hunterh2o

Capacity and Capability Review

Baradine WTP

NSW Health

JULY 2020

ABN 16 602 201 552

Report Details

Report Title	**Capacity and Capability Review: Baradine WTP**
Project No.	5397-VAR3
Status	
File Location	P:\NSW Health\5397 - Drinking Water and Fluoride Improvement Projects\2. Tasks\VAR3 - Baradine WTP Assessments\1. Report
Enquiries	Michael Carter P: (02) 4941 4957 E: Michael.Carter@hunterh2o.com.au

Document History and Status

Revision	Report Status	Prepared by	Reviewed by	Approved by	Issue Date
A	Draft	Thomas Davies, Michael Carter	Emily Hyde, Michael Carter	Michael Carter	23/07/2020

Executive Summary

Hunter H_2O was commissioned by NSW Health to conduct a capacity and capability review of Baradine Water Treatment Plant (WTP) on behalf of Warrumbungle Shire Council WSC) as part of a broader fluoride and drinking water improvements project.

A summary of the process capacity findings is presented in Figure ES-1. The assessment was undertaken by rating the capacity of the process units against a series of typical industry design criteria. These criteria include loading rates, detention times, and capacity to meet maximum dose rates. These have been referred to as Industry Standard Design Values (ISDV) in this report.

The actual values for ISDV may change between water authorities, regulators and designers around the world. The ISDV used in the assessment of Baradine WTP are values Hunter H_2O considers typical in the industry in Australia and are a useful guide in considering the capacity of a process in lieu of an in depth performance assessment of individual process units. The ISDV provide a reasonable estimate on the ability of the plant to consistently achieve industry standard water quality and operational performance targets. They do not guarantee an outcome and should not be relied upon in isolation.

The capacity assessment is focused on process production/capacity performance to identify bottlenecks and highlight operational risk associated with process units that are approaching, or have exceeded, their typical capacity. The capability assessment, part of the review, includes hydraulic issues, performance issues, areas of improvement, redundancy and provision of recommendations (where required) for each major process unit. However, individual site water quality/treatability, plant automation and control, site attendance and operational practices all have a role in whether or not the performance is satisfactory for current and future objectives. This report however serves to be a comprehensive review of the whole WTP to identify issues and areas for improvement.

The key process units identified as having a shortfall against the ISDVs are:

- Coagulation rapid mixing time
- Clear water storage – minimum disinfection C·t and treated water storage time
- Soda Ash Carbon dioxide maximum dosing and storage capacity.

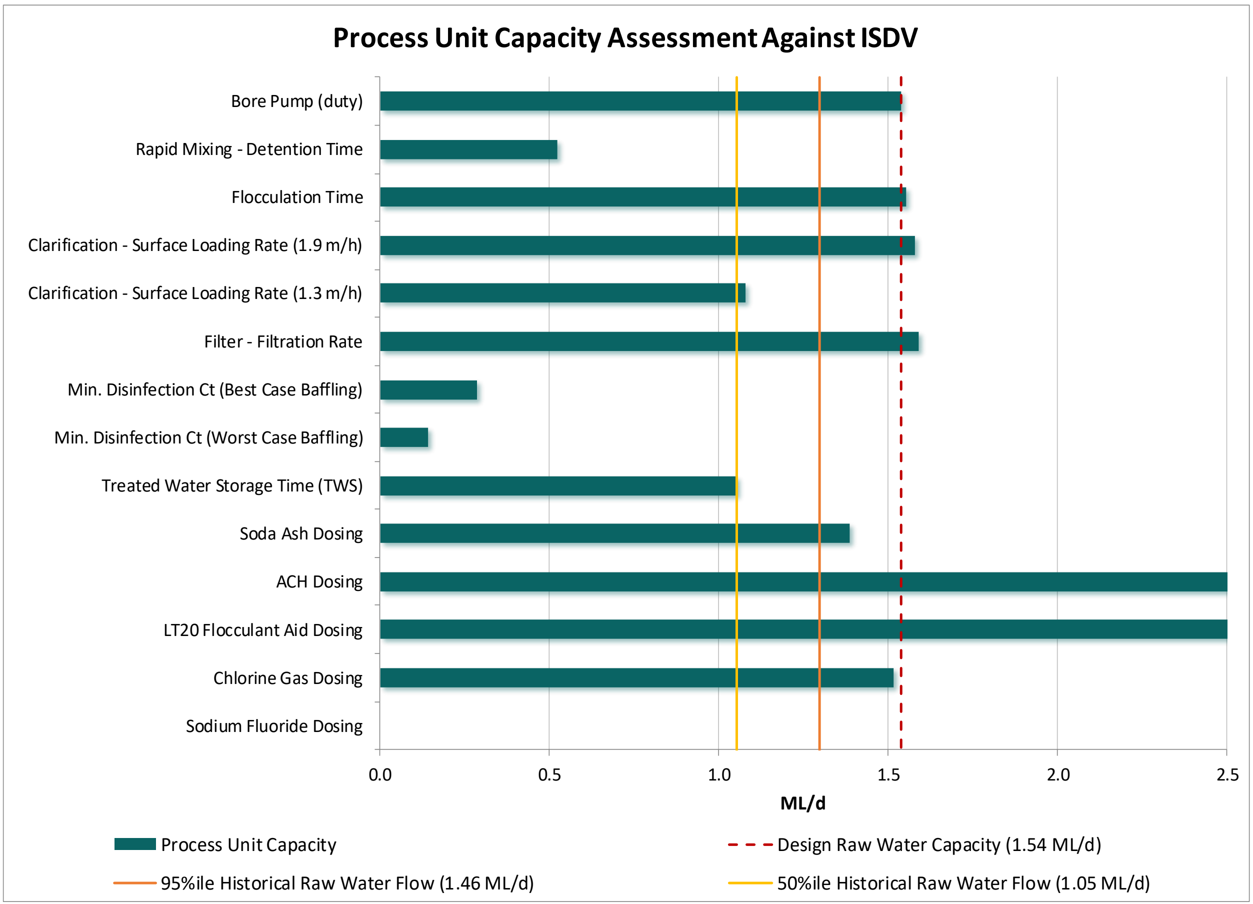


Figure ES-1: Process Capacity Assessment Summary

Recommendations were developed and a strategic discussion on upgrade consideration. The high-level strategic discussion of upgrading the WTP considers the broader range of issues at the WTP and takes a holistic viewpoint raising the option of a potential full WTP replacement.

Given the extent of the issues uncovered at Baradine WTP through recent investigations and studies commissioned by Council and supported by DPIE and NSW Health, the justification for a new WTP presents itself as a long term, holistic approach to addressing each major issue at the WTP. In comparison, upgrade of individual process units would result in a more complex treatment system with a mix of old and new infrastructure.

The order of magnitude of costs for refurbishment are estimated to be in the order of approximately ~$4M. While based on Hunter H2O's benchmarking cost database, for a 1.5 ML/d WTP, it could be expected that a new WTP may be procured for a similar cost in the order of ~$3M - ~$6M.

Recommendations to improve WTP performance and resilience are provided in Table ES-1, grouped in their order of priority.

Table ES-1: Process Capacity Assessment Recommendations

Priority	Recommendation
Short Term (High Priority)	▪ **Investigations** – ○ Investigate the high raw water turbidity readings and confirm the results are not due to surface water ingress into the bore. This could be confirmed through event-based turbidity grab samples collected frequently during and following intense rainfall events. ○ Undertake further targeted investigation into the elevated filtered water turbidity. A targeted investigation may include frequent iron and manganese sampling of the raw, aerated, settled, filtered and treated water over a period of a few weeks combined with onsite jar testing to isolate the root cause of the elevated turbidity. ▪ **Clarifier** - Proceed with the replacement of the existing clarifier with a package inclined plate settler (as planned), which would also include/address the follow recommendations identified through this investigation: ○ Include a dedicated static mixer to replace the rapid mixing pot. ○ Eliminate flocc tank inlet flow issues. ○ Eliminate the hydraulic issue and air entrainment between the clarifier outlet and filter inlet which causes the filter outlet valve to hunt. ○ Reduce the occurrence of boil-ups through longer plant operation and more frequent sludge scours ▪ **Filter** - Plan and undertake a major upgrade or replacement of the existing filter due to media loss and design issues. Refer to the filter inspection report submitted in June 2020 (Hunter H2O, 2020). There is an opportunity to combine the clarifier and filter into a single prefabricated unit to realise cost savings. ▪ **Disinfection C.t.** – ○ Advise NSW health of the deficiency in the existing plants C.t. and ask DPIE and NSW Health to consider reviewing the Safe and Secure priority risk rating considering this report and other recent reports (Automation & Filter Inspection). ○ Investigate and implement options to increase the storage size and include baffling of the TWS tank to increase storage time and chlorine C.t. This may involve construction of a new treated water storage. Alternatively, an option could be considered to redirect connections from before the town reservoir to source water from after the reservoir. ▪ Undertake tracer testing to confirm the existing tanks baffle factor under a range of tank levels and plant flowrates.
Medium Term (Moderate Priority)	▪ Proceed with the automation upgrades as per the WSC WTP Automation & Process Instrumentation Audit report (Hunter H2O, Jun 2020) which would also address the follow recommendations identified through this investigation:

Priority	Recommendation
	○ Online monitoring with feedback trim control dosing is recommended, along with improved automation and control over plant flowrates and operational times to allow for longer plant operation at lower flowrates. ○ Automation of backwashing due to headloss accumulation rates or turbidity breakthrough would alleviate these issues and improve the overall plant efficiency. ○ Replace the soda ash and ACH dosing pumps and pipework with the normal pipework safeguards on skid mounted systems within cabinets to improve WHS. Include provision for standby dosing capacity for ACH, polymer and chlorine gas dosing systems. Increase the primary chlorinator dosing capacity and decrease the ACH dosing capacity to a pump that can provide sufficient turndown accuracy. ○ Replace the MCC and relocate to above the flood levels
Long Term (Low Priority)	▪ Increase sampling and monitoring of raw water quality parameters such as turbidity, CO_2, iron and manganese concentrations with less frequent true colour and UVt monitoring. ▪ Undertake further investigation into the aeration performance by collecting samples before and after the aerator to assess CO_2, iron and hydrogen sulphide removal efficiency. ▪ Increase of the soda ash batching strength to increase both the batch storage and dosing capacity. ▪ Reduce the polymer batch concentration or batching volume to reduce the age of the batched solution and increase the frequency of polymer batching. ▪ Undertake a review against the latest Australian Standard for chlorine gas facilities (AS2927 Storage of Chlorine Gas) to confirm compliance.

Contents

1 Introduction ... 1
1.1 Background ... 1
1.2 Scope ... 1
1.3 Report limitations and assumptions ... 1
2 WTP background ... 2
2.1 WTP history ... 2
2.2 WTP description ... 2
2.3 Flows and demand ... 4
2.4 Water quality ... 5
2.4.1 Raw water quality ... 5
2.4.2 Treated water quality ... 6
3 Plant capacity and performance ... 11
3.1 Definition of plant capacity ... 11
3.2 Assessment reports ... 11
3.2.1 Overview of assessment reports ... 11
3.2.2 WTP design capacity ... 12
3.2.3 Aerator ... 13
3.2.4 Pre-treatment (pH adjustment) ... 14
3.2.5 Coagulation and rapid mixing ... 16
3.2.6 Flocculation aid dosing ... 18
3.2.7 Flocculation ... 19
3.2.8 Clarification ... 20
3.2.9 Filtration ... 21
3.2.10 Filter backwashing ... 23
3.2.11 Disinfection ... 25
3.2.12 Fluoridation ... 26
3.2.13 Treated water storage ... 26
3.2.14 Overflows and stormwater ... 30
3.2.15 Service water and compressed air systems ... 30
3.2.16 Plant electrical and control system ... 30
3.2.17 Plant amenities and laboratory ... 30
4 Summary and recommendations ... 32
4.1 Summary of assessment reports ... 32
4.2 Recommendations ... 33
4.3 Plant upgrade considerations ... 34
5 References ... 37

Figures

Figure 2-1: Site layout (aerial image taken from SIX Maps) 3
Figure 2-2: Process flow diagram 4
Figure 2-3: Daily WTP input/usage 5
Figure 2-4: Raw water turbidity data 6
Figure 2-5: Treated water turbidity (January 2015 – June 2020) 7
Figure 2-6: Treated water turbidity, iron and manganese 8
Figure 2-7: Treated water free chlorine 9
Figure 3-1: Existing treated water storage general arrangement 27
Figure 3-2: Existing treated water storage section view 28
Figure 3-3: Photos of outside plant analysis room 31
Figure 3-4: Photos of inside plant analysis room 31
Figure 4-1: Process unit capacity comparison with ISDVs for the WTP flows 32
Figure 4-2: IWCM issues paper Baradine demand forecast (Hydrosphere Consulting, 2018) 35

Tables

Table 2-1: WTP daily production flowrate statistics (2015 – 2020) 5
Table 2-2: Raw water quality data summary 6
Table 2-3: Summary of CCPs for Baradine water treatment 7
Table 2-4: Treated water quality data summary 9
Table 3-1: WTP design capacity and flow performance data 13
Table 3-2: Pre-treatment design criteria used in process assessment 15
Table 3-3: Pre-treatment process capacity and performance data 15
Table 3-4: Coagulation and rapid mixing design criteria used in process assessment 16
Table 3-5: Coagulation process capacity and performance data 17
Table 3-6: Rapid mixing process capacity and performance data 17
Table 3-7: Flocculation aid design criteria used in process assessment 18
Table 3-8: Flocculation aid dosing process capacity and performance data. 18
Table 3-9: Flocculation design criteria used in process assessment 19
Table 3-10: Flocculation process capacity and performance data 20
Table 3-11: Clarification design criteria used in process assessment 20
Table 3-12: Clarification process capacity and performance data 21
Table 3-13: Filtration design criteria used in process assessment 22
Table 3-14: Filtration process capacity and performance data 22
Table 3-15: Filter backwashing design criteria used in process assessment 24
Table 3-16: Filter backwashing capacity and performance data 24
Table 3-17: Disinfection design criteria used in process assessment 26
Table 3-18: Disinfection process capacity and performance data 26
Table 3-19: Treated water storage design criteria used in process assessment 27
Table 3-20: Treated water storage process capacity and performance data 28

Table 4-1: Summary of recommendations...33

Appendices

Appendix A Capacity Review Spreadsheets

Appendix B Filter Inspection Report

1 Introduction

1.1 Background

The town of Baradine is located in Central New South Wales, 45 km north west of Coonabarabran, with a population of approximately 625 people (Hydrosphere Consulting, 2018). Warrumbungle Shire Council (WSC) has 354 registered connections (Hydrosphere Consulting, 2018) to their potable water network in this township.

Baradine Water Treatment Plant (WTP) treats water primarily sourced from an onsite artesian bore, with a second artesian bore available for emergency use. The second bore is located in town and otherwise used to irrigate sporting fields. Raw water undergoes aeration, pH correction, coagulation, flocculation, clarification, gravity filtration and disinfection with chlorine. It is stored in the onsite treated water storage (TWS) tank, before being pumped to the 1.1 ML town reservoir. Treated water then gravitates through the reticulation network to connections in town. However, there are also several connections to the treated water network between the onsite TWS tank and the town reservoir.

The treatment plant is designed to treat 1.5 ML/day (however the existing clarifier design capacity was originally stated as 0.908 ML/d) and operate up to a flowrate of 19 L/s.

NSW Health has engaged Hunter H2O to deliver a range of drinking water quality and fluoridation improvements for Warrumbungle Shire Council (WSC).

The capacity and capability review of Baradine Water Treatment Plant (WTP) was included as a deliverable for this project by an approved variation.

1.2 Scope

This capacity and capability report was designed to collate the findings from a complete plant process review of Baradine WTP, and in doing so identify areas that can be targeted to improve overall plant performance. This report and the Baradine WTP Filter Inspection Report (Hunter H2O, 2020) were commissioned to investigate the elevated filtered water turbidity during winter.

