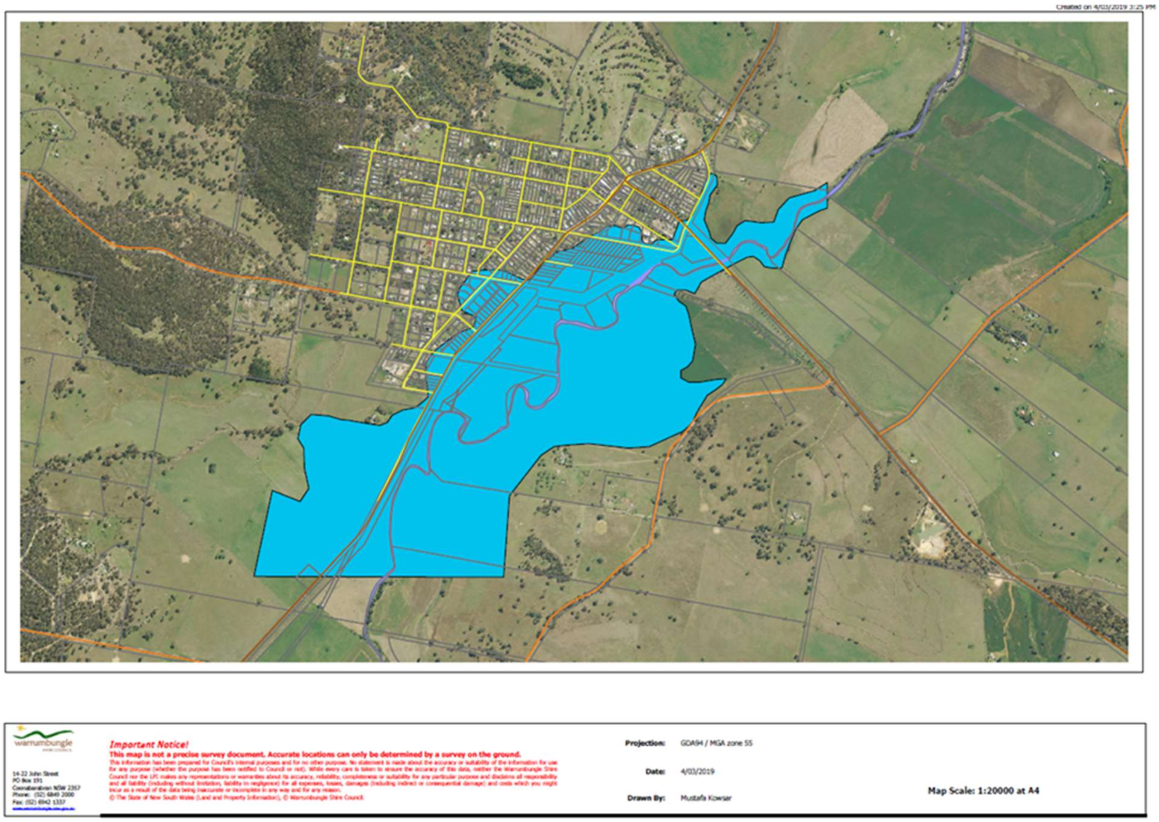

Figure 5-2 Coolah tower flood prone area – elevation 490 m

The fluoride system is housed within a small chemical dosing room mounted on skids and a concrete slab. Due to a lack of operator training and issues with the fluoride dosing system, fluoride is currently not dosed into the Coolah Water Supply Scheme. According to discussions with the operations team the current fluoride system is being replaced with a larger capacity unit.

Figure 5-3 Fluoride dosing room at the main bore field

The chlorine gas system is housed within an elevated concrete structure. Based on discussions with WSC and a scoping paper completed by CWT (WCC1291 Warrumbungle Coolah Portable Chlorination System), the existing chlorine gas system is schedule to be replaced by a new chlorine dosing system. The new chlorine dosing system is to be contained within portable housing and was originally intended to be relocated near the Martin St reservoir.

Figure 5-4 Elevated concrete chlorine dosing structure at the main bore field

The main bore field is a potential location for future treatment options. A summary of the existing infrastructure available at the main bore field has been included in Table 6-1.

5.2 Martin St Reservoir

The Martin St reservoir site contains the 1.08 ML primary reservoir and a Chlorine Clam sampling station. The site is securely fenced off from the public and is accessible via a sealed bitumen road. The current instruments at the site are powered by a solar panel on top of the reservoir. Telemetry and communications are available onsite via an antenna and 4G is also available.

The internals of the reservoir were not inspected during this site visit, but it has been reported by Hunter H2O that the reservoir is in poor condition due to extensive concrete spalling and corrosion of the steel reinforcements. The reservoir has also been shown to have precipitates forming in the tank. The Martin St reservoir is due to be replaced in 2023 – 2024 with a new reservoir to be built at the existing site.

Figure 5-5 Martin St reservoir

The Martin St reservoir site is a potential location for future treatment options. A summary of the existing infrastructure available at the site has been included in Table 6-1.

5.3 Wentworth Ave Reservoir

The Wentworth Ave reservoir is the secondary reservoir and contains two hydraulically linked tanks with a combined capacity of 0.09 ML. A pumping pit containing booster pumps is located outside of the securely fenced reservoir site.

The internals of the reservoir were not inspected during this site visit, but it has been reported by Hunter H2O that the reservoir also has precipitates forming in the tank. The pumping pit was observed to be partially flooded due to a leak in one of the pipe fittings.

Figure 5-6 Wentworth Ave reservoir

Figure 5-7 Pumping pit for booster pumps near Wentworth Ave reservoir

5.4 Neilrex Rd Backup Bore

The site on Neilrex Rd contains the backup bore and a chlorine dosing system. The bore also has a dedicated pipeline to the Martin St reservoir. The backup bore at Neilrex Rd was never properly commissioned and is currently not in use.

Figure 5-8 Neilrex Rd backup bore site

5.5 New Rising Main

A schematic of the current Coolah reticulation network, current rising main and new rising main has been included in Figure 5-9 below.

Construction of the new rising main is still ongoing and the expected date of completion has not been specified. Once completed, the new rising main will supply the Martin St reservoir directly from Back-up Bore and 2. Water can then only be supplied to the Coolah reticulation network from the Martin St reservoir. This will ensure the water is appropriately treated before being distributed to customers and will reduce the overall age of water within the network.

Figure 5-9 Rising main and Coolah reticulation network schematic

6 Design Basis

6.1 Upgrade Objectives

6.1.1 General

Design criteria to be considered during the assessment and design of upgrades for the Coolah Bore Water Treatment include:

- Treated water production capacity;
- Treated water quality targets; and
- General operability/ reliability and safety requirements.

The design basis for these criteria is outlined in the sub-sections below.

6.1.2 Capacity Design Basis

Design basis parameters adopted for the options assessment and subsequent preliminary design of the shortlisted options include:

- 15 L/s instantaneous flow of Bore pumps 1 and 2. These are on/off style pumps so the delivery flow cannot be varied. These bore pumps are never operated simultaneously, meaning that treatment capacity at the bore site is also 15 L/s or 1.3 ML/d, based on 24 h/d operation.

6.1.3 Treated Water Design Basis

Water quality performance targets adopted for the options assessment and subsequent preliminary design of the shortlisted options include:

- Compliance with ADWG, including free chlorine and total hardness;
- Optimal Chlorine contact to maximise log reduction of harmful pathogens; and
- CCPP between 0 and -4.

6.1.4 Health Based Targets

Water quality performance targets must also include adequate log-reduction value (LRV) credits. The following characteristics of a bore source must be considered when characterising the microbial risk and level of protection required:

- Bore depth;
- Surface water influence;
- Protected headworks and bore integrity;
- Regular E.Coli and Coliforms monitoring data – especially after major weather events.

As stated in Section 3, the depth of the main Town Wells Bore is considerably deeper than the Backup Bore and most likely draws from a different aquafer. Without considerable microbial data, the risk is difficult to quantify, however ground water sources with a depth of less than 10 metres are generally considered equivalent to surface water supplies.

Category and Level of Protection	Minimum Pathogen LRV			Typical Minimum Treatment Train Requirement
	Bacteria	Viruses	Protozoa	
Recommended for Category 1 Source	4	0	0	Chlorine disinfection Ct > 15 mg.min/L with pH < 8.5 at all water temps Feed water turbidity < 1.0 NTU

6.1.5 Operability, Reliability and Safety

Operational and other issues considered for the options assessment and subsequent preliminary design of the shortlisted options include:

- Appropriate levels of standby equipment to be provided to minimise risk of plant shutdown;
- Robust process design to minimise potential failures;
- Reliability to allow potential for 24-hour constant operation; and
- Designed to operate automatically with no operator intervention required under normal operation.

6.2 Site Land Area Constraints

6.2.1 Location 1 Bore Field

The current main Bore site (Town Wells Bore and Back-up Bore) is located approximately 3km north east of the town of Coolah. This potential site will be referred to as Location 1. The area within the site boundaries are extensive with ample space for additional treatment processes.

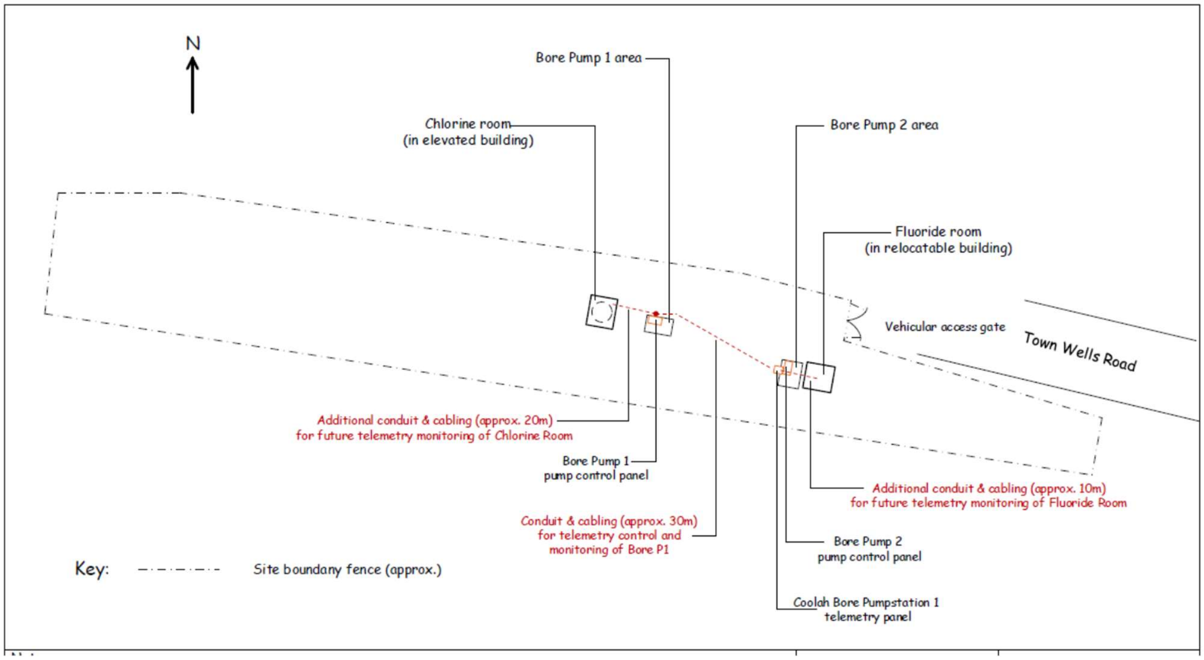

Figure 6-1 Location 1

6.2.2 Location 2 Martin St Reservoir

With the addition of the new rising main, the Martin St reservoir site can also be considered. This potential site will be referred to as Location 2. As seen in the figure below, there is also ample space for additional treatment processes.

Figure 6-2 Location 2 Martin St Reservoir

6.2.3 Location 3 Wentworth Avenue Site

The Wentworth Avenue site is reportedly slightly elevated above the rest of town and could be an appropriate location for a new primary storage reservoir. This potential site will be referred to as Location 3. The current Martin St reservoir is very old and funding has been allocated in the coming years to replace this reservoir. Should a new reservoir be built on the Wentworth Avenue site instead of the Martin St Reservoir site, Coolah could establish a fully linear supply system without the need for additional storage sites. Furthermore, building a new reservoir on the existing Martin St site poses difficulties as the current reservoir would need to be operational during construction.

Comments Peter Mosse on CWT's findings indicate that the Wentworth Ave site may be the best site for a new reservoir and treatment system. Should treatment options be implemented prior to the construction of this new reservoir, considerations about the future relocation of the major water storage should be considered.

6.2.4 Other Site Location Considerations

The addition of the new rising main means that water pumped from the bores must travel to the Martin St reservoir prior to entering the reticulation. This increases the minimum chlorine contact time and reduces water age in the reticulation. Due to this, it is now possible to have treatment options at the reservoir site rather than the bore site.

Treatment options for CO_2 removal, pH correction and hardness removal would all occur prior to chlorination and fluoridation. This means that the chlorine and fluoride dosing systems would need to be moved if treatment is preferred at Martin St reservoir. A major downside of having treatment at the Martin St reservoir is the loss of Chlorine contact time within the new rising main. In this case, the Martin St reservoir must act as a Chlorine Contact Tank with sufficient contact time and baffling. The reservoir is sufficiently large to act as a chlorine contact tank; however, the configuration of the inlet and outlet must be considered to avoid potential short circuiting.

6.3 Existing Infrastructure

A summary of the existing infrastructure at Location 1 and Location 2 is summarised below in Table 6-1. The idea of utilising Location 3 to construct a new reservoir and treatment services was not raised until after the site visit was completed so was not included in the table below.

Table 6-1 Existing Infrastructure Summary

Category	Location 1 – Bore Field		Location 2 – Martin St reservoir	
Power	✓	▲ 3-Phase ▲ Connected to power lines	✗	▲ Can organise connection to power lines ~50 m away ▲ Solar power panel on top of reservoir
Telemetry	✓	▲ Antenna	✓	▲ Antenna
Phone signal	✓	▲ 4G (2bar signal with Telstra)	✓	▲ 4G (4bar signal with Telstra)
Wastewater disposal	✗	▲ Septic tank required	✗	▲ Septic tank required
Hydraulic survey available	✗	▲ Not available	✗	▲ Not available
Geotechnical survey available	✗	▲ Not available	✗	▲ Not available
Site footprint, m²	2400		1700	
Road access	✓	▲ Unsealed road	✓	▲ Sealed bitumen
Parking	✗	▲ Roadside parking only	✓	▲ Parking area available
Fencing	✓	▲ Secure gate and fence	✓	▲ Secure gate and fence
Safe from flooding	✗	▲ Roads prone to flooding	✓	▲ Not in flood zone
Safe from bushfires	✓	▲ Low lying grassland	✗	▲ Surrounded by bushland
Emergency equipment	✓	▲ 2 x eye wash station	✗	▲ Can be organised if required
Rubbish collection	✗	▲ Can be organised if required	✗	▲ Can be organised if required
Underground infrastructure	▲ Back-up Bore and 2 pipework ▲ Service water lines ▲ Chlorine dosing lines		▲ Existing rising main ▲ Backup bore pipework	
Overhead infrastructure	▲ Power lines		▲ None	
Other existing assets	▲ Back-up Bore and 2 pump station ▲ Elevated concrete chlorine dosing room ▲ Fluoride dosing room on skid and concrete slab ▲ Service water tank		▲ Martin St reservoir ▲ Chlorine clam sampling station	
Assets to decommission / remove	▲ Elevated concrete chlorine dosing room		▲ Martin St reservoir to be replaced 2023-2024	

7 Treatment Options

7.1 CO_2 Removal and Water Stability

Concentration of carbon dioxide varies widely in groundwater, but the levels are usually higher than in surface water. Water from a deep well normally contains less than 50 mg/L, but a shallow well can have a much higher level, up to 50 to 300 mg/L.

Excessive amounts of carbon dioxide (above 5-15 mg/L) in raw water can increase the acidity of the water, making it corrosive. Carbon dioxide forms a "weak" acid, H_2CO_3 (carbonic acid).

Most aerators can remove carbon dioxide by the physical scrubbing or sweeping action caused by turbulence. At normal water temperatures, aeration can reduce the carbon dioxide content of the water to as little as 4.5 mg/L.

Aeration brings water and air in close contact to remove or oxidize dissolved compounds such as carbon dioxide, iron, hydrogen sulfide, and volatile organic chemicals (VOCs). Aeration is often the first major process at the treatment plant.

For water with high alkalinity, as seen in Coolah, aeration and subsequent removal of CO_2 will result in an increase in pH. It is likely that pH correction will be required to ensure effective chlorine disinfection. This can be achieved through the addition of a mineral acid such as hydrochloric or sulfuric acid. However, delivery and handling of strong acids poses challenges for small rural communities.

7.2 Hardness Removal (Softening)

Hardness describes the difficulty in obtaining a lather from soap, and the tendency for scale to form in pipes and fittings. These phenomena are caused by higher concentrations of calcium and magnesium ions primarily, but also by other cations to a lesser degree.

The ADWG provides the following ranges to define the degrees of hardness:

- <60 mg/L $CaCO_3$ soft but possibly corrosive
- 60–200 mg/L $CaCO_3$ good quality
- 200–500 mg/L $CaCO_3$ increasing scaling problems
- >500 mg/L $CaCO_3$ severe scaling

The ADWG also states that public acceptance of hardness can vary considerably among communities and is generally related to the hardness than the consumer has come to expect. The aesthetic guideline is set at 200 mg/L as $CaCO_3$ "to minimise undesirable build-up of scale in hot water systems".

7.2.1 Brackish Water Reverse Osmosis

Reverse osmosis is a process that uses high pressure to push water through a semi-permeable barrier, eliminating unwanted dissolved solids and minerals. Reverse osmosis is often used to purify water in a range of different applications. There are many suppliers that provide containerised Reverse Osmosis skids which can be highly automated and require very little operator intervention.

The main challenge with in-land Reverse Osmosis is the disposal of the concentrated brine waste stream that is produced. Brackish Water Reverse Osmosis (BWRO) brine contains a high concentration of TDS removed from the feed water. Depending on what pre-treatment steps are performed before BWRO, brine can also contain relatively high concentrations of anti-scalant and oxidants, as well as a significantly different pH and temperature to environmental flows.

Mainstream methods of brine disposal include:

- Evaporation ponds;
- Inland surface water discharge;
- Sewerage discharge;
- Land application and soil infiltration; and
- Deep well injection.

Table 7-1 Summary overview of brine disposal methods for application at Coolah

Brine Disposal Method	Strengths	Weaknesses	Further Investigation
Surface water discharge	Low capital cost	May exacerbate high TDS and conductivity problems for the Coolabundy River and groundwater	Ascertain EPA licensing likelihood
Sewerage discharge	Low capital cost Uses existing infrastructure	May not be possible with existing sewage treatment plant	Investigate Coolah sewage treatment capacity and potential impact on treatment process
Land application	Some improvement to wastewater quality.	High footprint. High capital expenditure. Would have to provide suitable soil and plants. Risk of impact on groundwater quality.	Determine brine composition from TDS removal and pre-treatment additives for suitability for irrigation. Calculate land area needed and compare to available land.
Evaporation ponds	Low operating costs. Well-suited to dry climate.	High footprint. Risk of leaking into groundwater.	Research land availability, and salt precipitate disposal options. Accurate evaporation rates and rainfall data required to size ponds correctly.
Deep injection wells	Avoids surface water contamination.	High capital cost. Risk of leaking into groundwater or being ruptured by mining.	Geological and hydrological survey of potential sites.