The report follows Hunter H2O's standardised approach to capacity and capability assessments. It provides consistently presented commentary based from the site visit on the following aspects, where relevant to each key unit process:

- Description
- Process capacity and performance
- Performance issues and areas for improvement
- Redundancy
- Information gaps.

1.3 Report limitations and assumptions

The major limitations of this report are surrounding information gaps in the details of the water treatment plant, namely:

- Raw water quality could not be accurately used to assess the WTP requirements and performance due to a lack of data.
- A full assessment of the aeration process could not be completed due to a lack of information regarding the internal structure of the aerator.
- Filter backwashing could not be accurately assessed due to a lack of information regarding backwash flow rate, bed expansion and backwash supply tank volume.
- Fluoridation was not assessed as the fluoride dosing system is currently non-operational and due for replacement.

Furthermore, due to the lack of information available, the 2001 Baradine WTP Operation and Maintenance Manual (WTA, 2001) and drawings had to be used for many aspects of the capacity assessment. The information in this manual pre-dates many of the more recent upgrades undertaken at the WTP. It has been assumed that information provided in both the manual and the drawings is still applicable to the WTP unless it has been explicitly stated otherwise.

2 WTP background

2.1 WTP history

Baradine WTP has had several augmentations, additions and upgrades since it was first constructed. The clarifier, treated water storage tank, main building and associated pumps were all built in 1962. The current aerator, dosing equipment and filter were all constructed in a major upgrade completed in 2002, and the new ground level concrete backwash supply tank was added in 2012.

A fluoride dosing system was added in 2010 and commissioned in 2014. However, the system has not been operational since January 2017 as it is unable to produce a saturated feed solution of sufficient fluoride strength. Upgrade of the fluoride dosing system is currently being investigated.

A clarifier condition assessment undertaken in January 2014 found severe pitting corrosion throughout the structure. Following a clarification options assessment in 2015, Hunter H2O formed the opinion that delaying the refurbishment or replacement of the existing clarifier for longer than 12 – 18 months would increase the risk of structural failure and the safety concerns of the structure itself. It was also considered possible that rehabilitation of the clarifier would no longer be practical if the structure was left for up to 18 months. This 18-month period has since expired.

A concept design was submitted by Hunter H2O in 2016 for a new inclined plate settler (IPS) to replace the existing clarifier. However, this project has not been approved by the Department of Planning, Industry and Environment (DPIE) at that stage, and thus the original clarifier continues to be used without refurbishment. Council have continued to collaboratively engage with DPIE on this issue since 2016 with the aim to come to a solution to enable the clarifier to be replaced.

The key historical raw water quality risks are iron, manganese, hydrogen sulphide and carbon dioxide.

2.2 WTP description

Baradine WTP is a conventional treatment plant, consisting of; aeration, pH correction, coagulation, flocculation, clarification, gravity filtration and chlorine disinfection. The existing fluoride dosing system is currently not operational, and thus there is currently no fluoridation process at the WTP.

Raw water is primarily sourced from the onsite artesian bore which draws ground water from the confined aquifer, approximately 218 m below ground level. A second artesian bore is available for emergency use, however this bore is mainly used to irrigate sporting fields.

The bore water is aerated to strip carbon dioxide and oxidise sulphide, iron and manganese compounds. The aerated water is dosed with sodium carbonate (soda ash) to increase pH for improved oxidation of soluble iron, manganese and sulphur compounds. These oxidised compounds then precipitate and can be removed through the clarification and filtration processes.

Once the pH of the aerated water has been adjusted/increased, the water is dosed with aluminium chlorohydrate (ACH) coagulant before passing through an inline rapid mixing pot. Polyacrylamide LT20 is also dosed to assist the formation of particle flocs, which subsequently settle out in the clarifier. The clarified water is then filtered through a dual media gravity filter before being dosed with chlorine gas for disinfection. Treated water is stored in the underground onsite treated water storage (TWS) tank, before being pumped to the 1.1 ML town storage reservoir.

Solids from the clarifier are discharged manually to one of the two sludge lagoons. Filter washwater is also sent to the sludge lagoons. The sludge lagoons operate in duty/standby configuration and can overflow to the creek located approximately 500 m to the east of the WTP. This is a licenced EPA discharge point, for which the details are described in Section 3.2.14 of this report.

The site layout can be seen in Figure 2-1 and a process flow diagram of the Baradine water supply system is shown in Figure 2-2.

Figure 2-1: Site layout (aerial image taken from SIX Maps)

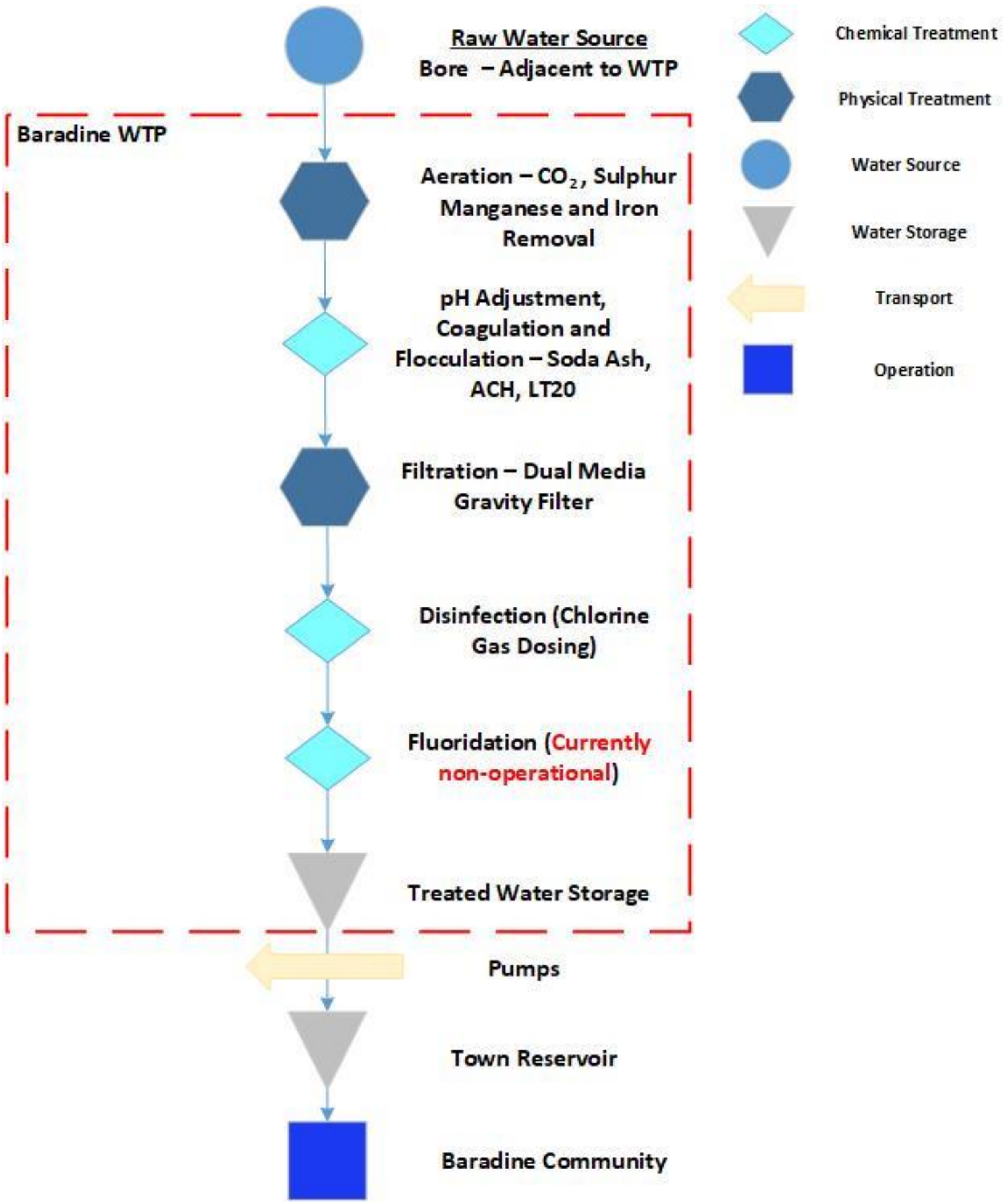


Figure 2-2: Process flow diagram

2.3 Flows and demand

Daily water usage data from January 2015 to May 2020 is shown in Figure 2-3 below, taken from Council's meter reading data provided in Council's 'Baradine operational monitoring v2.0' spreadsheet. The data shows a typical pattern of high demand in Summer and low demand in Winter, particularly during early 2015 and 2017/18.

As can be seen in the linear trendline on Figure 2-3, there is a slight increase in average demand observed since 2015.

It can also be seen that some flow records are higher than the WTP capacity, and Council believes these readings are due to inaccuracy from the flow meter.

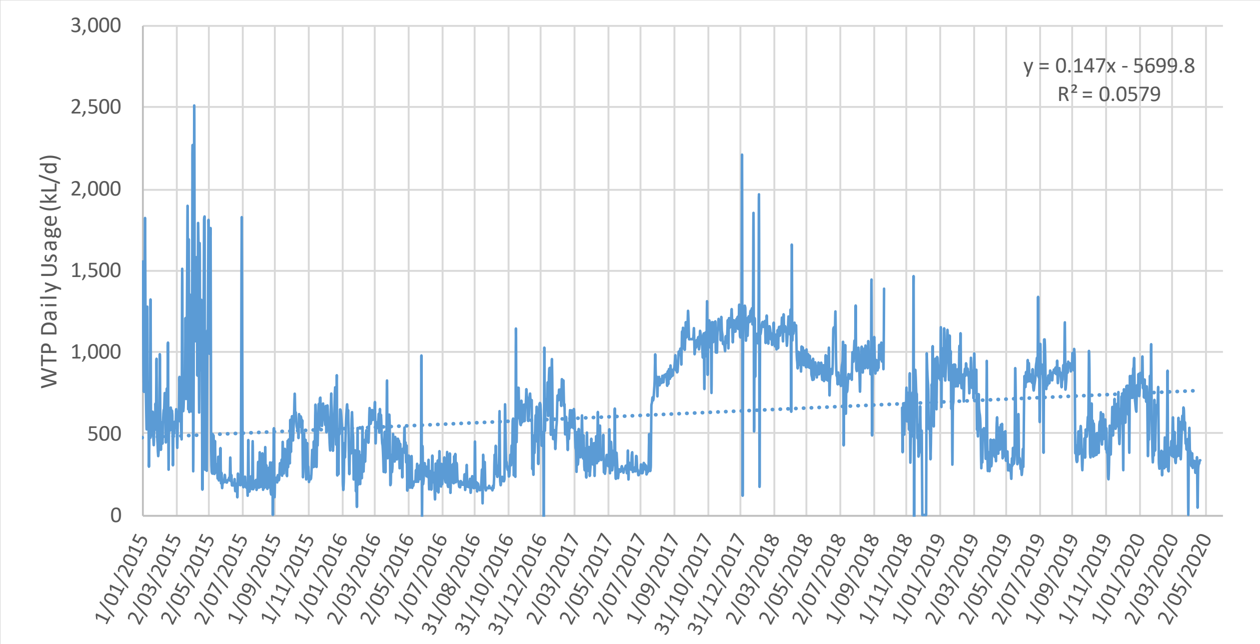


Figure 2-3: Daily WTP input/usage

Hunter H2O also undertook a brief statistical analysis on flow data provided in Council's 'Baradine operational monitoring v2.0' spreadsheet, as seen in Table 2-1 below. The data analysed is the entirety of the data provided to Hunter H2O in the spreadsheet, namely from 01/01/2015 to 28/05/2020.

The WTP daily input flowrate is based on the flow rate provided from the bore fixed flowrate on a daily basis, in units of L/s. Whilst the 95 percentile input flow rate is just below the design capacity of 19 L/s, the maximum recorded flow rate is well above this value. This could potentially be due to inaccuracy in the flowmeter, as previously stated by Council.

The daily production shown in Table 2-1 is based on the difference in total meter readings between the current and previous day. It represents the total amount of water produced by the plant each day.

Table 2-1: WTP daily production flowrate statistics (2015 – 2020)

Flow Parameter	Minimum	5%ile	Average	Median	95%ile	Maximum
WTP Daily Plant Fixed Flowrate (L/s)	8.0	10.0	12.8	13.0	18.0	25.0
Daily Production Based on Meter Reading (kL/d)	44.7	181	615	553	1160	2508

Note: The maximum production flowrate can be seen to be higher than the maximum daily input flowrate. This is also attributed to inaccuracy of the flowmeters, as previously stated by Council.

2.4 Water quality

2.4.1 Raw water quality

Raw water quality data was taken from the spreadsheet provided by Council, entitled 'Baradine operational monitoring v2.0'.

The only raw water quality data available for Baradine WTP was pH and turbidity. Daily pH data was available from 01/01/2015 to 28/05/2020. However, in the spreadsheet provided by Council, daily raw water turbidity data (Figure 2-4) was only recorded from 20/09/2019 to 28/05/2020.

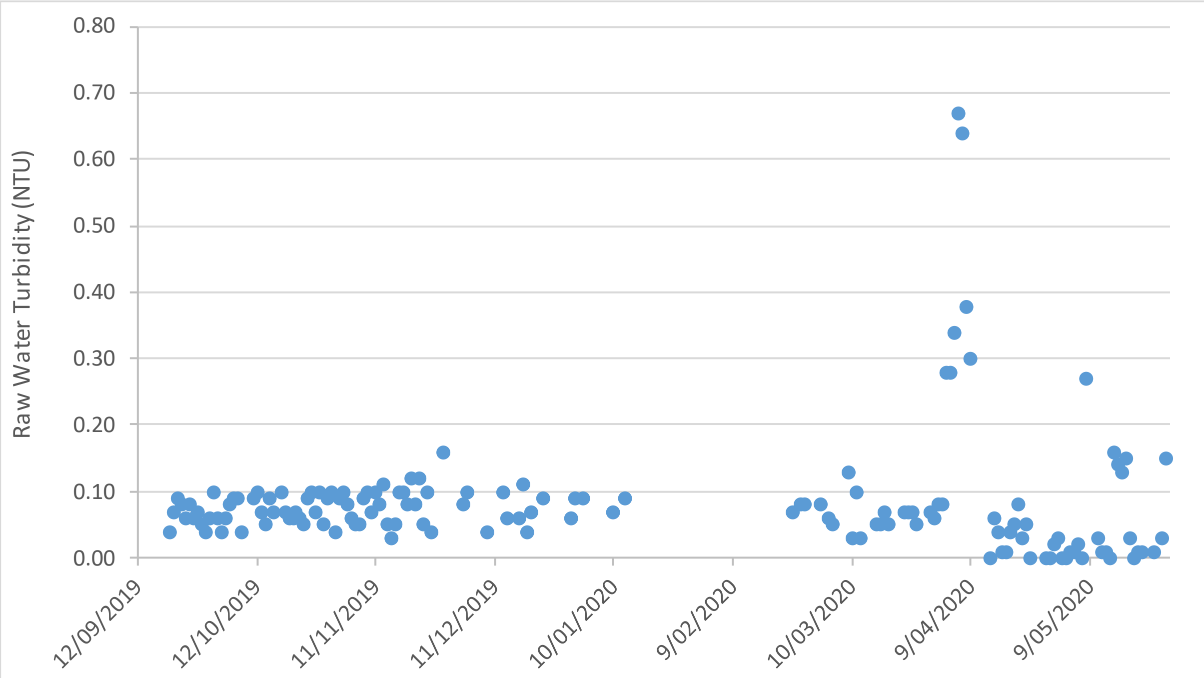


Figure 2-4: Raw water turbidity data

It can be seen in Figure 2-4, that raw water turbidity was less than 0.20 NTU for the majority of the data provided, however, there was some turbidity spikes up to a maximum of 0.67 NTU in April 2020. Low turbidity is a typical characteristic of a bore water supply. Higher results could be due a number of reasons which should be investigated, such as:

- Surface water infiltration
- Sample not being analysed immediately and iron precipitation occurring
- Sample temperature causing fog on the sample vial and inflating readings.

The statistical summary for raw water pH and turbidity can be seen in Table 2-2 below. However, it should be noted that the statistics shown for raw water turbidity only present a brief 'snapshot' due to the limited data available. The raw water pH is usually below 7, which must be increased for oxidation removal processes to be effective. This is why soda ash is currently dosed near the start of the treatment process at Baradine WTP.

It is recommended that Council increase sampling and monitoring of raw water quality parameters, such as, turbidity, CO_2, iron and manganese concentrations with less frequent true colour and UVt monitoring. Consistent monitoring of raw water quality provides a basis for the treatment required to meet treated water quality objectives, as well as, allowing the identification of areas where an increased level of treatment may be required. Event based monitoring is also recommended to confirm there is not surface water ingress/contamination occurring during rainfall events.

Table 2-2: Raw water quality data summary

Parameter	Count	Minimum	Average	Median	95%ile	Maximum
Turbidity (NTU)	146	0.00	0.08	0.07	0.28	0.67
pH	1955	5.45	6.46	6.48	6.79	7.56

2.4.2 Treated water quality

Council's targets for treated water quality are presented in the critical control points (CCPs) for the Baradine water treatment network. These are summarised in Table 2-3 below.

CCP targets are where the system should be operating, alert limits are the first indication that the system may have a problem, and critical limits represent a loss of control of the system.

Table 2-3: Summary of CCPs for Baradine water treatment

CCP ID	Control Point	Hazard	Control Parameter	Target	Alert Limit	Critical Limit
BDN1	Filtration	All pathogens	Turbidity	<0.2 NTU	>0.4 NTU	>0.8 NTU
BDN2	Disinfection (gas)	Chlorine sensitive pathogens	Chlorine	1.4 – 1.9 mg/L	<1.2 mg/L, >2.5 mg/L	<1.0 mg/L, >4.0 mg/L
BDN3	Fluoridation	Fluoride	Fluoride	1 mg/L (leaving WTP, leaving reservoir and throughout distribution system)	<0.9 mg/L for >24 hrs, >1.1 mg/L	>1.5 mg/L, <0.9 mg/L for >72 hrs, 0.0 mg/L for >24 hrs
BDN4	Reservoirs	All pathogens and all chemicals	Reservoir integrity	No breach of integrity (hatches locked, no holes in meshing)	-	Breach of integrity identified
BDN5	Distribution	Chlorine sensitive pathogens and all chemicals	Chlorine	>0.8 mg/L, <2.0 mg/L	< 0.5 mg/L, >2.5 mg/L	< 0.2 mg/L, >4.0 mg/L
BDN6	Distribution (OCP)	All Pathogens	Turbidity	<1.0 NTU	>1.0 NTU	>4.0 NTU

Note: there is a discrepancy between the CCP for filtration adopted in 2018 and that reported in the latest NSW Health DWMS annual report (July 2019) which presents the old CCP values prior to 2018 (TBC).

Treated water quality data was provided in Council's operations spreadsheet for the period from 01/01/2015 to 28/05/2020. The treated water parameters recorded in the spreadsheet were turbidity, pH, free chlorine, iron and manganese. Turbidity, pH and free chlorine were recorded daily, whilst iron and manganese concentrations are currently scheduled to be recorded weekly. However, iron and manganese concentrations were recorded sporadically across the data range, rather than on a regular weekly basis.

The treated water turbidity data can be seen in Figure 2-5 below. The lines on the chart represent the CCP target, alert and critical limits for treated water turbidity entering the distribution network.

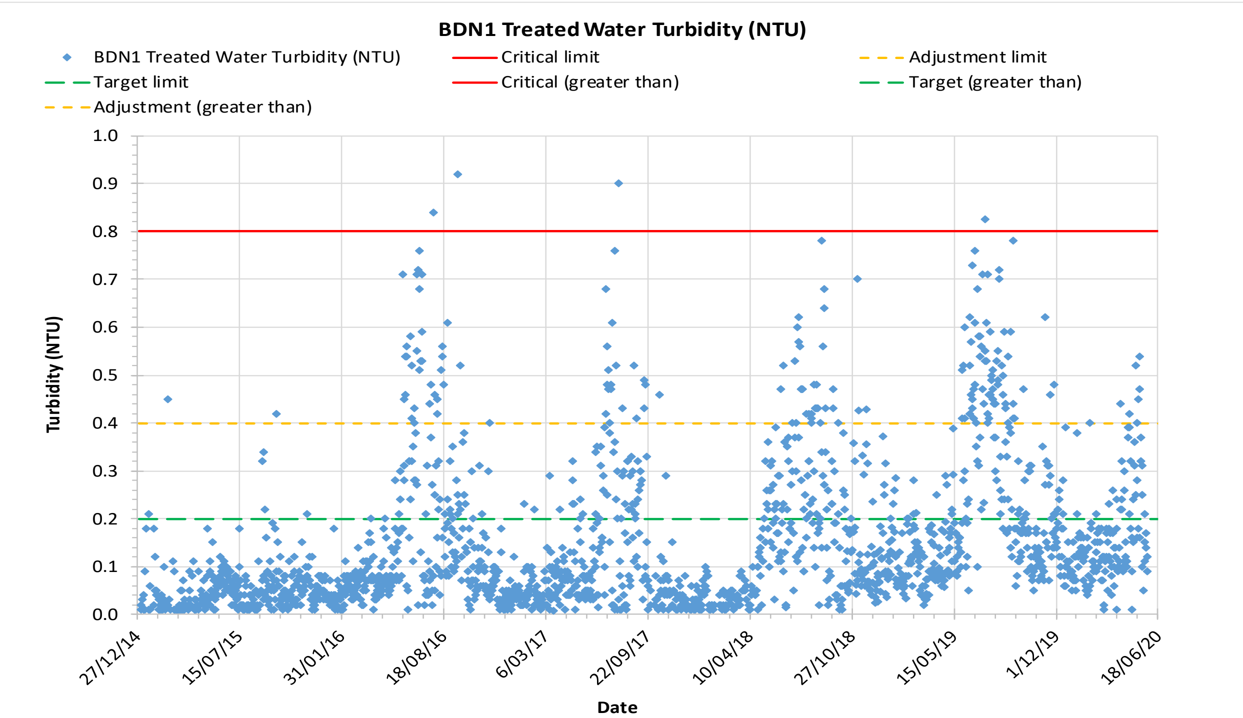


Figure 2-5: Treated water turbidity (January 2015 – June 2020)

The treated water turbidity (filtered water) data (seen in Figure 2-5) was discussed in detail within the Baradine WTP Filter Inspection Report. The key observation was that some variable or event has occurred which has resulted in poor filtered water quality at times, with greater variability occurring during the winter months. The likely causes were identified as:

- Sampling techniques or times
- Sample temperature causing fog on the sample vial and inflated readings
- Overdosing of ACH and post flocculation issues
- Cold water affecting coagulation, causing elevated aluminium and hence post flocculation issues
- Potentially insufficient contact time between soluble manganese and filter media due to the decreased filter media bed depth (due to the media loss event caused by the incorrect level switch position).

Further targeted investigation in this area was therefore recommended. A targeted investigation may include frequent iron and manganese sampling of the raw, aerated, settled, filtered and treated water over a period of a few weeks combined with onsite jar testing to isolate the root cause of the elevated turbidity.

However, the data for treated water iron and manganese concentrations can be seen in Figure 2-6 below alongside the turbidity data. As Council does not have any CCP limits related to treated water iron and manganese, the data has been compared to limits provided by the Australian Drinking Water Guidelines (ADWG) (NHMRC, NRMMC, 2011).

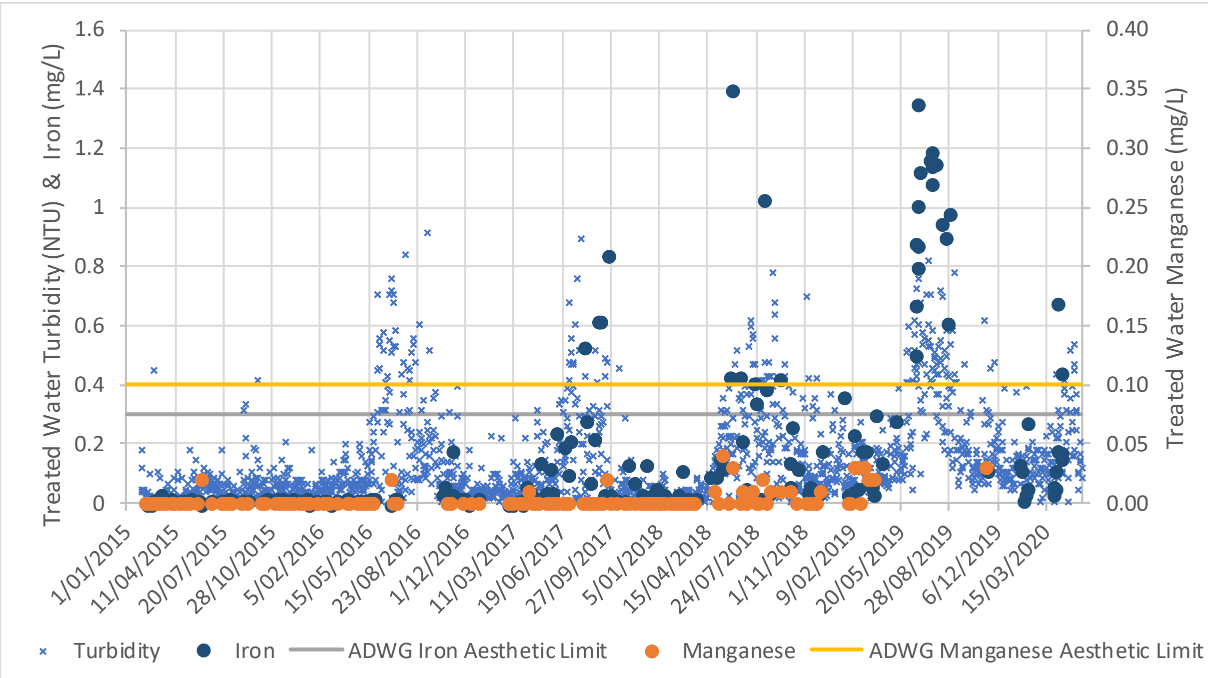


Figure 2-6: Treated water turbidity, iron and manganese

It can be seen in Figure 2-6 that there appears to be some correlation between spikes in treated water iron and turbidity. Although there are far fewer iron and manganese data points, there appears to be some correlation between spikes in treated water iron and manganese as well. Hence it is possible that the reduced filter media depth is impacting on the particle capture and/or the reduced bed depth has decreased the effectiveness of the natural oxide coated media process.

The lower dashed line represents the aesthetic limit of 0.3 mg/L for iron in treated drinking water. It can be seen that there are a significant number of exceedances of this limit, particularly between July 2017 and August 2019. Exceedances in the aesthetic limit will often lead to customer complaints and can ultimately lead to a distrust in the potable water supply. There is currently no health-related guideline provided for iron in drinking water. It is, however, likely that the iron would be oxidised by subsequent chlorine dosing and deposited in the TWS, retic or town reservoir.

The upper dashed line represents the aesthetic limit of 0.1 mg/L for manganese in treated drinking water. There are no recorded exceedances of this limit. Treated water manganese should be continuously monitored to ensure it stays below the ADWG aesthetic limit in order to avoid customer complaints. The health-related guideline for manganese in drinking water is 0.5 mg/L, which is well above the concentration of manganese seen in the data provided for Baradine WTP treated water.

The data for treated water free chlorine can be seen in Figure 2-7 below. The lines on the chart represent the target (innermost), alert (middle) and critical (outermost) upper and lower CCP boundaries for free chlorine after disinfection.

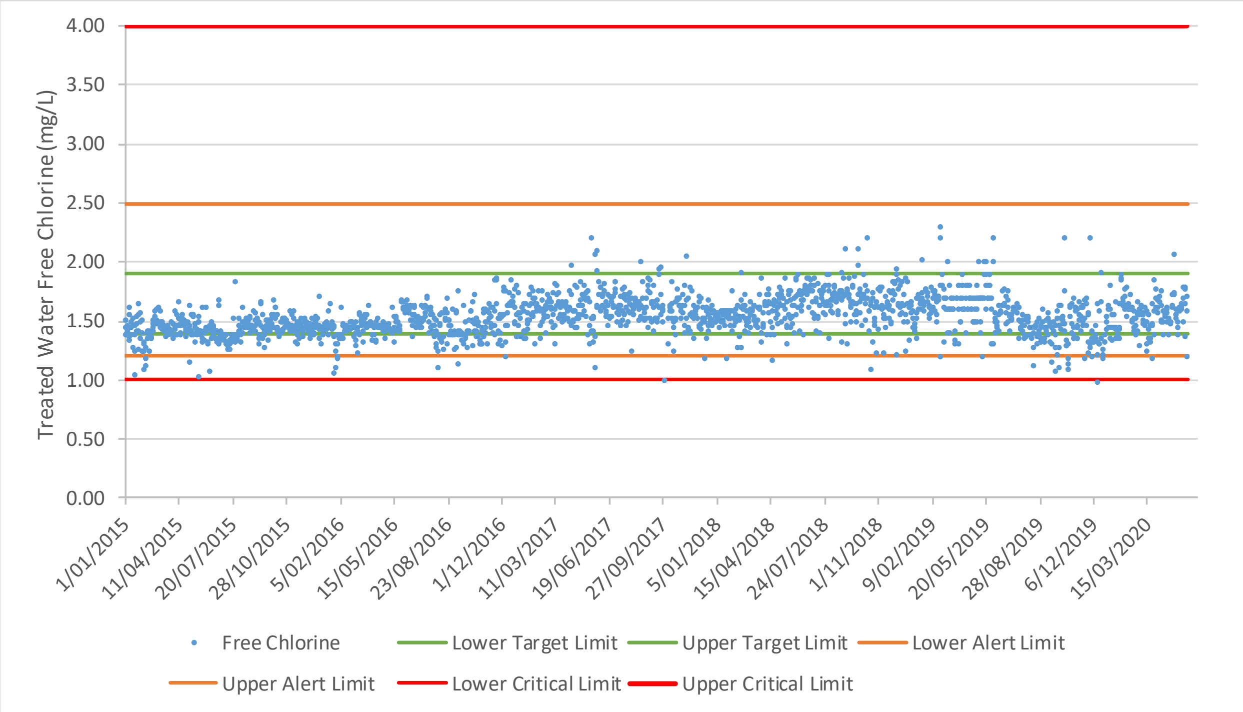


Figure 2-7: Treated water free chlorine

It can be seen in Figure 2-7 that the free chlorine concentration is operating mostly within the target range, although there is significant operation below the lower limit of the target range, and significant spiking below the lower limit of the alert range. There were also two recorded drops below the lower critical CCP limit on the 28th of September 2017 and the 12th of December 2019.

Free chlorine concentrations that are too high can lead to increased formation of disinfection by-products (DBPs), as well as potential taste and odour issues. Conversely, free chlorine concentrations that are too low mean that a sufficient disinfection barrier is not provided to protect against pathogenic microorganisms, which are the greatest risk to the safety of drinking water. The data provided in Figure 2-7 shows that the free chlorine concentration could be easily increased at Baradine WTP to avoid spiking below the lower target and critical limits, whilst still ensuring operation below the upper target and critical limits. The manual dosing control arrangement, however, makes this difficult to control. Online monitoring with feedback trim control dosing is recommended along with improved automation and control over plant flowrates and operational times to allow for longer plant operation at lower flowrates.