7.2.2 Ion Exchange

Ion exchange resins are typically comprised of small plastic porous beads. The resin structure has fixed ions permanently attached that cannot be removed or displaced. To electrically balance the resin, a counterion is used to neutralise the fixed ion. This counterion can be displaced and exchanged by different ions in the water with the same charge. Resins can be made that exchange with either cations or anions, but never both.

By passing the hard water through a cationic resin containing sodium or hydrogen ions, the calcium and magnesium ions are deposited into the resin. This exchange will not result in an appreciable change in total dissolved solids (TDS), due to the one-to-one exchange of TDS constituents. However, the increase in salinity (sodium concentration) may be perceptible to some consumers.

When the softening resin has reached saturation with the target ion, the resin must either be regenerated or replaced. The regeneration process is the reverse of that described above, where the original ion is deposited back into the resin from a concentrated salt or acid solution, depending on the ion.

As with Reverse Osmosis, the main challenge for the ion exchange process is the disposal of the saline waste that is produced when regenerating the resin. The brine disposal methods explained in Table 7-1 are also relevant to ion exchange. When comparing the two technologies, ion exchange generally produces far less waste. This means that options with hydraulic constraints such as sewer discharge may be more feasible.

8 Options Assessment

8.1 Long List Options

The long list options have been summarised in Table 8-1.

Table 8-1 Long listing options for Coolah Water Supply System

Main Option/ System No.	Option Description/ Main System	Sub-Option No.	Sub-Option Description:	General Issues	Technical Feasibility:	Option Discussion	Process Risk		CAPEX Costs	Additional OPEX Costs	Footprint Increase?	Environmental Risk?	
				Notes	Feasible?	General Notes	(H/M/L)	Principal Risks	Indicative cost level	Additional ongoing OPEX costs			Shortlist?
1	**Raw Water Source**	**1.1**	No changes to existing configuration	High CO2 concentration in Town Wells Bore	✓		L		N/A	N/A	N/A	N/A	
		1.2	Change main supply from Town Wells Bore to Back-up Bore	Back-up Bore appears to have less dissolved CO2 and less corrosive than Town Wells Bore	?		M	Increase risk of microbial contamination	Very Low	N/A	N/A	N/A	
2	**CO2 removal/pH stabilisation**	**2.1**	No improvements	Aggressive CO2 can cause concrete corrosion and low pH events	?		M	Low pH and high heavy metal concentrations	N/A	N/A	N/A	N/A	
		2.2	Lime Dosing	Lime reacts with excess CO_2 to form bicarbonate	?		M		Medium	High	Low	N/A	
		2.3	Aeration with no pH adjustment	Aeration removes excess CO_2	?	Aeration without any post pH correction could result in treated water with an unacceptably high CCPP and pH for effective disinfection.	M	High scaling potential and less effective chlorine disinfection	Medium	Very Low	Low	N/A	✓
		2.4	Aeration with pH adjustment	Aeration removes excess CO_2, Allows for optimal pH for effective disinfection	✓	Increased opex due to additional chemical delivery, handling, and dosing.	L		Medium	Medium	Low	Low	✓

Main Option/ System No.	Option Description/ Main System	Sub-Option No.	Sub-Option Description:	General Issues	Technical Feasibility:	Option Discussion	Process Risk		CAPEX Costs	Additional OPEX Costs	Footprint Increase?	Environmental Risk?	
				Notes	Feasible?	General Notes	(H/M/L)	Principal Risks	Indicative cost level	Additional ongoing OPEX costs			Shortlist?
3	**Hardness removal**	**3.1**	No improvements	Hardness can exceed ADWG limit	?		M	High Hardness	N/A	N/A	N/A	N/A	
		3.2	Reverse Osmosis with Evaporation Ponds	Common water purifying process. Large quantity of concentrated brine produced	✓	Feasibility of evaporation ponds dependent on expected evaporation rates and annual rainfall	L		Very High	Low	Extremely High	Low	
		3.3	Reverse Osmosis with Sewer Discharge	Common water purifying process. Large quantity of concentrated brine produced	?	Waste disposal subject to regulatory legislation and WWTP capability	L		High	Medium	Medium	Medium	
		3.4	Reverse Osmosis with Deep Well Injection	Common water purifying process. Large quantity of concentrated brine produced	?	Waste disposal subject to regulatory legislation and aquifer availability	L		Very High	Low	Medium	Medium	
		3.5	Lime Soda Softening	Commonly used in Australia	✓	High operating costs	L		Medium	High	High	Low	
		3.6	Ion Exchange with evaporation ponds	Replaces calcium and magnesium ions with sodium. Subsequent sodium concentration will be around ADWG limit.	?	Feasibility of evaporation ponds dependent on expected evaporation rates and annual rainfall	M	High Sodium	High	Medium	Medium	Medium	
		3.7	Ion Exchange with Sewer Discharge	Replaces calcium and magnesium ions with sodium. Subsequent sodium concentration will be around ADWG limit.	✓	Sewer discharge should be feasible considering low waste volume	M	High Sodium	Medium	Medium	Medium	Medium	✓
4	**Disinfection**	**4.1**	No changes to existing configuration	Potential issues with maintaining chlorine residual	?		M	Chlorine residual	N/A	N/A	N/A	N/A	
		4.2	Martin St Chlorination - dose prior to entering reservoir	Existing chlorination station can be moved	?	Potential issues with maintaining chlorine residual	M	Chlorine residual and insufficient Chlorine Contact	Very Low	N/A	Low	N/A	

Main Option/ System No.	Option Description/ Main System	Sub-Option No.	Sub-Option Description:	General Issues	Technical Feasibility:	Option Discussion	Process Risk		CAPEX Costs	Additional OPEX Costs	Footprint Increase?	Environmental Risk?	
				Notes	Feasible?	General Notes	(H/M/L)	Principal Risks	Indicative cost level	Additional ongoing OPEX costs			Shortlist?
		4.3	Martin St Chlorination - dose prior to entering reservoir, also a secondary trim dosing configuration.	Existing chlorination station can be moved	✓	Will ensure chlorine residual leaving the reservoir and entering the town is consistent.	L		Low	Very Low	Low	N/A	✓
		4.4	Martin St Chlorination - dose at the outlet of reservoir	Insufficient contact time	☒		H	Insufficient Chlorine Contact	Very Low	N/A	Low	N/A	
		4.5	Chloramination	Commonly used technique used for maintaining disinfection	✓	Adds operational complexity	L		Low	Medium	Low	N/A	
		4.6	UV	Commonly used to increase log removal credits Most applicable to treatment of protozoa in surface waters	✓	Unnecessary for Coolah	L		High	Low	Low	N/A	

8.2 Short Listed Options

8.2.1 Assumptions

Common assumptions for Option 1 to Option 3 are listed below:

- The preferred location for the new reservoir has not yet been determined therefore all options have assumed Martin St reservoir as the site for the new reservoir;
- Martin St reservoir has only been used as an example location and was only used due to early information favouring this location but additional research suggests the Wentworth Avenue site would be better suite to a new reservoir and treatment system;
- A portable gas chlorination system and fluoride dosing system will be purchased independent of additional water treatment options proposed in this report. These systems can be transported to the Wentworth Av site if this was to become the location of the town's primary water storage.

8.2.2 Cost Estimate Basis

Project cost estimates were prepared based on the following:

- The cost estimates have an accuracy of ±30% and exclude:
  - GST
  - Electrical modifications and additional power infrastructure
  - Major earthworks and significant foundations associated with poor geological conditions
  - Site preparation and groundwork, roadworks, drainage, fencing
  - Refurbishment of existing equipment to be re-used
- Equipment (capital) costs were obtained from:
  - Recent quotations from other projects
  - Quotations provided by suppliers
  - Budget prices provided by suppliers
  - List prices
  - Estimates based on experience
- Installation costs include:
  - Mechanical (pipework, manual valves, fittings, brackets, supports, etc)
  - Electrical (cables runs, trays, termination, cabinets, switch gear, relays, breakers, etc)
  - Civil (concrete pads, enclosures/buildings, foundations, bunds, plinths, enclosures, frames, etc)
  - Control (RTUs, Ethernet cards, I/O, PLC, etc)
- Installation costs for each treatment system were estimated based on a fixed percentage of the installed system cost (equipment + installation):

- For non-packaged treatment systems, when each item of equipment must be individually installed onsite, installation was assumed to comprise 50% of the installed system cost and was calculated as follows:
  - System installation cost = 1 x total equipment cost
- Engineering costs include:
  - Project management
  - Detailed design
  - Surveying
  - Drafting
  - Documentation
  - Commissioning
  - Operator training
- Engineering costs were estimated to comprise 30% of the total material costs and were calculated based on the following:
  - Total engineering costs = 0.3 x total installed equipment cost
- Overall contingency 15 – 30% for each option was based upon the following factors:
  - Potential risks
  - Constructability
  - Available information
  - Complexity of Project

8.2.3 Option 0 – No Major Improvements (Change to Back-up Bore)

The primary goal of Option 0 is to reduce the corrosivity of the water. Option 0 is a short-term solution and would involve changing from Town Wells Bore to Back-Up Bore as the main raw water supply for the Coolah Water Supply system.

Based on the monitoring data presented in Table 4-1, and the heavy metal analysis in Table 4-2, water from the Back-up Bore does not contain high levels of aggressive CO_2 compared with the Town Wells Bore. Assuming the monitoring data is representative, changing to Back-up Bore would likely improve pH stability and solve any corrosion or heavy metals issues experienced in the town reticulation.

The existing equipment and telemetry at the main bore field would have to be re-configured to ensure this Back-up Bore can be operated remotely. Adopting this option would be relatively simple and would require very little capital investment, but scaling, water age / disinfection effectiveness, palatability and soap lathering would still be an issue.