A statistical summary of the treated water quality data provided can be seen in Table 2-4 below.

Table 2-4: Treated water quality data summary

Parameter	Count	Minimum	Average	Median	95%ile	Maximum
Turbidity (NTU)	685	0.01	0.21	0.16	0.54	0.83
pH	1957	7.00	7.75	7.76	7.94	8.35
Free Chlorine (mg/L)	1957	0.98	1.54	1.53	1.80	2.30
Iron* (mg/L)	178	0.00	0.20	0.04	1.12	1.40
Manganese* (mg/L)	132	0.00	0.00	0.00	0.02	0.04

Note: Iron and manganese concentrations listed as 0.00 are assumed to be below the limit of detection (LOD), although the precise value of this limit is unknown as the analysis technique has not been provided.

The average, median and 50th percentile turbidity values can be seen to be above the CCP alert limit of greater than 0.1 NTU. This shows that the CCP target for turbidity is rarely being met by the current treatment process. Furthermore, the 95th percentile and maximum values are well above the CCP critical limit of greater than 0.4 NTU. Turbidity above 0.1 NTU can reduce the effectiveness of disinfection treatment processes and, therefore, the removal/inactivation of pathogenic microorganisms cannot be guaranteed.

Treated water pH can be seen to be within the acceptable ADWG range of 6.5 to 8.5 (NHMRC, NRMMC, 2011) for all values between the minimum and maximum, although it should be noted that the maximum treated water pH value recorded is above 8. Chlorine disinfection efficiency is impaired at a pH of above 8, which should be considered for Baradine WTP along with the treated water parameters of free chlorine and turbidity.

Treated water free chlorine data has been analysed with reference to Figure 2-7, however it should be noted that Table 2-4 shows that the average, median and 50th percentile values are much closer to the CCP target lower limit of 1.4 mg/L than the target upper limit of 1.9 mg/L. This suggests that there is ‘room’ within the target range for an increase in chlorine dose rates at Baradine WTP and thus increase in C.t.

The 95th percentile and maximum values for treated water iron concentration are above the ADWG aesthetic guideline, as identified in reference to Figure 2-6. This may cause occasional issues with customer complaints. The full range of data for treated water manganese concentration is below the ADWG aesthetic guideline, as identified in reference to Figure 2-6, and is therefore not considered to be an issue.

3 Plant capacity and performance

3.1 Definition of plant capacity

Baradine WTP has a treatment design capacity of 1.5 ML/d (however, the existing clarifier design capacity was originally stated as 0.9 ML/d) and a design instantaneous raw water flow of 19 L/s. At the operational period of 22.5 hours per day, the stated output capacity of 1.5 ML/d equates to an instantaneous treated water flow of approximately 18.5 L/s. The remaining 1.5 hours per day is a general allowance to account for plant downtime and filter backwashing. The difference between the design instantaneous raw and treated water flows is based on the capacity over a whole day and is mainly due to wastage of filter backwash water. The stated difference provides a plant design efficiency of 97.5%.

3.2 Assessment reports

3.2.1 Overview of assessment reports

Capacity and performance assessments have been completed on the Baradine WTP by Hunter H2O. The assessment reports have been split into each major section of the plant. These include:

- WTP design capacity
- Aerator
- Pre-treatment (pH adjustment)
- Coagulation and rapid mixing
- Flocculation aid dosing
- Flocculation
- Clarification
- Filtration
- Filter backwashing
- Disinfection
- Fluoridation (currently not operational)
- Treated water storage
- Overflows and stormwater
- Service water and compressed air systems
- Plant electrical and control system
- Plant amenities and laboratory.

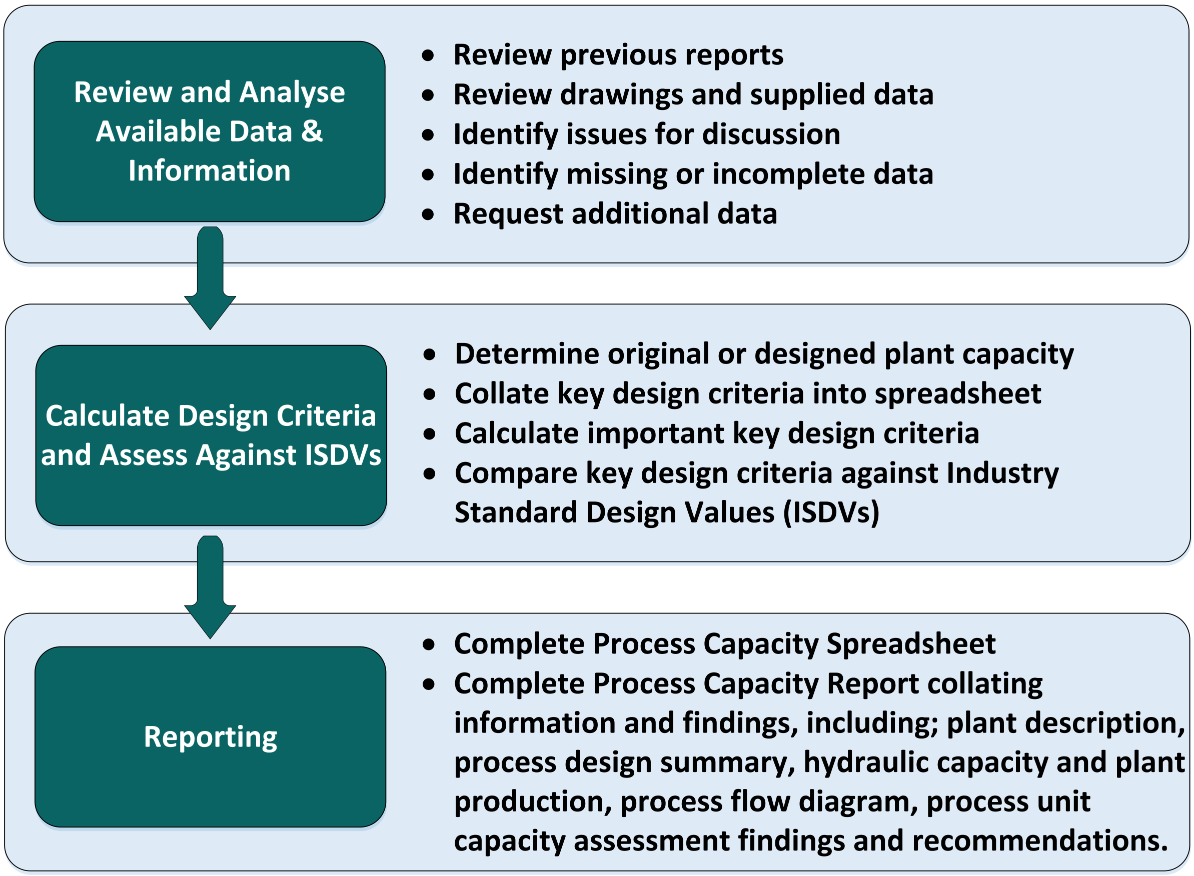
Each capacity and performance assessment report adhere to the following report structure:

- Description
- Hydraulic issues
- Process capacity and performance
- Performance issues and areas for improvement
- Redundancy
- Information gaps (where relevant).

Each assessment defines the unit process capacity as per the 2001 upgrade design, as well as 95th percentile and 50th percentile flow rates obtained from operational data taken between 2015 and 2019. Main unit processes are also compared to contemporary Industry Standard Design Values (ISDVs) to allow comparison between current standards and the original design.

3.2.1.1 Capacity assessment methodology

The capacity assessment part of the process capacity and performance review is primarily based around the application of ISDVs, and hence may not correlate directly to capacity constraints or bottlenecks experienced by operations in the past. Hence, the results from this assessment should be complimented with an assessment of the historical plant performance to deliver the design water quality and quantity.



The capacity assessment sections were undertaken by rating the capacity of the process units against a series of typical industry design criteria, including loading rates, detention times and capacity to meet maximum dose rates. These have been referred to as ISDV in this report. The actual values for these criteria may change between water authorities, regulators and designers around the world. The ISDV used in the assessment of Baradine WTP are values Hunter H_2O considers typical in the industry in Australia and are a useful guide in considering the capacity of a process in lieu of an additional detailed performance assessment. The ISDVs provide a reasonable estimate on the ability of the plant to achieve modern water quality performance targets, although further investigation quantifying actual performance is recommended.

3.2.1.2 Data collection

A site inspection of the Baradine WTP was undertaken by Michael Carter on the 26th and 27th of November 2019 to collect information and complete onsite measurements to perform the assessment, to complement the reports and documentation provided by WSC.

3.2.2 WTP design capacity

Description

As described in Section 3.1, the treatment plant is designed for a daily treated water production of 1.5 ML/d over a 22.5 hour day of operation (however, the existing clarifier design capacity was originally stated as 0.9 ML/d). This provides an instantaneous treated water flowrate of 18.5 L/s. Compared to the design instantaneous raw water flowrate of 19 L/s, this provides a plant design efficiency of 97.5%, which can mainly be attributed to water wastage from filter backwashing and clarifier sludge scours.

Hydraulic issues

Raw water is delivered by a single onsite fixed speed bore pump. Water is pumped through a DN150 pipe into the aerator. The flowrate can be reduced through operation of a manual gate control valve by creating higher pumping head.

The onsite bore that supplies water to the treatment plant was found to have an estimated capacity of 20 L/s during a bore test conducted in 2009. This is slightly above the WTP design flow, however it should be noted that there is no spare capacity in the bore pump for future WTP capacity upgrades.

Process capacity and performance

The WTP design capacity and flow performance data can be seen in Table 3-1, along with the calculated plant efficiency.

Table 3-1: WTP design capacity and flow performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow
Treated Water Plant Production	ML/d	1.5	1.16	0.55
Plant Operation	h/d	22.5	21.6	13.5
Treated Water Flow Rate	L/s	18.5	14.9	0.56
Raw Water Flowrate	L/s	19	18.0	11.3
Plant Efficiency	%	97.5%	93.4%	87.0%

Design flows were taken from the 'Baradine WTP Operation and Maintenance Manual' (WTA, 2001), whilst the 95th and 50th percentile flows were taken from the Baradine WTP operational monitoring spreadsheet using data from 2015 to 2020. Raw water flow rate data is based on the flow measured from the bore, while the raw water demand (ML/d) was determined through a back calculation using the treated water plant production and subtracting the combined plant wastage voumes (clarifier scours and filter washwater). Plant efficiency was then claculated using the difference between the treated water plant production and the raw water demand. The plant operational time was also calculated using the raw water demand and the bore flowrate (L/s) recorded in the operational spreadsheet.

Performance issues and areas for improvement

At 95th and 50th percentile flows, the plant efficiency can be seen to decrease when compared against the design flow. This occurs as the filter is backwashed once a day and the clarifier is also scoured once a day, hence the wastage volume remains constant as the plant demand or treated water production changes. This is most likely due to backwash water that is wasted to the sludge lagoons making up a larger portion of the overall flow at these times. This may mean that backwashing is occurring too frequently or for too long at these lower plant flow rates and lower plant production rates. At lower WTP flow rates, the frequency of backwashing can usually be decreased as there is a lower volume of water passing through the filter and therefore a lower solids loading. Automation of backwashing due to headloss accumulation rates or turbidity breakthrough would alleviate these issues and improve the overall plant efficiency.

Redundancy

Water supply redundancy is provided by the second bore located in town. Although this bore is primarily used to irrigate sporting fields, it can also be used to supply Baradine WTP if there is an issue with the primary bore.

However, it is uncertain as to whether the secondary bore has sufficient capacity to meet the full design demand of the WTP. Additionally, the water quality from the secondary bore has been historically different to that of the primary bore, and the WTP has previously had issues with effectively treating water from the secondary bore.

Information gaps

The maximum yield and detailed water quality of the secondary bore is unknown, and therefore it is uncertain whether this bore can provide full redundancy for the WTP supply.

3.2.3 Aerator

Description

Water supplied from the on-site bore is immediately passed through a spray aerator to strip carbon dioxide from the water and oxidise sulphide, iron compounds and assist with manganese oxidation. The aeration process is prior to pH correction with soda ash dosing.

Due to a lack of water quality information such as raw bore and aerated water CO_2, iron and hydrogen sulphide concentrations, the performance of this process unit cannot be verified. Therefore, a full assessment report has not been completed for this process unit.

Hydraulic issues

Although no hydraulic issues were identified during the site visit, visual inspection of the inside of the aerator revealed a significant amount of iron or manganese build-up on and around the sprays. If bore pump capacity issues were found to be an issue in the future this may be a logical spot to check as it may be possible that the sprays will continue to scale and eventually be clogged at some point in the future. Clogging would require removal of the scale via cleaning.

Process capacity and performance

No issues have been reported in the capacity of the aeration process, however the unit's performance efficiency is unknown. Undertaking pH monitoring of the aerated water prior to soda ash dosing, could allow the aerator performance to be somewhat confirmed due to the change in pH between the raw water and aerated water, indicating the level of dissolved carbon dioxide removal.

The ISDV guideline has a target of greater than 95% removal of carbon dioxide, hydrogen sulphide and iron through an aeration process. The aeration process at Baradine should be aiming to achieve these removal targets, however there is insufficient pre and post aerator water quality information to assess this at this point in time. Further data collection would be required to assess and confirm the performance.

During the site visit, when the aerator was opened during operation there was a very strong noticeable hydrogen sulphide odour suggesting the gas was being evolved from the dissolved state.

Performance issues and areas for improvement

The pH of raw water is too low (average 6.46) for effective oxidation processes to occur. The ISDV guideline for pH during aeration oxidation of iron and manganese compounds is a pH of greater than 8.50. From data collected between 2015 and 2020 and provided in the Baradine WTP operational monitoring spreadsheet, the maximum recorded raw water pH was 7.56, whilst the median was 6.48. This is much lower than the ISDV value, and efficient oxidation of the target compounds would not be expected to occur during the aeration process.

However, performing pH correction with soda ash before the aeration process could lead to scaling in the aerator and is not practical. The dosing of soda ash immediately after the aeration process is intended to increase the pH (average of 7.87) to the target range for effective oxidation whilst the water remains high in dissolved oxygen to drive the oxidation reaction.

Furthermore, analysis of treated water data in Section 2.4.2 of this report highlighted the issue that treated water iron concentrations have frequently measured above the ADWG aesthetic limit, which may lead to customer complaints. Although unlikely, this could suggest that the aeration process may not be operating efficiently and adding sufficient DO into the water for removal of iron from the raw water. Conversely, it was seen that manganese concentrations have been consistently below the ADWG aesthetic limit, however due to a lack of raw water quality data, it is uncertain as to whether manganese concentrations could already be low in the raw water. Therefore, the efficiency of the aeration process for removal of manganese cannot be proven with the available data either.

Redundancy

All raw water must pass through the single aeration unit, and therefore there is no redundancy available for the aeration process. This means that the entire plant would need to be stopped if there was a need to take the aerator offline for maintenance or upgrades.

Information gaps

Insufficient information is currently available to assess the aerator capacity and performance. Detailed water quality information pre and post aerator would be required, along with information on the internal structure and aeration mechanism used in the process unit to perform a full process unit assessment.

3.2.4 Pre-treatment (pH adjustment)

Description

Soda ash dosing is used for pH correction to increase the pH of the raw water in order to promote the oxidation of soluble iron, manganese and sulphur compounds after aeration. It is dosed immediately after aeration of the raw water.

The design criteria for the pre-treatment soda ash dosing system can be seen in Table 3-2. The dose rates were taken from the Baradine WTP operational monitoring spreadsheet, using daily dose rate data from 2015 to 2020.

The intermediate batch storage is based on the batched soda ash solution available for use in the soda ash dosing tank. There is currently only one pallet of soda ash bulk bags stored on the raised platform inside the main building, however the bulk chemical storage design criteria assumes that there is space for 2 pallets on this raised platform as space allows.

Table 3-2: Pre-treatment design criteria used in process assessment

Design Criteria	Value/Description	Units
Chemical	Soda Ash	-
Typical Dose (Median)	140	mg/L
Minimum Dose	69	mg/L
Maximum Dose	188	mg/L
Intermediate Batch Storage	9000	L
Batch Concentration	50	g/L
Bulk Chemical Storage	2000	kg

Hydraulic issues

There were no hydraulic issues identified during the site visit as soda ash is dosed via dosing pumps to the dose point and there was sufficient head available in the mixing tank to supply the dosing pump.

Process capacity and performance

The capacity and performance data for the soda ash dosing system can be seen in Table 3-3. The data is compared to the industry standard design values (ISDVs) shown in the table.

Table 3-3: Pre-treatment process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Intermediate Batch Storage (at maximum dose)	days	1.6	1.9	3.8	>4
Bulk chemical storage (at average dose)	weeks	1.3	1.6	3.2	>4
Dosing pump standby capacity	%	100%	-	-	100%
Maximum dosing capacity	%	99%	118%	145%	>110%

It can be seen that the intermediate batch storage and bulk chemical storage are all below their respective ISDVs. The maximum dosing capacity is also below ISDV target for design flows. These performance issues have been described in the section below.

Dosing pump standby capacity can be seen to meet the ISDV of 100%.

Performance issues and areas for improvement

Intermediate batch chemical storage is below the industry standard design value. This is based on a batch concentration 0.05 kg/L in the 9000 L soda ash storage tank. The lack of batch storage available means that the soda ash must be manually re-batched approximately every two days. This presents an issue for continuous plant operation if operators are unavailable or unable to manually batch the soda ash solution over periods of more than two days. This lack of storage could be addressed by increasing the batch concentration in the soda ash storage tank, which would result in a reduction of the soda ash solution required, allowing a decrease in the frequency of batching. It is noted that currently operations staff are topping up the batch every day.

Bulk chemical storage is also below the industry standard design value. Currently, there is only one storage pallet, which stores 40 x 20 kg bags of soda ash, however there is space for another pallet on the adjacent raised platform. Therefore, two pallets have been assumed as the current storage capacity, however this only provides just over a week of bulk chemical storage at average dose and maximum plant flow. Therefore, bulk soda ash storage space on site needs be increased to meet the ISDV value of greater than 4 weeks storage at average dose.

Dosing capacity is also slightly below the ISDV for the design flow, meaning the soda ash dosing pump is not rated to deliver the required dosing rate of soda ash at the maximum plant flowrate. This suggests that the dosing pump capacity may need to be increased to allow higher dosing flowrates. Alternatively, the batch strength concentration could be increased to allow for a greater applied dose at a lower dosing flow rate.

The dosing system pipework around the dosing pump presents a number of risks and should be replaced. The pipework does not contain the typical industry standard safety and reliability safeguards, such as, flow switches or non-return valves. In addition, the pressure relief valve is directed to the concrete step where the dosing pumps are mounted, thus creating a safety risk if it was to open when operations staff are standing nearby. The dosing pipework and pumps are not bunded and any leaks have been resulting in concrete corrosion. In addition, the soda ash dosing tank is not bunded and there is evidence of leaks around the tank and in the surrounding area with exposed concrete aggregate. Hunter H2O recommends that the storage tank is bunded and the dosing pumps and pipework are replaced with the normal pipework safeguards on a skid mounted system within a cabinet to improve WHS.

Redundancy

The current redundancy arrangement of two soda ash dosing pumps in a duty/standby configuration meets the ISDV for dosing pump standby capacity, and therefore does not require improvement.

3.2.5 Coagulation and rapid mixing

Description

Megapac 23 Aluminium chlorohydrate (ACH) is dosed for coagulation after the aeration process. The water dosed with ACH immediately enters a small inline rapid mixing pot to uniformly disperse the coagulant in the water and promote particle collisions for effective coagulation. The inline rapid mixing pot is open to the atmosphere and has a single mixing impellor to provide the rapid mixing energy for coagulation.

The design criteria for the coagulation and rapid mixing system can be seen in Table 3-4. The dose rates were taken from the Baradine WTP operational monitoring spreadsheet, using daily dose rate data from 2015 to 2020. The chemical storage value is based on storage of ACH at the supplied strength of 23% (as Al_2O_3) in the existing coagulant storage tank without dilution.

The volume of the rapid mixing pot is based on WAE drawings; and an assumption regarding the standard water level in the pot which is based on photos from the site visit. Due to uncertainty regarding the exact shape of the mixing impeller and baffling provided by the mixing pot, the value of the impeller constant used to calculate mixing energy has been estimated as a range. This range is carried through into the calculation of rapid mixing energy.

Table 3-4: Coagulation and rapid mixing design criteria used in process assessment

Design Criteria	Value/Description	Units
Coagulant type	Megapac 23 (ACH)	-
Typical Dose (Median)	12.8	mg/L
Minimum Dose	8.4	mg/L
Maximum Dose	20.2	mg/L
Chemical Storage	10,000	L
Rapid Mixing Type	Inline Rapid Mixing Pot	-
Rapid Mixing Volume	60	L
Mixer Impeller Diameter	0.25	m
Mixer RPM	521	RPM
Impeller Constant, K_T	0.16 – 0.32	-

Hydraulic issues

There were no hydraulic issues identified during the site visit as ACH is dosed via dosing pump to the dose point and there was sufficient head available in the mixing tank to supply the dosing pump.

Process capacity and performance

The capacity and performance data for the coagulation dosing can be seen in Table 3-5, whilst the data for the rapid mixing process can be seen in Table 3-6. The data for both processes are compared to the ISDVs shown in the tables.

Table 3-5: Coagulation process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Chemical storage (at average dose)	weeks	97.2	120.4	236.5	>4
Dosing pump standby capacity	%	0%			100%
Maximum dosing capacity	%	8729%	10365%	12757%	>110%

ACH chemical storage is well above the ISDV value of greater than 4 weeks. This is not considered an issue as the existing tank is already on site.

Dosing pump capacity is also well above what is required to achieve the maximum dose of ACH. This means a much larger pump is being used for ACH dosing than what is required. The turndown ratio of this pump should be considered as the pump is operating at such a low dose. If the pump does not have sufficient turndown ratio to operate at the current low dose range, accuracy in dose rate may be compromised and slight changes in the dose rate could be difficult to implement.

Table 3-6: Rapid mixing process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Rapid Mixing Energy	s^{-1}	1257 - 1778	-	-	500 - 2000
Detention Time	s	3	4	5	10 - 60

The rapid mixing energy was calculated as a range due to uncertainty in the mixing impeller shape and mixing pot baffling, however the calculated range can be seen to fall within the ISDV guidance range. This suggests that the rapid mixing energy imparted to the water per second is sufficient for effective coagulation.

However, the detention time over which this energy is imparted to the water is lower than the ISDV range. This is discussed further in the subsequent section.

Performance issues and areas for improvement

As described in the previous section, the ACH dosing pump capacity is much larger than what is required. The turndown ratio of the pump should be reviewed to the determine if the pump can accurately operate across the low range ACH doses used at the WTP.

Although the rapid mixing energy imparted to the water per second was found to be suitable for effective coagulation, detention time in the rapid mixing pot is only estimated to be between 3 and 5 seconds, which is lower than the ISDV value of 10 - 60 seconds. This means that the rapid mixing energy is not being imparted to the water for a long enough period of time, and therefore the water is not being mixed as effectively as it could be. The rapid mixing detention time could be increased by increasing the size of the mixing pot, however it would be more practical to replace the rapid mixing system with a static mixer as a longer term solution. A new static mixer could easily be implemented as part of the clarifier replacement upgrade.

Similar to the soda ash dosing system, the dosing system pipework around the dosing pump presents a number of risks and should be replaced. The same issues exist for this system and the same recommendations are made (refer Section 3.2.4 under “Performance issues and areas for improvement”).

Redundancy

There is currently only one duty dosing pump for ACH, and therefore there is no redundancy for dosing. It is suggested that there should be two dosing pumps in duty/standby operation to provide standby dosing capacity if there is an issue with the primary dosing pump.

Information gaps

The turndown ratio of the ACH dosing pump is unknown. This should be checked to ensure the pump is rated to operate at the low range of flow rates that are currently being used for ACH dosing. Overdosing could increase the amount of aluminium in the treated water which could lead to post flocculation issues.

As outlined in the previous sections, the rapid mixing energy has been calculated as a range due to uncertainty surrounding the mixing impeller shape and rapid mixing pot baffling.

3.2.6 Flocculation aid dosing

Description

Polyacrylamide LT20 polymer is dosed immediately following the rapid mixing pot to aid in the formation of flocs and assist with the clarification process. However, there is very little to no delay time between coagulant dosing and polymer dosing which can sometimes limit/delay flocc growth especially for lower water temperatures. LT20 is delivered as a powder in 25 kg bags and batched by hand to 0.15 wt.% in two 500 L batch tanks. The batch tanks are installed with mixers to ensure the polymer is sufficiently mixed during the aging period remains in a homogenous solution for dosing.

The design criteria for the flocculation aid dosing system can be seen in Table 3-7. The dose rates were taken from the Baradine WTP operational monitoring spreadsheet, using daily dose rate data from 2015 to 2020. There was no polymer stored on-site at the time of the site visit, however there is enough space in the polymer dosing room to store at least one 25 kg bag of polymer powder, and therefore this has been assumed as the bulk storage capacity.

Table 3-7: Flocculation aid design criteria used in process assessment

Design Criteria	Value/Description	Units
Chemical	Polyacrylamide (LT20)	-
Typical Dose (Median)	0.2	mg/L
Minimum Dose	0.1	mg/L
Maximum Dose	0.2	mg/L
Intermediate Batch Storage	1000	L
Batch Concentration	0.15%	wt.%
Bulk Chemical Storage	25	kg

Hydraulic issues

There were no hydraulic issues identified during the site visit as polymer is dosed via a dosing pump to the dose point and there was sufficient head available in the mixing tank to supply the dosing pump.

Process capacity and performance

The capacity and performance data for the flocculation aid dosing system can be seen in Table 3-8. The data is compared to the ISDVs shown in the table.

Table 3-8: Flocculation aid dosing process capacity and performance data.

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Intermediate Batch Storage (at maximum dose)	days	6.3	7.8	15.4	1 - 2
Bulk chemical storage (at average dose)	weeks	12	105	207	>4
Dosing pump standby capacity	%	0%	-	-	100%
Maximum dosing capacity	%	217%	258%	318%	>110%

The intermediate batch storage of polymer is well above the ISDV value of 1-2 days. This could potentially present an issue with polymer degradation, which is discussed further in the following section.

Bulk chemical storage is well above the ISDV value of greater than four weeks, under the assumption that one 25 kg bag of polymer powder is stored in the polymer dosing room. It is understood that Council currently stores their polymer at another site, however it is suggested that at least one bag be stored at Baradine WTP to provide suitable bulk storage capacity.

The maximum dosing pump capacity is between double and triple what is required for maximum polymer dose rates, however this is expected to be well within the turndown ratio of the pump and is therefore not considered an issue.

Performance issues and areas for improvement

The intermediate batch storage size currently provides between 6-10 days of polymer storage at a batch concentration of 0.15 wt.%. Storing polymer in a batched liquid for this length of time can allow the polymer to degrade, which decreases its effectiveness as a flocculant aid. Polymer suppliers recommend that a batch of polymer is used within 2 days. Degradation can become a concern when period of use for a polymer batch exceeds approximately 5 days. Degradation results in the polymer being much less effective. This issue could be addressed by decreasing the volume of polymer batched into the two polymer tanks. This will increase the frequency of polymer batching required, but will ensure minimal polymer degradation occurs. Alternatively, the batch concentration could be decreased and subsequently the dose rates could be increased, however this option would be limited by the capacity of the dosing pump.

Redundancy

There is currently only one duty dosing pump for LT20, and therefore there is no redundancy for dosing. It is suggested that there should be two dosing pumps in duty/standby operation or a cold standby pump to provide standby dosing capacity if there is an issue with the primary dosing pump.

3.2.7 Flocculation

Description

Flocculation occurs in a single square compartment in the centre of the clarifier. Water dosed with coagulant and flocculant aid is gently mixed in this compartment with a single paddle/picket fence mixer, before flowing below the compartment wall and upward into the surrounding clarifier.

The design criteria for the flocculation system can be seen in Table 3-9. Flocculation volume is based on plant drawings and a water level assumption of approximately 1 ft below the top of the compartment, as observed during the site visit.

The paddle mixing speed and exact structure of the paddle mixer are both unknown.

Table 3-9: Flocculation design criteria used in process assessment

Design Criteria	Value/Description	Units
Flocculation Type	Mechanical	-
Compartments	1	no.
Flocculation Volume (per compartment)	34.3	m^3
Flocculation Mixer Type	Vertical paddle mixer	-
Number of paddles	4 (TBC)	no.
Area of paddles	1.98	m^2
Flocculation Mixing Speed	6 (assumed - TBC)	RPM

Hydraulic issues

During the site visit, when the plant was online momentarily, it was noticed that the coagulated water feed into the flocculator inlet distribution weir was resulting in splashing which was causing some water to enter the settled water zone and bypass the flocculator. Although only minimal splashing occurred and is thus not likely to cause major issues, the splashing should be minimised where possible. It is noted that a new clarifier would eliminate these issues.

Process capacity and performance

The capacity and performance data for the flocculation system can be seen in Table 3-10. The data is compared to the ISDVs shown in the table.

Table 3-10: Flocculation process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Flocculation Mixing Energy	s^{-1}	75 (TBC)	N/A	N/A	30 - 80
Flocculation Time (total)	min	30.3	36	44	>30

The flocculation mixing energy was estimated based on an assumed 6 RPM. This assumption requires confirmation. The mixing speed could not be confirmed whilst onsite as the plant was offline for the majority of the time for the filter inspection.

The flocculation time can be seen to be just above the ISDV value for design flows. This is acceptable for normal operation, although it should be noted that there is not spare capacity in this area to allow for any future upgrades. In addition, as the original design capacity of the clarifier was for 0.9 ML/d it was therefore designed for additional flocculation time which may be due to the time required for manganese oxidation to occur which is a slow process.

Performance issues and areas for improvement

No performance issues or areas for improvement were noted.

It is also noted that the flocculation system would be replaced when the new clarifier is built.

Redundancy

There is only one flocculation compartment/train. This is common for small WTPs. However, this arrangement does not provide any redundancy for the flocculation process. This means it is impossible to take this process offline for maintenance or upgrades without stopping the entire plant.

Information gaps

The mixing speed of the paddle mixer in the flocculation compartment is unknown.

Therefore, the flocculation mixing energy could not be calculated in this assessment without an assumed RPM.

3.2.8 Clarification

Description

Clarification occurs in a singular circular up flow clarifier. Water flows under the walls of the flocculation centre wall and upward into the clarifier. Flocs then settle to the conical base of the clarifier whilst settled water overflows into the clarifier launder channel that runs around the perimeter of the structure. Clarifier sludge is sent daily to one of the two onsite sludge lagoons through manual desludging.

The design criteria for the clarification system can be seen in Table 3-11. Clarification volume and surface area is based on plant drawings and a water level assumption of approximately 1 ft below the top of the clarifier tank, as observed during the site visit. The clarification surface area was calculated by subtracting the surface area of the flocculation centre well from the overall clarifier vessel open top surface area.

Table 3-11: Clarification design criteria used in process assessment

Design Criteria	Value/Description	Units
Clarification Type	Circular Upflow Clarifier	-
Number of basins	1	No.
Desludge type	Gravity	-
Clarifier Volume (without flocculation compartment)	139	m^3
Surface Area (without flocculation compartment)	37	m^2

Hydraulic issues

During plant operation, and exacerbated at lower plant flowrates, the clarifier settled water outlet bellmouth feeding the filter is not submerged and thus entrains air into the filter feed pipe. The air can be seen surging as it enters the filter and disturbing the water level in the filter. This issued caused by this is discussed in Section 3.2.9.