It should also be noted that the depth of the back-up bore is significantly less than the town wells bore (as discussed in Sections 3 and 6). This means that extensive chemical (especially turbidity following rainfall) and microbiological testing should be conducted to determine the risk of surface water ingress and subsequent microbiological contamination.

8.2.4 Option 1 – Aeration and Improved Chlorine Disinfection at Martin St Reservoir Site

The primary goal of Option 1 is to reduce the corrosivity of the water, reduce water age and improve chlorine disinfection. The small treatment facility associated with Option 1 would consist of the following:

- Aeration;
- Chlorine disinfection (primary and secondary disinfection by trim dosing); and
- Fluoridation.

Raw water will travel from the main bore field via the new rising main and will remain untreated until it reaches the Martin St reservoir site. Raw water will flow through an aeration tower to remove excess levels of CO_2, resolving the corrosion and pH stability issues. The aeration tower will be installed above a holding tank. Aeration is a cost-effective solution and has very limited operation and maintenance requirements, especially when compared with Lime dosing. Table 8-2 shows expected water quality parameters and stability indices for each bore source before and after aeration and CO_2 stripping.

Table 8-2 Estimated water quality parameters for aeration process

Water Source	Pre-Aeration				Post Aeration			
	Carbon Dioxide Concentration (mg/L)	Total Alkalinity (mg/L as $CaCO_3$)	pH (measured)	CCPP (mg/L as $CaCO_3$)	Carbon Dioxide Concentration (mg/L) *	Total Alkalinity (mg/L as $CaCO_3$)	pH (calculated)	CCPP (mg/L as $CaCO_3$)
Town Wells Bore	67	489	7.25	34.7	6.7	489	8.21	82.5
Back-up Bore	58	480	7.26	44.0	5.8	480	8.26	85.1

***estimated 90% CO2 removal**

These modelled results show an increase in the pH and CCPP following aeration. It was assumed that CO_2 is the only acidic compound present in the water and that the aeration process achieves a CO_2 removal efficiency of 90%. The modelled post-aeration pH of 8.2 is similar to the average measured pH from the Wentworth Ave reservoirs which is assumed to have undergone significant natural CO_2 stripping and aeration. A pH of 8.2 is considered acceptable for chlorine disinfection, however disinfection is more effective at a lower pH. If alkalinity or CO_2 removal were to increase, post-aeration pH could rise above 8.5. This would result in an increase in disinfection Ct (concentration x contact time) required for effective removal of harmful pathogens as stated in the health-based targets. A CCPP of 82.5 mg/L as $CaCO_3$ indicates the water entering the town reticulation could lead to scaling.

Water from the holding tank will be pumped to the Martin St Reservoir. On route to the reservoir, the water will be dosed with chlorine (primary disinfection) and fluoride. Chlorine should be dosed after aeration, as aeration will rapidly deteriorate the chlorine residual resulting in an increased chlorine demand. Dosing chlorine gas at a total of 4 mg/L post-aeration for disinfection purposes will also cause the pH and CCPP to drop to 8.0 and 76.3 mg/L, respectively. A lower pH will improve disinfection effectiveness and a decrease in the CCPP value will result in a minor reduction in scaling. Option 1 does not reduce hardness therefore poor palatability and soap lathering will still be an issue.

The reservoir will act at as chlorine contact tank to achieve the required Ct for primary disinfection. The tank is sufficiently large to achieve the desired contact time, however considerations for optimising the inlet and outlet configuration of the tank should be made to prevent short-circuiting. Chlorine dosing at the bore will be retained if required for increased Ct. A secondary chlorine dosing point followed by a free chlorine analyser would be installed to ensure a consistent chlorine residual can be maintained through trim dosing.

Once the new rising main has been completed all raw water will pass through the small treatment facility prior to being distributed to the Coolah reticulation network. The new rising main, along with the primary and secondary disinfection systems, will improve water age issues and help minimise low chlorine residual events in reticulation dead spots despite seasonal changes in demand.

Instrumentation for the treatment options would include online pH monitoring and online chlorine residual monitoring for primary and secondary disinfection. Online pH monitoring can provide early warning for water approaching the CCP limit since aeration will be raising the pH significantly and online chlorine monitoring will be necessary to maintain the desired chlorine residual levels.

The process flow diagram for Option 1 has been included in Figure 8-1.

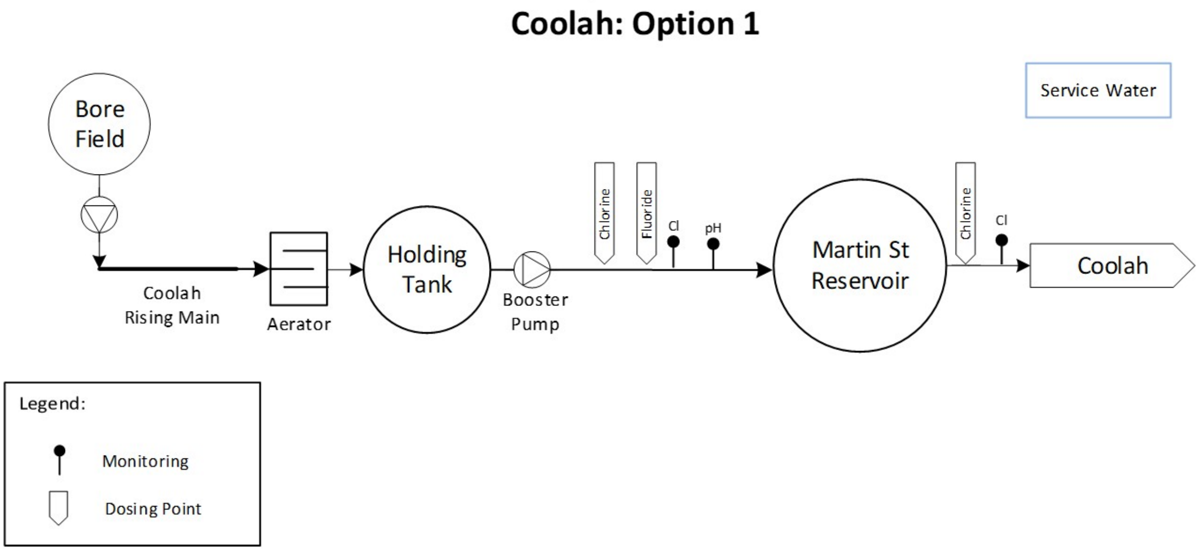

Figure 8-1 Process flow diagram for Option 1

Figure 8-2 shows a high-level scaled layout of the Martin St reservoir site with the additions proposed in Option 1. This also includes the relocation of Chlorine and Fluoride areas from the main bore field.

It should be noted that the Martin St site may not be the long-term location for primary town water storage. For this reason, transportability should be considered when designing the system, for example, shipping containers to be used to house the chlorine and fluoride dosing.

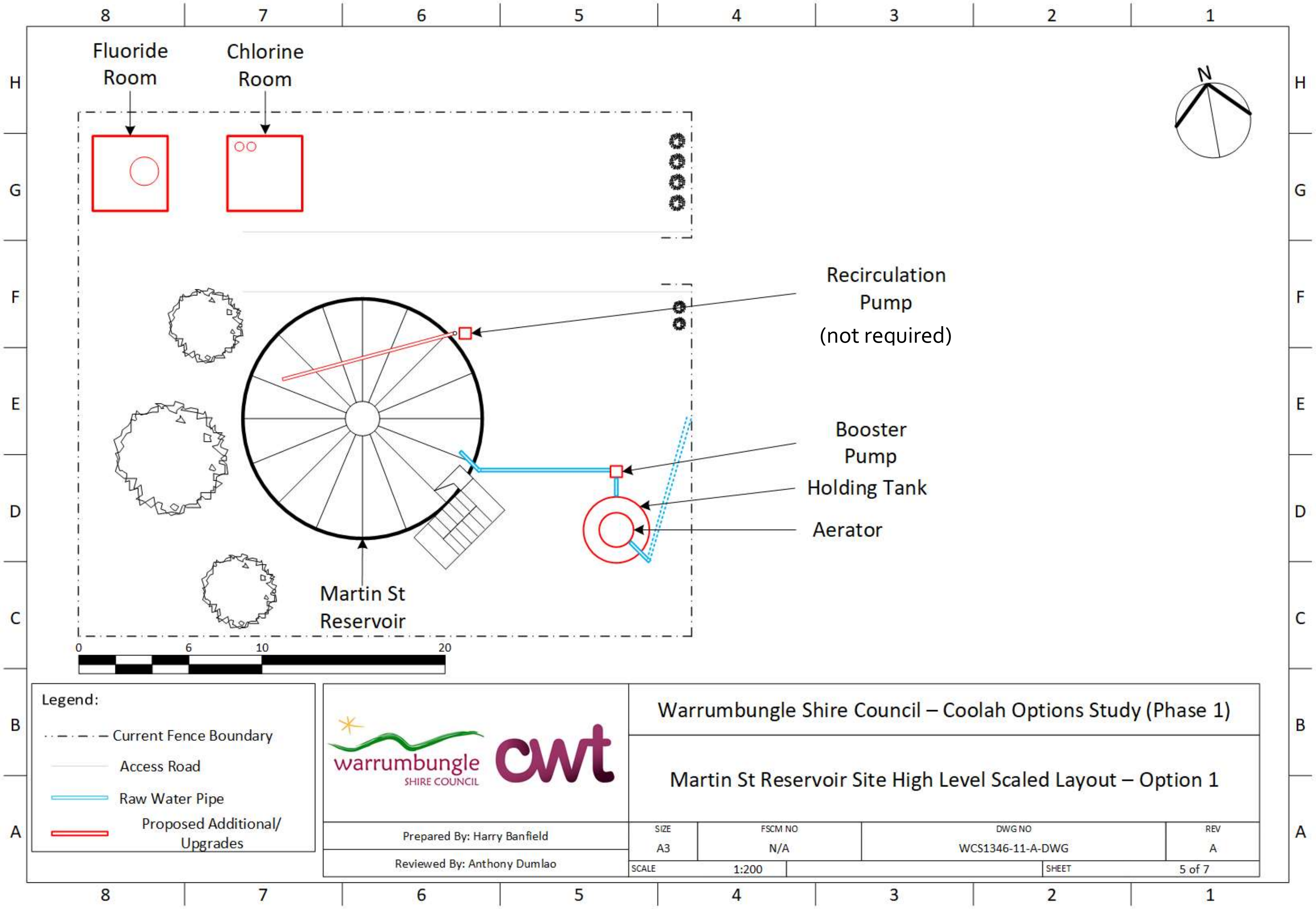

Figure 8-2 High level scaled layout of Option 1

Table 8-3 and Table 8-4 present a breakdown of capital and additional operation expenses respectively for Option 1. A total project cost of $187,200 is estimated including materials, installation, engineering, design, and project management. A small continency of 15% takes the total CAPEX to $215,280. OPEX has been estimated as $10,880 per annum.