Process capacity and performance

The capacity and performance data for the clarification system can be seen in Table 3-12. The data is compared to the ISDVs shown in the table.

Table 3-12: Clarification process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Surface loading rate	m/h	1.9	1.6	1.3	1.3 - 1.9
Detention time	h	2.0	2.1	3.0	1.0 - 3.0

The clarification surface loading rate and clarifier detention rates can be seen to be within the acceptable ISDV ranges for design, 95th and 50th percentile flows. This suggests that there are no obvious capacity issues with the clarification process, although it should be noted the original design capacity of the clarifier was 0.9 ML/d and thus a lower ISDV value may have been adopted. Hence at design flowrates the clarifier performance may not be as good as expected.

Performance issues and areas for improvement

Although there are no major capacity issues identified for the clarification process based on comparison against ISDVs, the clarifier itself is in need of immediate refurbishment or replacement due to its condition.

As outlined in Section 2.1, a 2014 condition assessment of the clarifier found that the extent of pitting corrosion in the clarifier walls presented major structural integrity issues, and that the clarifier should be immediately refurbished or replaced (Hunter H2O, 2014). It is recommended that the existing clarifier is replaced as soon as possible to avoid the current WHS issues and a situation where a potential clarifier structural failure leads to a loss in potable water supply.

An additional issue with the current clarifier is the occurrence of boil-ups which can result in significant flocc carry over to the filters. Operations staff have indicated that during summer the clarifier could be operated for 18 hours without significant flocc carry over, however in winter (when water viscosity increases) boil-ups and flocc carry over can occur within a few hours, resulting in high settled water turbidity. It is noted that the clarifier sludge is being withdrawn at the beginning of each day before plant start-up. It is possible that a more regular or frequent de-sludge may reduce the effects of flocc carryover. Alternatively, lower plant flowrates could be used in winter along with optimisation of polymer dosing to result in heavier flocc that is able to settle quicker than the clarifier rise rate. It is recommended that further investigation into this issue is undertaken. Although once the clarifier is replaced this issue would be eliminated.

Redundancy

There is currently only one clarifier that can be used for the clarification process. This is common for small WTPs. However, this arrangement does not provide any redundancy for the clarification process. This means it is impossible to take this process offline for maintenance or upgrades without stopping the entire plant.

3.2.9 Filtration

Description

Gravity filtration occurs in a dual media filter that consists of anthracite coal and a fine sand layer, supported by coarse sand and gravel layers. Clarifier supernatant passes through the single filter before undergoing disinfection and storage. The filter backwashing process is described in Section 3.2.10.

The design criteria for the filtration process assessment can be seen in Table 3-13. The filtration area and design media bed depth, and media effective particle sizes were taken from the 2001 *Baradine WTP Operation and Maintenance Manual* (WTA, 2001).

However, Hunter H2O's filter inspection has shown that the actual filter bed depth is significantly lower than the design value (Hunter H2O, 2020). This suggests that filter media has been lost during backwashing sequences. For the purposes of the process assessment, it has been assumed that all the lost media came from the top layer of filter coal.

Table 3-13: Filtration design criteria used in process assessment

Design Criteria	Value/Description	Units
Filtration type	Gravity Filtration	
No of filters	1	No.
Filtration area	7.1	m^2
Filter media type	Dual Media - Coal and Sand	-
Design media bed depth	1.525	m
Actual media bed depth (after media loss)	1.020	m
Design depth of coal layer	1.00	m
Actual depth of coal layer	0.495	m
Depth of fine sand layer	0.200	m
Coal effective particle size	1.30	mm
Fine sand effective particle size	0.65	mm

Further detailed description of the current Baradine WTP filter can be seen in the filter inspection report submitted by Hunter H2O in June 2020 which can be found in Appendix B.

Hydraulic issues

As mentioned in the Filter Inspection Report (Appendix B) the filter outlet valve has hunting issues. This is either due to disturbance of the water surface due to wind action and/or the disturbance of the water surface due to air entrainment from the clarifier outlet as described in Section 3.2.8. Filter outlet valve hunting causes changes in filtration rate and thus velocity changes within the filter bed which can cause particle shedding and spikes in filtered water turbidity.

Process capacity and performance

The capacity and performance data for the filtration process can be seen in Table 3-14. The data is compared to the ISDVs shown in the table. Due to the difference in design and actual filter media bed depth, both the design and actual L/D values have been provided to compare to the ISDV.

Table 3-14: Filtration process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
No. of filters	No.	1.0	-	-	>3
Filtration rate	m/h	9.7	8.1	6.6	<10-12
Elapsed time between backwashes	h	24	-	-	>24
Unit Filter Run Volume (UFRV)	m^3/m^2	218	176	89	>250-500
Design L/D ratio - combined (coal and sand)	-	1077	-	-	>1250
Actual L/D ratio - combined (coal and sand)	-	688	-	-	>1250

The single filter is lower than the recommended ISDV of greater than 3 separate filter units, however a single filter is common for many small WTPs and is not considered a major concern for a plant of this capacity.

The filtration rate can be seen to be below the maximum ISDVs for all flows, which suggests that there are no major issues with the filtration rate currently in place at the WTP.

The elapsed time between backwashes of 24 hours is on the minimum ISDV, and would ideally be longer. Backwashing reduces the plants efficiency as it uses treated water to pass back through the filter and be wasted to the sludge lagoons. Filter backwashing has been discussed further in Section 3.2.10.

The unit filter run volume and both design and actual filter L/D ratios are well below the ISDVs. This is discussed further in the subsequent section.

Performance issues and areas for improvement

Unit filter run volume (UFRV) is well below the minimum ISDVs for all flows. This parameter is a measure of the total throughput of the filter per unit area before each backwash is required. The low UFRV may suggest that backwashing is occurring too frequently for this filter, which coincides with the comparison of the elapsed time between backwashes and the ISDV. The backwashing process is discussed further in Section 3.2.10.

The design L/D ratio for the filter media is below the ISDV, and the actual L/D ratio when accounting for the lost filter media is significantly lower than this. Furthermore, as more media is lost the L/D ratio continues to decrease. To address this issue, the filter either needs larger bed depths or smaller filter media. The dual media of anthracite coal and fine sand used in the current filter is of a standard particle size that is used across many treatment plants, and so particle size is not expected to be the major issue. Therefore, it is suggested that the filter media bed depth should be increased.

However, even though the filter has already lost a significant amount of media during backwashing procedures, a refill to the original design bed depth will still not achieve the ISDV. The Baradine WTP Filter Inspection Report (Appendix B) highlights a number of issues surrounding the existing filter and recommends that the filter be refurbished or replaced. During design, the capacity in the filter for bed fluidisation during backwashing procedures would need to be considered, and the filter should be designed as such to accommodate an increased filter bed depth.

The filter inspection report submitted by Hunter H2O in June 2020 (Appendix B) should be consulted for further analysis and recommendations regarding the Baradine WTP filtration process.

Redundancy

There is currently only one filter that all water must pass through in the treatment process. This is common for small WTPs. However, this arrangement does not provide any redundancy for the filtration process. This means it is impossible to take this process offline for maintenance or upgrades without stopping the entire plant.

Information gaps

The assumption that all of the lost media was from a uniform top coal layer may not be entirely correct, as in reality fluidisation may have mixed the media layers, and some sand may have been lost as well. This assumption was made to make up for the lack of information on the exact extent of mixing between these layers, and the potential loss from the sand layer. However, the observations regarding the L/D ratio remain valid, as the ratio for the design capacity was already below the ISDV, and it can only decrease with a loss of media.

3.2.10 Filter backwashing

Description

Filter backwashing is undertaken approximately once every 24 hours at Baradine WTP, during which operators manually initiate the backwash sequence. The procedure involves an air scour, followed by a constant rate of washwater for a duration set by the operator.

Backwash washwater is currently pumped from a ground level backwash water tank. Previously backwash water was gravitated from an elevated backwash water tank above the clarifier, which is still present on site but not currently in use.

The design criteria for the filter backwashing process assessment can be seen in Table 3-15. The air scour and washwater durations and flow rates were taken from the 2001 *Baradine WTP Operation and Maintenance Manual* (WTA, 2001).

It should be noted that these parameters are the guide for normal backwashing procedures as outlined by the O&M manual, however as backwashing can be altered by operators they may vary from these values. Furthermore, the washwater flowrate is based on gravity flow from the old elevated backwash tank, and it is unknown as to whether the same flow is currently provided by the backwash pumps.

Table 3-15: Filter backwashing design criteria used in process assessment

Design Criteria	Value/Description	Units
Air scour duration	3	min
Air scour flow rate	118	L/s
Water wash duration	9	mins
Water wash flow rate	88	L/s

Hydraulic issues

No hydraulic issues were identified during the site visit in respect to the filter backwash process.

Process capacity and performance

The capacity and performance data for the filter backwashing process can be seen in Table 3-16. The data is compared to the ISDVs shown in the table.

It should be noted that all calculations of wash water rates, bed expansion, wash water volume and capacities are based off the backwash water flow rate of 88 L/s. As described above, it is unknown as to whether this previous backwash water flow rate from the elevated backwash tank is the same as what is supplied by the backwash pumps.

Additionally, it is noted that the backwash expansion shown in the table below is an approximation determined using Hunter H2O's in house backwash expansion model. The actual extent of backwash expansion can be influenced by a number of other factors that are not taken into account in this estimation. Therefore, it is suggested that the backwash bed expansion should be measured for more accurate analysis.

Table 3-16: Filter backwashing capacity and performance data

Parameter	Units	Design Flow	95%ile & 50%ile Flow	ISDV
Air scour duration	mins	3.0	3.0	>3
Air scour rate	m/h	60.1	60.1	>60
Water wash duration	mins	5.0	9.0	>5
Water wash rate	m/h	44.8	44.8	>45
Bed expansion	%	22%	22%	>20%
Wash water volume	# Bed volumes	3.7	6.6	>3.5
Backwash supply tank capacity	# Bed volumes	7.8	7.8	>7.7
Backwash supply tank capacity	No. of backwashes	2.1	1.2	>2

The wash water duration is above the ISDV value, and is not considered to be an issue, however the wash water rate should be confirmed.

The current wash water volume used during backwashing is almost double the ISDV. Therefore, the lack of washwater passing through the filter is not considered an issue, however that large amount could be slightly excessive, leading to unnecessary wastage of washwater.

The overall capacity and performance of the filter backwashing process has been analysed further in the filter inspection report submitted by Hunter H2O in June 2020 (refer Appendix B).

Performance issues and areas for improvement

The backwash supply tank capacity can be seen to be estimated as only just sufficient for one filter backwash under the current filter backwash times and configuration. There was no available information on the actual volume capacity of the new ground level backwash supply tank, and this volume had to be estimated. Therefore, this capacity estimate contains a significant amount of uncertainty. However, the amount of uncertainty is not expected to be large enough that the actual backwash supply capacity could be over the minimum ISDV of two filter backwash volumes under current backwash conditions. Therefore, it is suggested that the backwash duration should be reviewed for adequacy with a view to reducing the backwash time or considering a larger backwash storage.

As outlined in Section 3.2.9, the backwash frequency is right on the ISDV value, whilst the unit filter run volume (UFRV) is below it. Both of these parameters suggest that backwashing may be occurring too frequently for this filter. Filter headloss and outlet turbidity would need to be monitored to determine if filter run time between backwashes could be increased to address this issue. Reinstatement of the filter headloss meter is required to enable confirmation that longer filter runtimes could be achieved.

Media loss is also a significant issue occurring in the Baradine WTP filter. Hunter H2O's filter inspection led to the conclusion that the major cause of media loss is due to the incorrect placement of a float level switch causing the filter water level to remain above the top of the backwash launder during the air scour process. This was allowing filter media to bubble over into the backwash launder and be lost to the sludge lagoons, however, was rectified onsite.

The filter inspection report submitted by Hunter H2O in June 2020 should be consulted for detailed recommendations regarding the Baradine WTP filter and filter backwashing process.

Redundancy

There is no redundancy available for the filter air scour or washwater systems apart from duty/standby backwash pump. However, this is common practice for WTPs of this capacity and is not considered a major issue.

Information gaps

The backwash flow rate used for assessment of the backwashing process is the original flow rate fed by gravity from the old elevated backwash tank. It is unknown whether the backwash flowrate provided by the pumps from the ground level backwash supply tank is different from this value. The process assessment for filter backwashing would need to be updated if that were found to be the case.

The filter bed expansion during backwash has not been directly measured, and therefore the exact expansion is not known. The bed expansion has been estimated using Hunter H2O's in-house model, however this does not consider all potential factors and can therefore only be used in a high level assessment of the process performance.

The exact volume of the ground level backwash supply tank is unknown, and therefore an estimation was made based on dimension estimates from the site visit notes, photos and Google Earth. There is a level of uncertainty surrounding this estimation, and therefore this parameter can also only be used in a high level assessment.

Due to the significance of information gaps in the filter backwash process, it is suggested that this assessment report be treated only as a high level assessment. The filter inspection report submitted by Hunter H2O in June 2020 should be consulted for further information, and it is suggested that the assessment of the filter backwashing process should be updated if more information becomes available.

3.2.11 Disinfection

Description

A chlorine gas dosing system is used for disinfection of the Baradine water supply. The system consists of two chlorine gas cylinders and vacuum regulators in a duty/standby arrangement. The gas dose rate is controlled through a single duty manual chlorinator/rotameter with a capacity of 0.2 kg/h, and doses chlorine into the filtered water before it enters the treated water storage (TWS) tank.

A spare chlorine gas cylinder is also currently stored in the chlorine dosing room, however the is sufficient space for additional cylinders to be stored if required.

The design criteria for the disinfection process assessment can be seen in Table 3-17. The dose rates were taken from the Baradine WTP operational monitoring spreadsheet, using daily dose rate data from 2015 to 2020. The chemical storage value is based on storage of three 70 kg chlorine gas cylinders in the chlorine dosing room.

Table 3-17: Disinfection design criteria used in process assessment

Design Criteria	Value/Description	Units
Chemical type	Chlorine gas	-
Typical Dose (Median)	2.0	mg/L
Minimum Dose	0.75	mg/L
Maximum Dose	2.7	mg/L
Chemical Storage	210.0	kg

Hydraulic issues

No hydraulic issues were identified during the site visit in regard to the chlorine gas dosing system.

Process capacity and performance

The capacity and performance data for the disinfection process can be seen in Table 3-18. The data is compared to the ISDVs shown in the Table 3-18.

Table 3-18: Disinfection process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Bulk chemical storage (at average dose)	weeks	10.3	12.7	16.8	>4
Chlorinator standby capacity	%	0%	-	-	100%
Maximum dosing capacity	%	111%	142%	298%	>110%

Bulk chemical storage is based on the three 70 kg gas cylinders stored in the room at the time of site visit. Although this provides sufficient chemical storage, the chlorination room would be able to store more gas cylinders than this if necessary. Therefore, the bulk chemical storage is not considered an issue.

Maximum dosing capacity is also above the ISDV for all flows, although it should be noted that it is only slightly above the minimum limit for design flow. This shows that there is no major issue with chlorine dosing capacity now, but there is almost no spare capacity to allow for future upgrades.

Performance issues and areas for improvement

Apart from the lack of automation and a single duty manual chlorinator there were no major performance issues noted for the chlorine gas dosing system.

During the site visit it was noted, however, that additional ventilation is likely required within the building to enable cross flow ventilation. A review against the latest Australian Standard for chlorine gas facilities (AS2927 Storage of Chlorine Gas) should be undertaken to confirm compliance.