Table 8-3 Option 1 CAPEX breakdown

Process Element/s	Equipment/ Material Cost (Ex. GST)	Installed Cost (Ex. GST)
Aerator	$30,000	$60,000
Booster pump	$1,000	$2,000
Holding tank	$15,000	$30,000
Recirculation pump	$1,000	$2,000
Additional online Cl monitoring	$5,000	$10,000
Online pH monitoring	$3,000	$6,000
Telemetry and Control Integration	$10,000	$20,000
Additional piping and valves	$5,000	$10,000
New Service Water System	$2,000	$4,000
Total Construction Value ($CV)	-	**$144,000**
Engineering, Design and Project Management	-	**$43,200**
Total Project Costs	-	**$187,200**
Contingency Allowance @ 15%	-	**$28,080**
Grand Total	**-**	**$215,280**

Table 8-4 Option 1 OPEX breakdown

	Rate	Annual Usage	Cost	Comment
Power	0.3 $/kWh	20,000 kWh	$6,000	
Maintenance	2%	-	$2,800	Assumed 2% of total construction costs
Labour	40 $/hr	50 hr	$2,000	
Annual Operating Cost	**-**	**-**	**$10,880**	**-**

8.2.5 Option 2 – Aeration and pH correction at Martin Street Reservoir Site

The primary goal of Option 2 is to reduce the corrosivity and scaling tendency of the water, reduce water age and improve chlorine disinfection effectiveness. The small treatment facility associated with Option 2 would consist of the following:

- Aeration;
- pH adjustment;
- Chlorine disinfection (primary only); and
- Fluoridation.

Raw water will travel from the main bore field via the new rising main and will remain untreated until it reaches the Martin St reservoir site. Raw water will flow through an aeration tower to remove excess levels of CO_2 resolving the corrosion and pH stability issues. The aeration tower will be installed above a holding tank.

Water leaving the outlet of the aerator will be continuously dosed with sulfuric acid for pH adjustment prior to entering the holding tank. As shown in Table 8-2, the post aeration pH of water from Town Wells Bore will be 8.21 with a high CCPP of 86.0 mg/L. The pH will be lowered, as seen in Table 8-5, to improve chlorine disinfection effectiveness and to reduce the CCPP. A reduction in CCPP will decrease the tendency for scaling in the network however, due to the high hardness of the water, palatability and soap lathering will still be an issue.

Table 8-5 Estimated water quality parameters for pH correction process

Water Source	Pre-PH correction			Post pH Correction and Chlorine Gas			
	Total Alkalinity (mg/L as $CaCO_3$)	pH	CCPP (mg/L as $CaCO_3$)	Sulfuric Acid Dose (mg/L)	Total Alkalinity (mg/L as $CaCO_3$)	pH	CCPP (mg/L as $CaCO_3$)
Town Wells Bore	489	8.21	82.5	65	418	7.14	10.0
Back-up Bore	480	8.26	85.1	65	409	7.09	13.9

It should be noted that 98% sulfuric acid is extremely corrosive and would require special storage and handling practices. The sulfuric acid dosing system would require the following:

- A HDPE tank contained within a bund;
- Dedicated perimeter fence;
- Dedicated shading to prevent direct sunlight;
- Compatible dosing pumps (duty/standby) with pulsation dampeners;
- pH analyser and controller for dosing control;
- Service water system for acid dilution; and

- Heat and corrosion resistant mixing tee.

Table 8-6 shows the volume of 98% sulfuric acid and service water required for adequate pH correction at 15 L/s and 10 L/s. While the dosing equipment should be designed for maximum instantaneous design flow of 15L/s, the maximum daily consumption of Coolah town is approximately 0.8ML/d (10L/s) averaged over 30 days. For costing purposes, storage and chemical consumption will be based on 0.8ML/d (10L/s). A 3 kL tank would be required to store 3 months of sulfuric acid. If stored correctly, 98% sulfuric acid is extremely stable and would require replenishment every 3 months which is reasonable for a rural site.

Table 8-6 Operation requirement of sulfuric acid dosing system

Design Flow (L/s)	Sulfuric Acid Dose (mg/L)	Volumetric Flow (L/d) 98%w/w H2So4*	Service Water Required (L/d)	Tank Volume required (kL)**
15	65	47.8	936	4.3
10	65	29.5	578	2.7

*SG = 1.8, **3 Months storage

The pH-corrected water will then be directed to a holding tank then pumped into the Martin St reservoir. Prior to reaching the reservoir, chlorine (primary disinfection) and fluoride will be separately dosed into the line.

As is the case with Option 1, the new rising main will ensure all raw water passes through the small treatment facility prior to being distributed to the Coolah reticulation network. This will improve water age issues and help minimise low chlorine residual events in reticulation dead spots despite seasonal changes in demand.

Instrumentation for the treatment options would include online pH monitoring and online chlorine residual monitoring. Online pH monitoring will provide feedback to the sulfuric acid dosing system and online chlorine monitoring will be necessary to maintain the desired chlorine residual levels.

Figure 8-3 shows the configuration of the Coolah water treatment and supply systems with the addition of aeration, pH adjustment and improved disinfection at the Martin St reservoir site.

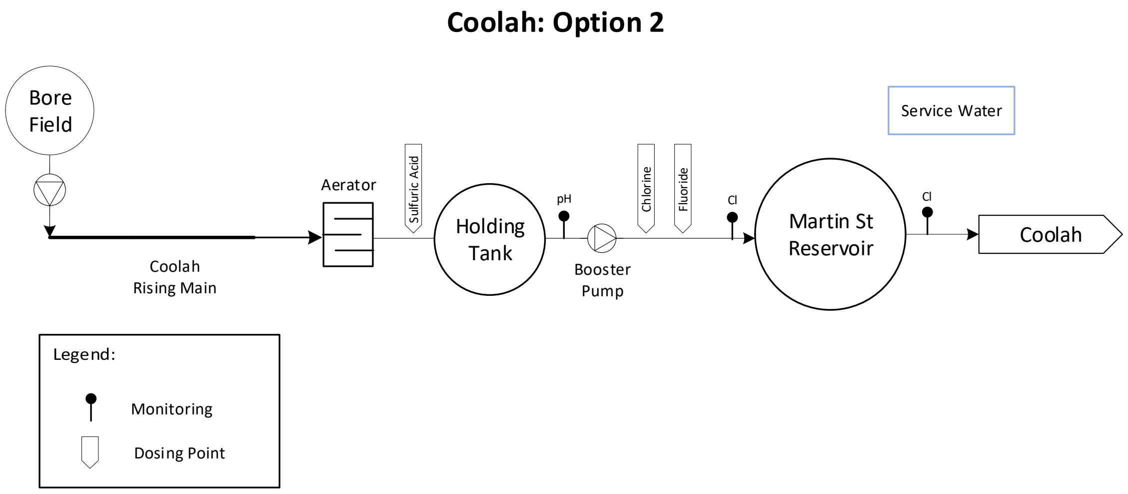

Figure 8-3 Process flow diagram for option 2

Figure 8-4 shows a high-level scaled layout of the Martin St reservoir site with the additions proposed in Option 2. This also includes the relocation of Chlorine and Fluoride areas from the main bore field.