Redundancy

There is currently only one duty chlorinator for chlorine gas dosing, and therefore there is no redundancy for disinfection. It is suggested that there should be two chlorinators in duty/standby operation to provide standby dosing capacity if there is an issue with the primary chlorinator.

3.2.12 Fluoridation

The fluoride dosing system at Baradine WTP has been non-operational since 2017, and therefore has not been considered in this capacity assessment.

It is currently being upgraded as a part of the greater project with NSW Health.

3.2.13 Treated water storage

Description

Following chlorine dosing, the treated water enters a square underground treated water storage (TWS) tank, located underneath a section of the main dosing building. The original construction drawings from

1962 indicate the TWS tank has a maximum capacity of 24.6 m³. From here, it is pumped to the town reservoir before entering the reticulation network for the majority of the town.

However, there are several customers connected to the network between the treatment plant and the reservoir, and as such the reservoir cannot be included in calculations of contact time and chlorine C.t. Therefore, these calculations have been based only on the storage provided by the TWS tank at the treatment plant.

The design criteria for the treated water storage assessment can be seen in Table 3-19. A number of assumptions were made which are discussed under the 'Information Gaps' section of this assessment report.

Table 3-19: Treated water storage design criteria used in process assessment

Design Criteria	Value/Description	Units
No. of treated water storages	1	-
Tank design	1 Square Underground TWS	
Total TWS tank capacity	24.6	m^3
Minimum TWS tank capacity	65% (assumed)	%
Free Cl2 residual	Refer to CCP Targets (Table 2-3)	-

In previous investigations there was a degree of uncertainty concerning the treated water storage and the disinfection C.t calculations. The below pictures are therefore provided which present the original work as executed configuration of the treated water storage, including the inlet 'weir' box, inlet pipe, pump draw off point and overflow pipe which is directed to the flowmeter pit. In addition, the basis of the C.t calculations along with all assumptions are provided for complete transparency.

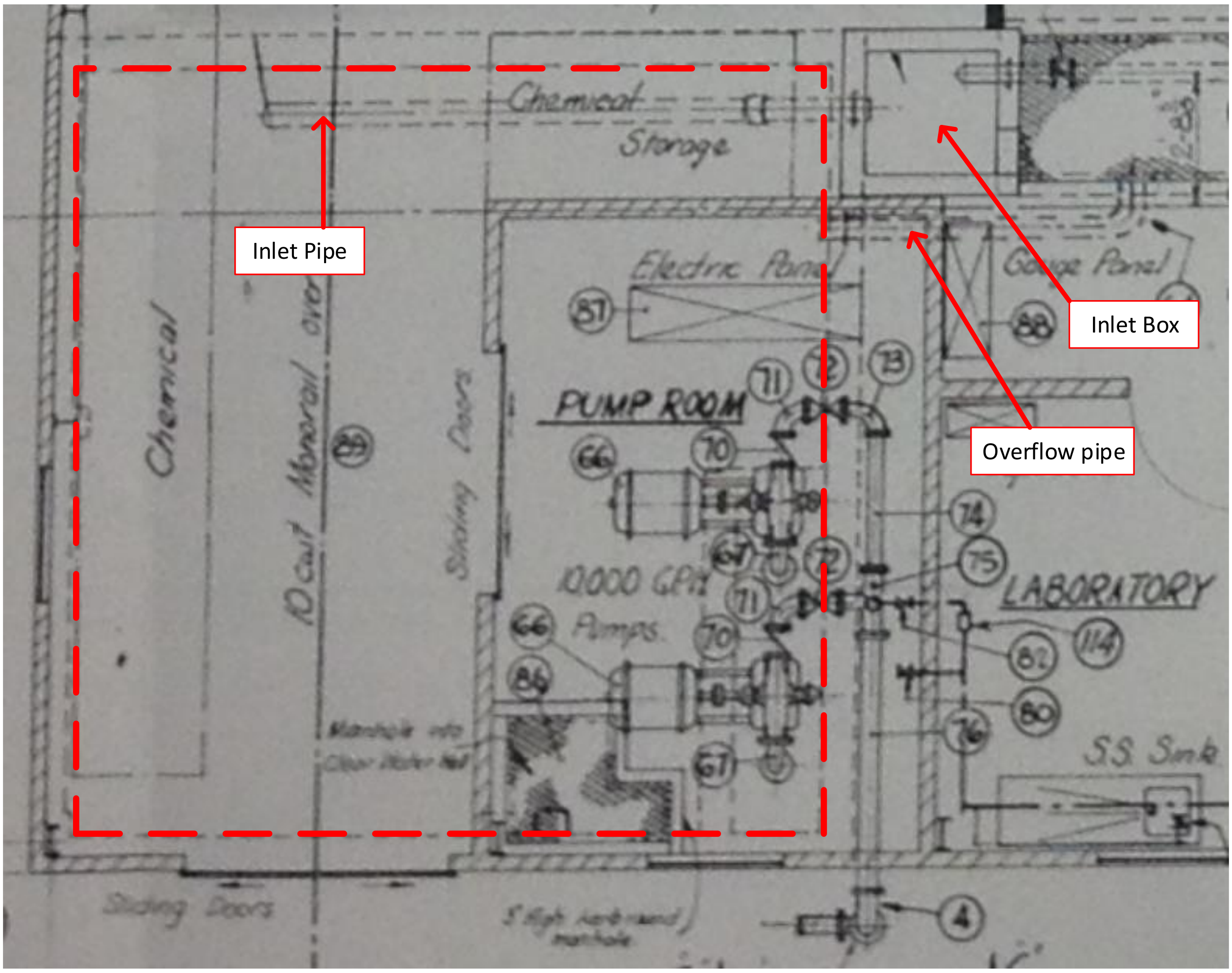


Figure 3-1: Existing treated water storage general arrangement

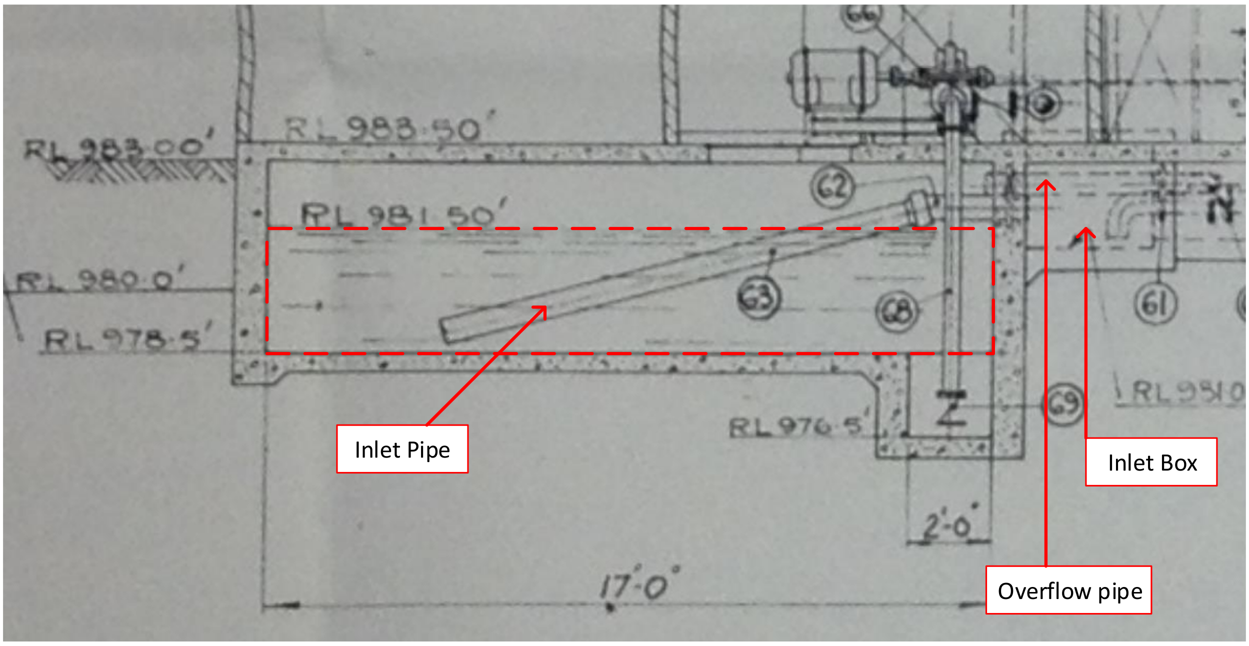


Figure 3-2: Existing treated water storage section view

Hydraulic issues

During the site visit it hydraulic surging was seen in the filtered water outlet pit which feeds the TWS. This was causing some water to overflow into the flowmeter pit. This surging could be a result of the filter valve hunting with operations reporting variation in flows ranging from 14 – 21 L/s throughout the day based on the filtered water magnetic flowmeter readings.

The TWS currently overflows back into the flowmeter pit (refer Figure 3-1 and Figure 3-2) where the filtered water main is dosed with chlorine and fluoride. Currently, the flowmeter pit also has the ability to overflow into the inlet of the TWS causing contamination of the treated water storage. To prevent contamination operations staff, have a sump pump installed with a float switch to pump leaks from the pit to the grass outside of the building.

Currently, in the event of a TWP failure, the WTP will not stop running. This arrangement means that the TWS would overflow to the flowmeter pit which would then be prevented overflowing back into the TWS and would instead start flooding the main building where the main switchboard is located on ground level.

The TWS is located at ground level and is below the 1 in 100 year flood level. This is considered a significant issue as the whole water supply could become contaminated in the event of inundation.

No other hydraulic issues have been noted however the overflow issues must be rectified in both directions to prevent contamination of the treated water supply and the risk of flooding or inundation during a flood should be addressed.

Process capacity and performance

The capacity and performance data for the treated water storage assessment can be seen in Table 3-20. The data is compared to the ISDVs shown in the table.

Table 3-20: Treated water storage process capacity and performance data

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Storage Time (max)	hours	16.9	21.6	45.2	>24
Baffling factor (T10/T)	-	0.1 - 0.2	-	-	>0.1
Chlorine C.t (min)	mg.min/L	1.4 - 2.9	1.8 - 3.6	2.4 – 4.7	>15
Chlorine C.t (max) - Lower CCP Target	mg.min/L	3.1 - 6.2	3.8 - 7.7	5.1 – 10.1	>15
Chlorine C.t (max) - Upper CCP Target	mg.min/L	4.2 - 8.4	5.2 - 10.4	6.9 – 13.8	>15

The storage time calculation is based on the total maximum storage in the TWS tank and the additional storage provided by the 1.1 ML town reservoir. As there are only a small number of connections before the reservoir, this additional storage can be included for the estimate of total storage time, but cannot be included for the calculation of the C.t. provided for disinfection.

The baffle factor is a measure of the extent of baffling to promote uniform flow in the TWS tank and reduce short circuiting effects. It is measured as a value between 0.1 and 1.0, with 0.1 representing no baffling, and 1.0 representing perfect plug flow (pipe flow). Currently there are no baffles within the TWS however there is an inlet pipe which is distributing the flow to the other side of the tank from where the treated water pump suction zone is (refer Figure 3-1 and Figure 3-2). In Hunter H2O's experience from undertaking tracer testing at various facilities, it is expected that the baffle factor would be between 0.1 – 0.2 under most flow scenarios. However, tracer testing is recommended to confirm the actual baffle factor. It is however considered unlikely that the baffle factor would be greater than 0.2. Due to the uncertainty surrounding the baffle factor for the TWS, the baffle factor has been estimated as a range from 0.1 - 0.2 and thus the C.t. values are provided as a range.

The minimum disinfection C·t was calculated based on the following assumptions:

- Worst-case chlorine residual = 1.0 mg/L (based on the CCP critical limit)
- Baffle factor = 0.1 and 0.2
- Minimum treated water storage level = 65% (assumed treated water transfer pump stop level)
- Minimum treated water storage volume = 16 kL.

The maximum disinfection C·t was calculated based on the following assumptions:

- Typical chlorine residual = 1.4 – 1.9 mg/L (based on the lower and upper CCP target value)
- Baffle factor = 0.1 and 0.2
- Maximum treated water storage level = 100%
- Maximum treated water storage volume = 24.6 kL.

Performance issues and areas for improvement

The ISDV for baffling recommends a baffling factor of greater than 0.1. As stated previously there is uncertainty surrounding the baffle factor as no tracer testing has been undertaken to validate the baffle factor under various plant flows and tank levels. It is recommended that tracer testing is undertaken to confirm the baffle factor.

A C·t of 15 mg·min/L is recommended by the World Health Organisation (WHO) and in the ADWGs, and should be achieved even at the worst-case operating conditions. Chlorine C.t. can be seen to be below 15 mg.min/L for all operating conditions. The minimum and maximum C.t values at all flows are well below the ISDV value even when factoring in the uncertainty regarding the TWS tank baffling. Furthermore, even if the upper chlorine residual target is maintained, the maximum C.t values can still not be achieved. This means that disinfection cannot be considered effective under the all operating conditions. Typically, this could potentially be rectified by increasing the CCP critical limit for free chlorine residual, or increasing effective contact time after the chlorine is dosed through an increase in TWS tank capacity and baffling. However, for the Baradine WTP the options are limited by the original design of the TWS tank itself (small volume, with no baffles and a shallow depth) and the close proximity of residents which limits the free chlorine concentration leaving the WTP without causing customer complaints. Indeed, the most practical solutions to consider in order to achieve a Ct of > 15 mg.min/L may be:

1. Increase the TWS capacity through an additional storage or replacement of the TWS itself; or
2. Increase minimum level to 80% (if this is feasible), increase CCP critical limit to 1.5 mg/L and increase the baffle factor to 0.6 through significant baffling within the tank.

The key area for improvement from the above performance issues is the capacity and baffling in the TWS tank to achieve the required C.t. The TWS tank capacity could be increased, and further baffling could be provided within the tank. A complete replacement of the TWS may potentially be more feasible than upgrading the existing underground tank. Alternatively, if the connections before the town reservoir were redirected to source water from after the reservoir, the additional 1.1 ML of storage could be included in the calculation of C.t. However, this would still not resolve the TWS overflow arrangement issues or the fact that it is located below the flood level. It is recommended that further investigation is undertaken to identify options if the replacement of the TWS is not considered during the plant upgrades.

Redundancy

As there are connections to the network before the town reservoir, the reservoir cannot be considered as providing storage redundancy for the TWS tank. Therefore, there is no storage redundancy available for situations where the TWS tank would need to be taken offline. This is common for small plants, and is not a major issue under normal operation, however it would need to be carefully considered if any upgrades were to be performed on the TWS tank.

Information gaps

There is uncertainty regarding the baffle factor in the TWS.

The minimum TWS tank level has been assumed to be 65% based on information from the 'WSC Drinking Water Management System Implementation Report' (Bligh Tanner, 2016), however there is no level indication data or other evidence to support this.

These information gaps lead to uncertainty in the calculation of the chlorine C.t. for the Baradine TWS.

3.2.14 Overflows and stormwater

All filter backwash washwater and clarifier sludge scours are sent one of the two onsite sludge lagoons. These sludge lagoons have the ability to overflow to the nearby creek, and miscellaneous discharge in the range of 0 – 20 ML is defined as a fee-based activity on Councils Environmental Protection Licence (EPL) with the NSW Environment Protection Authority (EPA) for Baradine WTP (WSC, 2020).

It should be ensured that the conditions of this licence are met for any overflows that do occur from the sludge lagoons.

3.2.15 Service water and compressed air systems

The plant utilises the existing water supply for service water supplying the polymer dosing system, soda ash dosing system, and chlorine gas dosing system.

A compressed air system supplies the pneumatic valves around the site (filter control valves). The air compressor is currently located inside the main dosing building, just outside of the analysis room.

No issues have been previously raised with these systems failing to meet demand and thus were not assessed in detail.