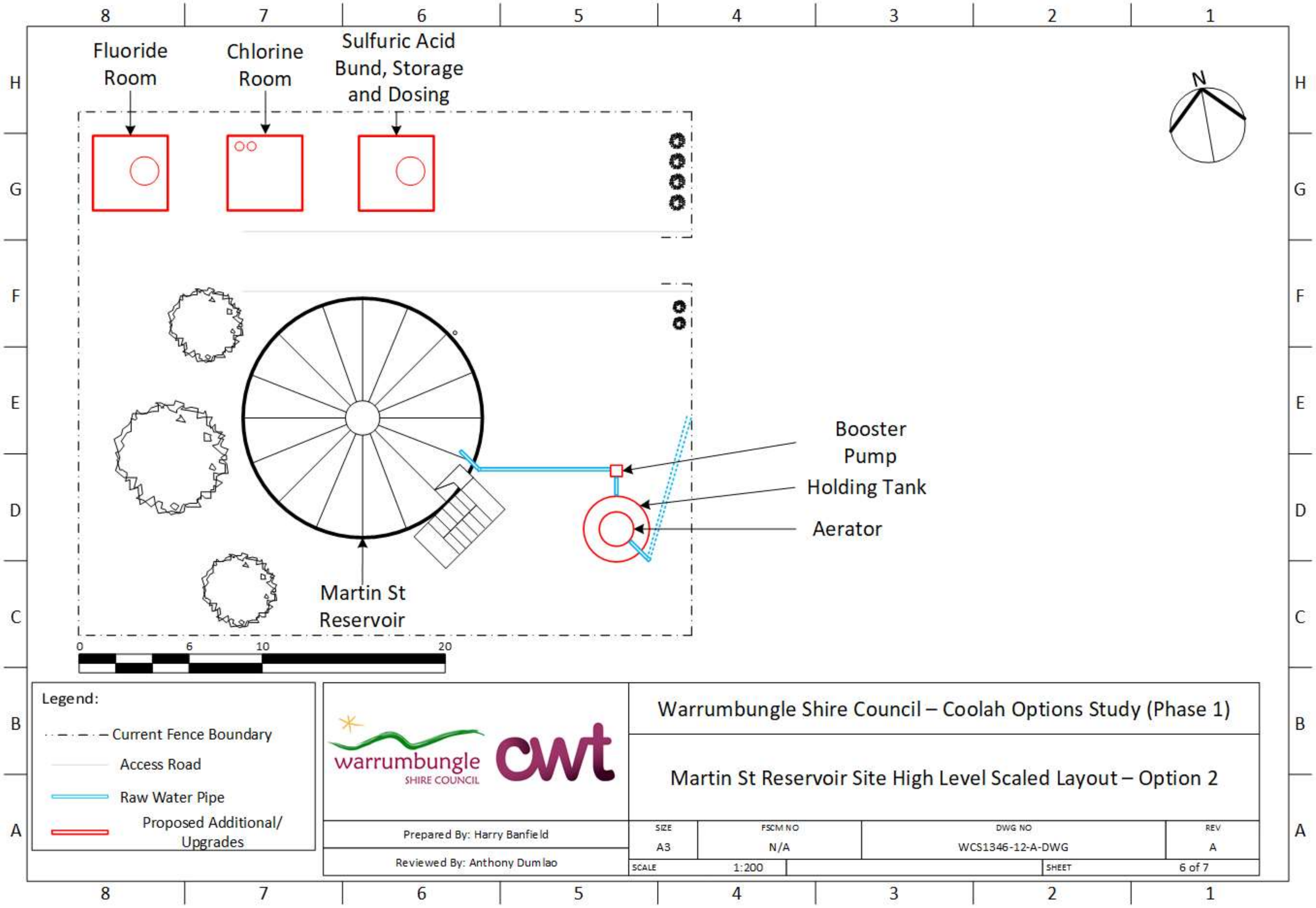

Figure 8-4 High level scaled layout of

Table 8-7 and Table 8-8 present a breakdown of capital and additional operation expenses respectively for Option 2. A total project cost of $293,800 is estimated including materials, installation, engineering, design, and project management. A small contingency of 15% takes the total CAPEX to $337,870. OPEX has been estimated as $24,256 per annum.

Table 8-7 Option 2 CAPEX breakdown

Process Element/s	Equipment/ Material Cost (Ex. GST)	Installed Cost (Ex. GST)
Aerator	$30,000	$60,000
Booster Pump	$1,000	$2,000
Holding Tank	$15,000	$30,000
Sulfuric Acid System	$40,000	$80,000
Storage Tank	Included	Included
Bunding	Included	Included
Dosing Pumps	Included	Included
System Piping	Included	Included
Valves	Included	Included
Online pH Analysis Control System	Included	Included
Documentation	Included	Included
New Service Water System	$2,000	$4,000
Additional Piping and Valves	$15,000	$30,000
Control integration	$10,000	$20,000
Total Construction Value ($CV)	-	**$226,000**
Engineering, Design and Project Management	-	**$67,800**
Total Project Costs	-	**$293,800**
Contingency Allowance @ 15%	-	**$44,070**
Grand Total	**-**	**$337,870**

Table 8-8 Option 2 OPEX breakdown

	Rate	Annual Usage	Cost (Ex. GST)	Comment
Power	0.3 $/kWh	26,000 kWh	$7,800	
Chemical	10.8 kL/year	19.44 tonne	$7,776	$400/tonne Sulfuric Acid, 1.8 SG
Maintenance	2%	-	$4,520	Assumed 2% of total construction costs
Labour	40 $/hr	104 hr	$4,160	
Annual Operating Cost	-	-	**$24,256**	-

8.2.6 Option 3 – Aeration, Ion Exchange Softening, and Improved Chlorine Disinfection at Martin St Reservoir Site

Previous options have addressed corrosion, scaling and disinfection effectiveness but none have provided solutions to resolve the issues caused by high hardness levels. The primary goal of Option 3 is to reduce the corrosivity of the water, reduce scaling tendency of the water, improve the palatability, improve soap lathering, reduce water age, and improve chlorine disinfection. The small treatment facility associated with Option 3 would consist of the following:

- Aeration;
- Softening;
- Chlorine disinfection (primary and secondary disinfection with recirculation); and
- Fluoridation.

Raw water will travel from the main bore field via the new rising main and will remain untreated until it reaches the Martin St reservoir site. Raw water will flow through an aeration tower to remove excess levels of CO_2, resolving the corrosion and pH stability issues.

In this scenario, ion exchange resins are the best option for reducing the hardness (softening) of the bore water at Coolah. Ion exchange requires less capital investment and produces less waste by volume compared to reverse osmosis processes. Ion exchange also requires far less chemicals and operator involvement compared to lime-soda softening. The softening system would consist of two fiberglass reinforced plastic (FRP) vessels each containing a bed of ion exchange resin, a backwash storage tank, backwash pump, wastewater holding tank and brine batching tank. General disadvantages for softening via an ion exchange system include an increase in sodium concentration in the treated water and managing the backwash waste.

Table 8-9 shows the approximate hardness and sodium concentrations of softened water and final water using a mixing ratio of 60% softened water to 40% raw water. Based on the results of these calculations, the final water has a sodium concentration below ADWG aesthetic limits therefore an increase in sodium concentration is not an issue.

Table 8-9 Summary of major cation concentrations for softening process

Parameter	Units	Raw Water	Softened Water	Final Water	ADWG Aesthetic Target
Calcium	mg/L	75.8	<1	29.8	N/A
Hardness, Total	mg/L $CaCO_3$	471	<1	185	200
Magnesium, Total	mg/L	68.4	<1	26.9	N/A
Sodium	mg/L	39.0	216	170	180

The resin used in the ion exchange system will need to be backwashed and regenerated every 4-8 days (depending on the size of vessels and average flowrate). Potential disposal methods of highly saline waste are described in Section 6.2 and include evaporation ponds, deep well injection and sewer discharge. Due to average evaporation rates and annual rainfall, evaporation is unlikely to be a feasible option. Sewer discharge would be the most cost-effective and simplest option; however, this is dependent on the hydraulic capacity and processing capability of the local WWTP. Alternatively, wastewater could be carted away and treated elsewhere at a premium cost.

Table 8-10 is an example of an ion exchange system design with similar capacity. It is estimated that 15 m^3 of waste will be generated per backwash/regeneration cycle.

Table 8-10 Example ion exchange design

Component	Parameter (Unit)	Design Criteria		
Resin Vessels	Maximum flowrate (L/s)	7.8		
	Material	Fibreglass reinforced plastic		
	Number	2		
	Area per Filter (m^2)	1.13		
	Total Filter Area (m^2)	2.26		
Resin	Bed depth (m)	1		
	Resin volume: (m^3) Per filter	2.26 1.13		
	Exchange capacity (kg/m^3 as $CaCO_3$) (per vessel)	64.6		
	Effective headloss (m)	3.6		
Backwashing Parameters	BW frequency (days)	4-8 (typical)		
	Backwash Procedure	**Rate (m/h)**	**Time (min)**	**Waste Volume (m^3)**
	Backwash	23	20	8.66
	Brining	2	20	0.75
	Slow rinse	2	40	1.51
	Fast rinse	32	6	3.62
	Total waste volume			**14.5**
	Backwash Storage Tank (kL)	20		
	Backwash Waste Holding Tank (kL)	40 (2 x backwashes)		

The softened water will be dosed separately with chlorine (primary disinfection) and fluoride. Similar to Option 1, a reservoir recirculation line, recirculation pump and chlorine doing point (secondary disinfection) for the reservoir would be installed to ensure a consistent chlorine residual can be maintained.

As is the case with Option 1 and Option 2, the new rising main will ensure all raw water passes through the small treatment facility prior to being distributed to the Coolah reticulation network. The new rising main, along with primary and secondary chlorine disinfection, will improve water age issues and help minimise low chlorine residual events in reticulation dead spots despite seasonal changes in demand.

Instrumentation for the treatment options would include online pH monitoring and online chlorine residual monitoring for primary and secondary disinfection.

Figure 8-5 shows the configuration of the Coolah water treatment and supply systems with the addition of aeration, Ion Exchange softening process and improved disinfection at the Martin St reservoir site.

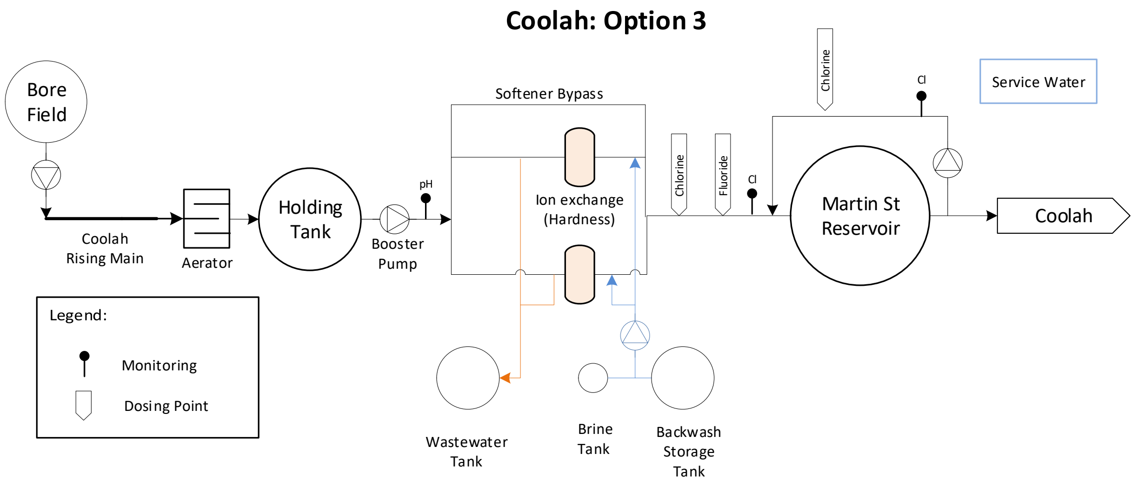

Figure 8-5 Process flow diagram for Option 3

Figure 8-6 shows a high-level scaled layout of the Martin St reservoir site including additions and upgrades proposed in Option 2.

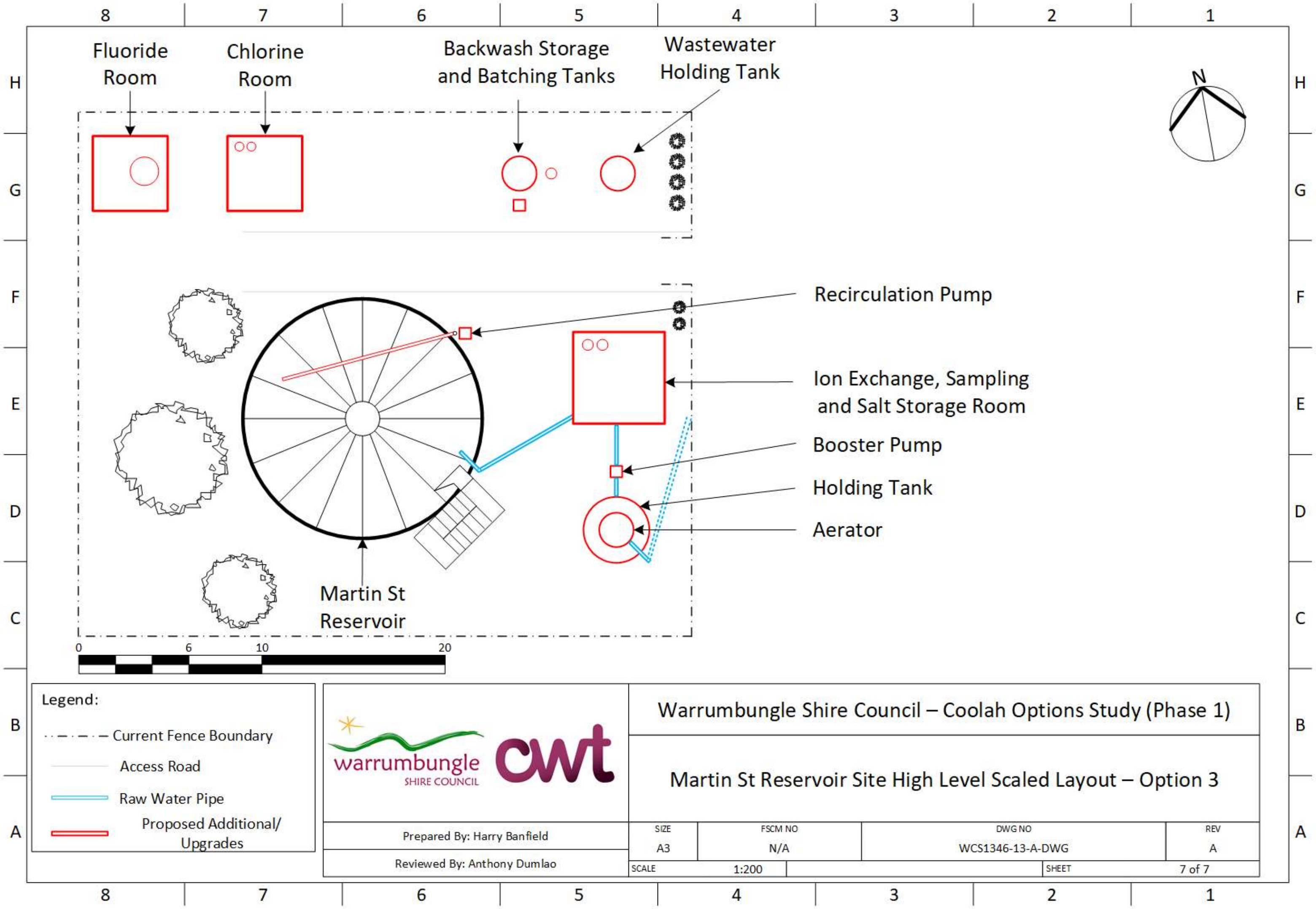

Figure 8-6 High level scaled layout for Option 3

Table 8-11 and Table 8-12 presents a breakdown of capital and additional operation expenses respectively for Option 3. A total project cost of $634,400 is estimated including materials, installation, engineering, design, and project management. Due to the increased complexity of the project, a larger 30% contingency is added to take the total CAPEX to $824,720. OPEX has been estimated as $135,880 per annum which includes costs for wastewater cartage. If sewer discharge is considered feasible, OPEX is lowered to $67,560 per annum. A majority of the costs are associated with a relatively high amount of labour required to operate and maintain the softening system. As a result, resource availability should also be considered when establishing the feasibility of Option 3 (or any water softening options).

Table 8-11 Option 3 CAPEX breakdown

Process Element/s	Equipment/ Material Cost (Ex. GST)	Installed Cost (Ex. GST)
Aeration Tower	$30,000	$60,000
Booster Pump	$1,000	$2,000
Softening System	$160,000	$320,000
Prefiltration	Included	Included
Ion Exchange Vessels	Included	Included
Resin	Included	Included
Resin Regeneration System	Included	Included
Backwash Pump	Included	Included
System Piping	Included	Included
Valves	Included	Included
Control System	Included	Included
Documentation	Included	Included
Containerised system (w/ A/C and lighting) installed	$15,000	$30,000
Delivery to Site	$3,000	$3,000
SCADA & control integration	$20,000	$40,000
Wastewater and Backwash Tanks	$10,500	$21,000
Reservoir Recirculation Chlorine Modification	$6,000	$12,000
Additional Piping and Valves		
Total Construction Value ($CV)	-	**$488,000**
Engineering, Design and Project Management	-	**$146,400**
Total Project Costs	-	**$634,400**
Contingency Allowance @ 30%	-	**$190,320**
Grand Total	**-**	**$824,720**

Table 8-12 Option 3 OPEX breakdown

	Rate	Annual Usage	Cost (Ex. GST)	Comment
Power	0.3 $/kWh	36,000 kWh	$10,800	
Chemical	-	-	$7,000	Regeneration Salt
Wastewater Cartage	0.04 $/L	1,708,000 L	$68,320	Subject to sewer discharge feasibility
Maintenance	2%	-	$9,760	Assumed 2% of total construction costs
Labour	40 $/hr	1000 hr	$40,000	
Annual Operating Cost	**-**	**-**	**$135,880**	**-**

8.3 Options Comparison

A non-financial and financial comparison of the short-listed options is summarised in Table 8-13. The non-financial comparison of each option was based on the degree of improvement to the primary issues of water stability, heavy metals, disinfection, and water age. The water quality issues due to hardness (scaling, palatability, and soap lathering) were also considered. The financial comparison of each option was based on the net present value (NPV) and annualised cost of production.

Table 8-13 Options comparison table

Main Option/ System No.	Option Description/ Main System	Water Quality Improvement						Financial Comparison		Equipment Footprint Increase (m^2)	Advantages/ Disadvantages
		Corrosion	Scaling	General Water Stability	Palatability	Soap Lathering	Disinfection / Water age	NPV ($'000 Ex. GST) *	Annualised Cost ($/ML Ex. GST) ***		
0	**No Major Improvement – Change to Back-up Bore**	M	N/A	L	N/A	N/A	N/A	<10	<5	N/A	• Quick improvement to corrosion and presence of heavy metals in the reticulation • No solution to other water quality issues • Water age in Martin St reservoir
1	**Aeration & improved disinfection**	H	N/A	M	N/A	N/A	M	331	103	5	• Elimination of CO_2 causing signs of asset corrosion and increased heavy metal concentration • Low maintenance requirements • Cost-effective • Increased scaling potential • High hardness remains • Disinfection at high pH
2	**Aeration & pH correction**	H	H	H	N/A	N/A	M	595	185	12	• Significantly improved water stability • Stability indices on or close to best practices • Lower consumption of chlorine • Improved disinfection efficacy • Relatively cost effective • High hardness remains • High chemical consumption • Chemical handling training required • Increased sulfates in drinking water
3	**Aeration, ion exchange & improved disinfection**	H	M	H	M	H	M	1,540/ 2,264**	478/ 703**	30	• Improved water stability • Significant hardness removal for improved palatability and soap lathering • Slightly improved disinfection reliability and efficacy • Disinfection at high pH • High capital cost • Regular maintenance and operator intervention required • Relatively large increase in footprint

* - Based on 20-year lifetime and 7% discount rate

** - NPV and Annualised Cost of option 3 is larger without sewer discharge of Ion Exchange waste

*** - Based on an average consumption of 161ML/a (2018 and 2019)

8.3.1 Non-Financial Comparison

Option 1

Option 1 moderately improves water stability by significantly reducing the corrosivity of the water which minimises the leaching of heavy metals from copper pipes and fittings. This option moderately improves water age by utilising the new rising main and relocating chlorine dosing to the Martin St reservoir site. Introducing water recirculation at the reservoir and adding a secondary chlorine disinfection will also provide a more consistent chlorine residual throughout the reticulation network. Option 1 does not resolve the issue of scaling, poor palatability, and soap lathering. Additionally, chlorine dosing will take place at a higher pH therefore a higher chlorine dose will be required to achieve the desired log removal of pathogens.

Option 2

Option 2 significantly improves water stability by reducing the corrosivity and scaling tendency of the water. This option also moderately improves water age and chlorine disinfection by utilising the new rising main and relocating chlorine dosing to the Martin St reservoir site. Chlorine dosing will also be more effective due to taking place at a lower pH. Option 2 will have to deal with the safety issues associated with the storing and handling of sulfuric acid and there will also be an increase in sulfates in the water. Additionally, this option does not resolve the issue of poor palatability and soap lathering.

Option 3

Option 3 significantly improves water stability by reducing the corrosivity and scaling tendency of the water. The palatability of the water and soap lathering is also improved. This option also moderately improves water age and chlorine disinfection by utilising the new rising main and relocating chlorine dosing to the Martin St reservoir site. Like Option 1, introducing water recirculation at the reservoir and adding secondary chlorine disinfection will provide a more consistent chlorine residual throughout the reticulation network. One of the drawbacks of this option is that chlorine dosing will take place at a higher pH therefore a higher chlorine dose will be required to achieve the desired log removal of pathogens

8.3.2 Financial Comparison

A financial comparison of the short-listed options was conducted by comparing the net present value (NPV) and annualised cost of production. The following assumptions were used in calculations:

- CAPEX and OPEX costs outlined in Section 8.2;
- The assets discussed in the options will have a 20-year lifetime;
- A discount rate or return of 7%; and
- Average production of 161 ML/a (2018 and 2019)

At this stage, the NPV analysis and annualised cost of production shows that aeration and improved chlorine disinfection at the Martin St reservoir (Option 1) will be the most cost effective over the life of the small treatment facility. This is due to the lower initial capital cost and lower operating cost compared to Option 2 and Option 3. A detailed analysis of Option 0 was not completed as it is considered a short-term solution and does not improve on the major issues of water age and disinfection. Refer to 0 for the NPV and annualised cost calculations. These estimated values are subject to verification and are based on cost estimates that have an accuracy of ±30%.

9 Recommendations

The recommendations of this report have been updated based on a peer review conducted by Peter Mosse in March 2021.

9.1 Air Scouring and Chlorine Dosing

The high chlorine dose needed to achieve a chlorine residual throughout the system and the high variability between the chlorine residuals indicates the presence of a dirty distribution system which is creating a high chlorine demand. In order to reduce the high chlorine demand and improve the chlorine residual throughout the system, CWT recommends the following:

- Perform immediate air scouring of the distribution system including the rising main;
- Implement scheduled air scouring of the distribution system at approximately 5 year intervals;
- Maintain primary disinfection at the main bore site to maximise Ct; and
- Implement residual trim dosing at the existing Martin St reservoir using the new portable gas chlorination system

9.2 Additional Monitoring Program

The inconsistency of results for metals between reticulation and bore water samples indicate that further water quality testing is required. If there are elevated levels of iron in the bore water then using an aerator will oxidise soluble iron and could lead to dirty water complaints from customers. Based on comments from Peter Mosse, CWT recommends that additional sampling should be conducted with a focus on the bores. Samples should be taken at each of the bores (including Neilrex Rd bore) over a 6 to 8 week period and should be continued as a regular monthly monitoring program thereafter.

The bore water samples should be tested for the following parameters:

- Total iron
- Soluble iron
- Total manganese
- Soluble manganese
- pH
- Alkalinity
- Temperature

The data gathered from this ongoing monitoring program can also be used to further confirm the presence of excess CO_2 levels in the bore water.

9.3 Confirmation of Preferred Location

The Wentworth Ave site would be the ideal location for a new reservoir and treatment units because it will allow the Coolah system to be fully linear with a single reservoir. CWT recommends the following:

- Conduct hydraulic modelling to determine the feasibility of operating a single reservoir at the Wentworth Ave site; and

- Determine the appropriate design for the new storage reservoir/s to ensure adequate supply to meet seasonal demand.

9.4 Identification of Preferred Option

In terms of treatment options, at this stage CWT recommends:

- Adopting Option 1 at the site of the new reservoir as a means of providing a cost-effective solution to improve the primary issues of water stability, heavy metals, disinfection, and water age; and
- Updating the design of Option 1 once the preferred location has been confirmed and the additional monitoring program has been completed.

9.5 Staged Implementation

A proposed staged pathway for the development and implementation of a sustainable, reliable, effective and affordable water supply system for Coolah is outlined in Table 9-1.

Table 9-1 Staged implementation for upgrades to Coolah Water Supply System

Stage	Action
1	Clean reticulation using air scouring and implement scheduled cleaning
2	Conduct additional monitoring program
3	Maintain primary chlorine disinfection at main bore field and implement temporary residual trim dosing at the existing Martin St Reservoir using portable chlorine gas dosing system
4	Conduct hydraulic modelling to confirm preferred location for new reservoir design and initiate development of reservoir design
5	Update Option 1 design based on outcomes of additional monitoring program and selection of preferred location for the new reservoir
6	Construct new rising main and new reservoir at preferred location
7	Implement Option 1 and move portable chlorine gas dosing system to the new reservoir
8	Decommission old Martin St reservoir
9	Review water quality data and verify improvements to water stability, heavy metals, water age and disinfection
10	Implement further treatment options (Option 2 or 3) if required

Appendix A NPV and Annualised Cost Analysis

Table 9-2 Option 1 NPV and annualised cost analysis

Year	Capital Cost ($ Ex. GST)	Operating Cost ($ Ex. GST)	Total Cost ($ Ex. GST)	Present Value @ Discount Rate 7%
0	$215,280	$-	$215,280	$215,280
1		$10,880	$10,880	$10,168
2		$10,880	$10,880	$9,503
3		$10,880	$10,880	$8,881
4		$10,880	$10,880	$8,300
5		$10,880	$10,880	$7,757
6		$10,880	$10,880	$7,250
7		$10,880	$10,880	$6,776
8		$10,880	$10,880	$6,332
9		$10,880	$10,880	$5,918
10		$10,880	$10,880	$5,531
11		$10,880	$10,880	$5,169
12		$10,880	$10,880	$4,831
13		$10,880	$10,880	$4,515
14		$10,880	$10,880	$4,219
15		$10,880	$10,880	$3,943
16		$10,880	$10,880	$3,685
17		$10,880	$10,880	$3,444
18		$10,880	$10,880	$3,219
19		$10,880	$10,880	$3,008
20		$10,880	$10,880	$2,812
			NPV	$330,543
			Annualised Cost ($/ML)	**103**

Table 9-3 Option 2 NPV and annualised cost analysis

Year	Capital Cost ($ Ex. GST)	Operating Cost ($ Ex. GST)	Total Cost ($ Ex. GST)	Present Value @ Discount Rate 7%
0	$337,870	$-	$337,870	$337,870
1		$24,256	$24,256	$22,669
2		$24,256	$24,256	$21,186
3		$24,256	$24,256	$19,800
4		$24,256	$24,256	$18,505
5		$24,256	$24,256	$17,294
6		$24,256	$24,256	$16,163
7		$24,256	$24,256	$15,105
8		$24,256	$24,256	$14,117
9		$24,256	$24,256	$13,194
10		$24,256	$24,256	$12,331
11		$24,256	$24,256	$11,524
12		$24,256	$24,256	$10,770
13		$24,256	$24,256	$10,065
14		$24,256	$24,256	$9,407
15		$24,256	$24,256	$8,791
16		$24,256	$24,256	$8,216
17		$24,256	$24,256	$7,679
18		$24,256	$24,256	$7,176
19		$24,256	$24,256	$6,707
20		$24,256	$24,256	$6,268
			NPV	$594,838
			Annualised Cost ($/ML)	185

Table 9-4 Option 3 (wastewater carting) NPV and annualised cost analysis

Year	Capital Cost ($ Ex. GST)	Operating Cost ($ Ex. GST)	Total Cost ($ Ex. GST)	Present Value @ Discount Rate 7%
0	$824,720	$-	$824,720	$824,720
1		$135,880	$135,880	$126,991
2		$135,880	$135,880	$118,683
3		$135,880	$135,880	$110,919
4		$135,880	$135,880	$103,662
5		$135,880	$135,880	$96,881
6		$135,880	$135,880	$90,543
7		$135,880	$135,880	$84,619
8		$135,880	$135,880	$79,083
9		$135,880	$135,880	$73,910
10		$135,880	$135,880	$69,075
11		$135,880	$135,880	$64,556
12		$135,880	$135,880	$60,332
13		$135,880	$135,880	$56,385
14		$135,880	$135,880	$52,697
15		$135,880	$135,880	$49,249
16		$135,880	$135,880	$46,027
17		$135,880	$135,880	$43,016
18		$135,880	$135,880	$40,202
19		$135,880	$135,880	$37,572
20		$135,880	$135,880	$35,114
			NPV	$2,264,235
			Annualised Cost ($/ML)	703

Table 9-5 Option 3 (wastewater discharge to sewer) NPV and annualised cost analysis

Year	Capital Cost ($ Ex. GST)	Operating Cost ($ Ex. GST)	Total Cost ($ Ex. GST)	Present Value @ Discount Rate 7%
0	$824,720	$-	$824,720	$824,720
1		$67,560	$67,560	$63,140
2		$67,560	$67,560	$59,010
3		$67,560	$67,560	$55,149
4		$67,560	$67,560	$51,541
5		$67,560	$67,560	$48,169
6		$67,560	$67,560	$45,018
7		$67,560	$67,560	$42,073
8		$67,560	$67,560	$39,321
9		$67,560	$67,560	$36,748
10		$67,560	$67,560	$34,344
11		$67,560	$67,560	$32,097
12		$67,560	$67,560	$29,997
13		$67,560	$67,560	$28,035
14		$67,560	$67,560	$26,201
15		$67,560	$67,560	$24,487
16		$67,560	$67,560	$22,885
17		$67,560	$67,560	$21,388
18		$67,560	$67,560	$19,989
19		$67,560	$67,560	$18,681
20		$67,560	$67,560	$17,459
			NPV	$1,540,452
			Annualised Cost ($/ML)	478