3.2.16 Plant electrical and control system

The existing plant electrical and control system was considered in the recent Warrumbungle Shire Council – WTP Automation and Process Instrumentation Report (Hunter H2O, 2020). It was noted in this report that:

"There is currently no PLC control system for this plant. The operation of the drives and devices are controlled via hardwired timers and relays. There is one main MCC control panel that is in the main treatment room. The serviceable life of most electrical equipment is 25-30 years, with the age of the MCC being well in excess of 30 years old (originally built in 1962 and thus 23 years past usual service design life), poor condition and not complying with the current AS3000 wiring rule, it should be replaced immediately."

In addition, the main MCC control panel is in the main building which is below the 1 in 100 year flood level. This, combined with the risk of the TWS overflowing into this same building and affecting the MCC, further supports the need to replace and relocate the MCC which would be considered as part of a full plant automation upgrade.

3.2.17 Plant amenities and laboratory

The WTP has an analysis room inside the main dosing building where bench scale testing is undertaken. The room has a testing benchtop space with various instruments, a fridge and a sink, as well as a desk space with a chair and three storage drawers. There is no extra space available in this room.

Figure 3-3 shows the outside of the plant analysis room within the main dosing building, whilst Figure 3-4 shows the inside of the analysis room, including bench and desk spaces.

There are currently no WTP amenities on-site other than the sink in the lab room which can be used for washing hands.

Figure 3-3: Photos of outside plant analysis room

Figure 3-4: Photos of inside plant analysis room

The main issue with the laboratory is the limited space. Any plant upgrades should also consider including a larger laboratory and dedicated control desk with SCADA system once the plant is automated. Additionally, amenities should be considered for the site (unless available at the next door depot).

4 Summary and recommendations

4.1 Summary of assessment reports

Figure 4-1 below shows a comparison of each process unit's capacity to ISDVs. The bars represent the unit capacity found through the process unit assessments, whilst the vertical lines represent the design, 95th and 50th percentile WTP flows.

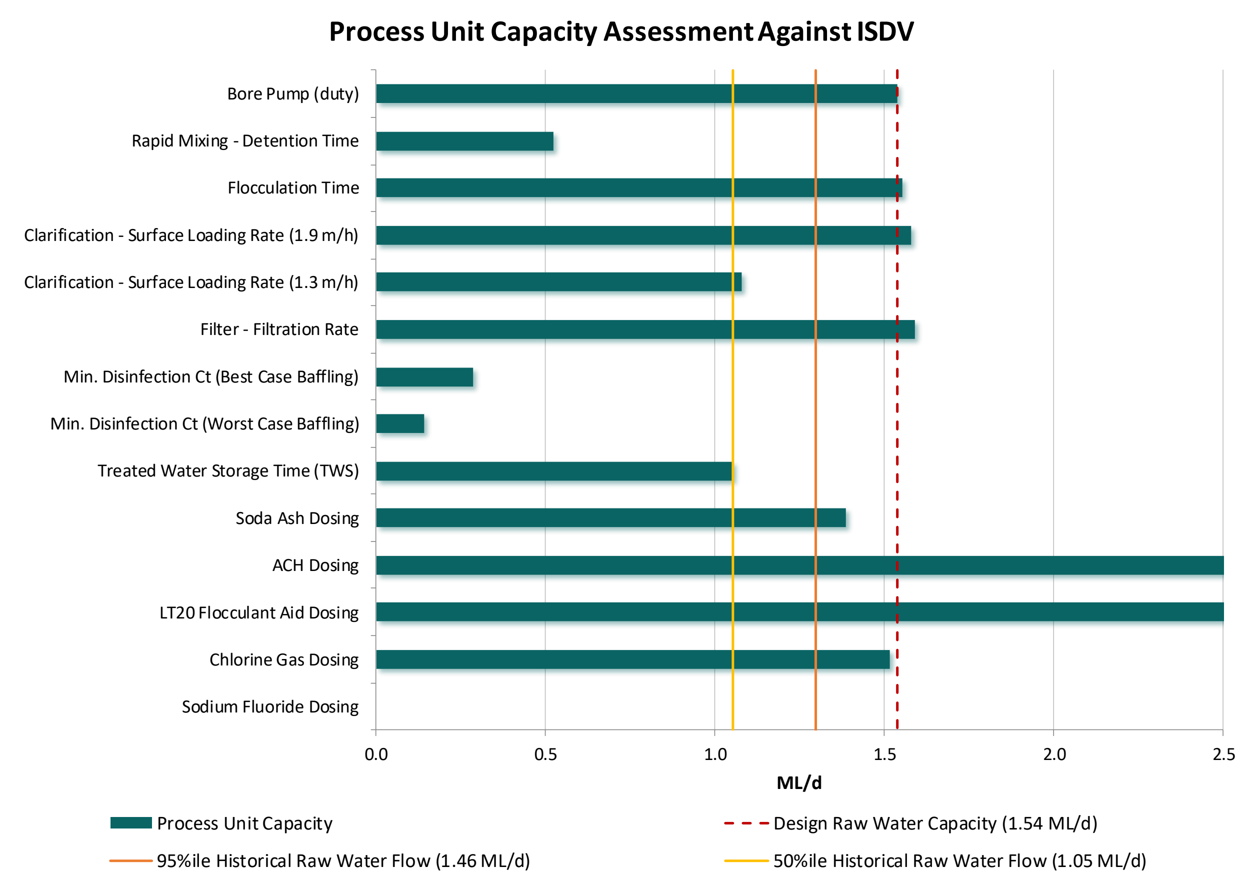


Figure 4-1: Process unit capacity comparison with ISDVs for the WTP flows

It can be seen from Figure 4-1 that the major areas lacking in capacity are the coagulation rapid mixing, the chlorine C.t. available for disinfection and the treated water storage time.

Flocculation time, clarification surface loading rate, filtration rate, soda ash dosing and chlorine gas dosing are all also either only just meeting capacity or falling slightly short. Fluoridation can be seen to have no capacity as it is currently not operational and was not assessed.

ACH and polymer dosing systems can be seen to be well above the required capacity, mainly due to the large size of the dosing pumps. The only issue that could be presented with this is a lack of precision in turndown to lower dose rates. This is not expected to be an issue for the polymer dosing pump, but should be investigated further for the ACH dosing pump.

Other key issues arising from the process capacity assessments are as follows:

- The WTP is failing to achieve treated water iron concentrations below the ADWG aesthetic limit, which may suggest a performance issue with the aerator or filter.
- Soda ash storage and dosing capacity are both too low to meet the current stated maximum demand and the maximum plant flowrate.
- Coagulation rapid mixing detention time is low.
- Both ACH and polymer dosing systems do not have any standby dosing capability.
- Flocculation mixing energy is unknown due to uncertainty in mixing speed.

- The designed clarification process capacity is assessed to narrowly meet the capacity requirement, or be below capacity if the lower ISDV is used. However, previous corrosion assessments found that the clarifier structure needs to be replaced (currently funded project).
- The filtration rate appears to meet the capacity requirements, however the filter was found to be lacking when compared to ISDVs in the unit filter run volume (UFRV), media depth (due to media loss), media L/D ratio. A full assessment of the filter is provided in the filter inspection report submitted by Hunter H2O in June 2020 (Hunter H2O, 2020) (refer Appendix B).
- The chlorinator capacity only narrowly meets the maximum dosing capacity ISDV for disinfection dosing rates. This means there is limited spare capacity available for any future plant upgrades or increases in ability to increase chlorine dose rates.
- Although there are two chlorine gas cylinders in a duty/standby arrangement, they both operate through a single duty chlorinator, and therefore there is no chlorinator redundancy provided for disinfection.
- Although there is a large amount of uncertainty in the baffling of the treated water storage (TWS) tank, it is well understood that the contact time provided by the current tank is far too low and very unlikely to be able to achieve the required Ct under most conditions. Both the storage size and baffling will likely need to be increased to provide sufficient C.t. for disinfection.

4.2 Recommendations

Recommendations from the capacity and capability assessment have been summarised and grouped into low, medium and high priority in the table below.

Table 4-1: Summary of recommendations

Priority	Recommendation
Short Term (High Priority)	▪ **Investigations** – o Investigate the high raw water turbidity readings and confirm the results are not due to surface water ingress into the bore. This could be confirmed through event-based turbidity grab samples collected frequently during and following intense rainfall events. o Undertake further targeted investigation into the elevated filtered water turbidity. A targeted investigation may include frequent iron and manganese sampling of the raw, aerated, settled, filtered and treated water over a period of a few weeks combined with onsite jar testing to isolate the root cause of the elevated turbidity. ▪ **Clarifier -** Proceed with the replacement of the existing clarifier with a package inclined plate settler (as planned), which would also include/address the follow recommendations identified through this investigation: o Include a dedicated static mixer to replace the rapid mixing pot. o Eliminate flocc tank inlet flow issues. o Eliminate the hydraulic issue and air entrainment between the clarifier outlet and filter inlet which causes the filter outlet valve to hunt. o Reduce the occurrence of boil-ups through longer plant operation and more frequent sludge scours ▪ **Filter -** Plan and undertake a major upgrade or replacement of the existing filter due to media loss and design issues. Refer to the filter inspection report submitted in June 2020 (Hunter H2O, 2020). There is an opportunity to combine the clarifier and filter into a single prefabricated unit to realise cost savings. ▪ **Disinfection C.t.** – o Advise NSW health of the deficiency in the existing plants C.t. and ask DPIE and NSW Health to consider reviewing the Safe and Secure priority risk rating in light of this report and other recent reports (Automation & Filter Inspection) o Investigate and implement options to increase the storage size and include baffling of the TWS tank to increase storage time and chlorine C.t. This may involve construction of a new treated water storage. Alternatively, an option could be considered to redirect connections from before the town reservoir to source water from after the reservoir.

Priority	Recommendation
	○ Undertake tracer testing to confirm the existing tanks baffle factor under a range of tank levels and plant flowrates.
Medium Term (Moderate Priority)	▪ Proceed with the automation upgrades as per the WSC WTP Automation & Process Instrumentation Audit report (Hunter H2O, Jun 2020) which would also address the follow recommendations identified through this investigation: ○ Online monitoring with feedback trim control dosing is recommended, along with improved automation and control over plant flowrates and operational times to allow for longer plant operation at lower flowrates. ○ Automation of backwashing due to headloss accumulation rates or turbidity breakthrough would alleviate these issues and improve the overall plant efficiency. ○ Replace the soda ash and ACH dosing pumps and pipework with the normal pipework safeguards on skid mounted systems within cabinets to improve WHS. Include provision for standby dosing capacity for ACH, polymer and chlorine gas dosing systems. Increase the primary chlorinator dosing capacity and decrease the ACH dosing capacity to a pump that can provide sufficient turndown accuracy. ○ Replace the MCC and relocate to above the flood levels
Long Term (Low Priority)	▪ Increase sampling and monitoring of raw water quality parameters such as turbidity, CO_2, iron and manganese concentrations with less frequent true colour and UVt monitoring. ▪ Undertake further investigation into the aeration performance by collecting samples before and after the aerator to assess CO_2, iron and hydrogen sulphide removal efficiency. ▪ Increase of the soda ash batching strength to increase both the batch storage and dosing capacity. ▪ Reduce the polymer batch concentration or batching volume to reduce the age of the batched solution and increase the frequency of polymer batching. ▪ Undertake a review against the latest Australian Standard for chlorine gas facilities (AS2927 Storage of Chlorine Gas) to confirm compliance.

4.3 Plant upgrade considerations

Given the extent of the issues found at Baradine WTP and given the WTP was constructed in 1962 and is therefore over 60 years old already, the following discussion is provided to assist Council in discussions with DPIE and NSW Health in the view of approaching any upgrades in a holistic manner.

Council currently has secured funding to replace the existing clarifier through the Safe and Secure Water Program (SSWP). However subsequent to the approval of this funding further issues have been investigated through other SSWP and NSW Health funded projects such as:

- Baradine WTP Capacity and Capability Report – This report
- Baradine WTP Filter Inspection Report (Hunter H2O, 2020) – refer Appendix B
- WSC WTP Automation and Process Instrumentation Audit Report (Hunter H2O, Jun 2020)
- Warrumbungle C.t Review Summary (CWT, 2019).

Given the nature of some of the pant deficiencies and issues identified needing upgrades such as:

- Major refurbishment or replacement of the filter
- Replacement of the MCC
- Automation, monitoring and instrumentation upgrades for the plant
- Potential replacement of the treated water storage.

In considering a plant upgrade a holistic viewpoint should be considered to realise economies of scale during the upgrade and lowering of risks with a long-term view in mind. Therefore, capacity and process issues are considered need to be considered.

As per Councils IWCM issues paper (Hydrosphere Consulting, 2018), the future demand was "*predicted to increase by 0.2 % p.a. for the next 20 years in line with connection growth*". *Demand reduction due to* *demand management measures (currently only Waterwise education and pricing) [was] also predicted to be negligible. The demand forecast for the next 30 years is given in the following figure*" (Hydrosphere Consulting, 2018).

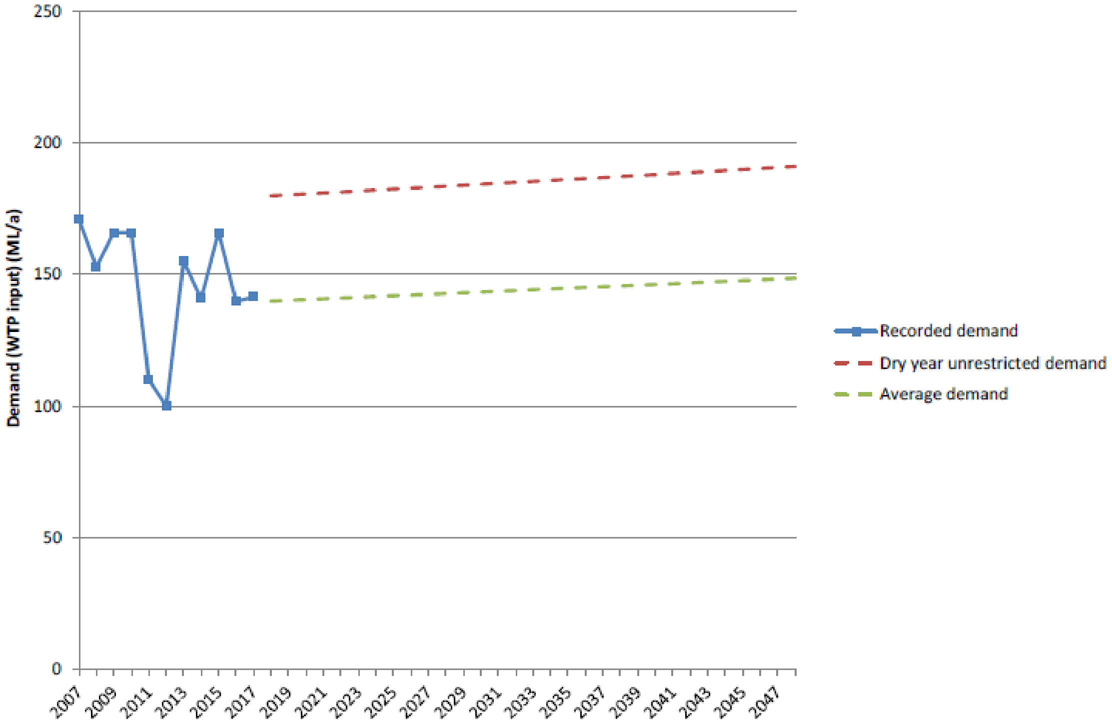


Figure 4-2: IWCM issues paper Baradine demand forecast (Hydrosphere Consulting, 2018)

Note: Data from 2007 – 2015 were reported in the Drought Management Plan (WSC, 2018b).

The existing plant capacity is therefore expected to be sufficient given modest predicted growth and the ability of council to reduce non-revenue water losses that were reported to be 27% in 2017. In the last five years there have only been 4 days when the recorded demand was greater than 1.5 ML/d however each event proceeded with a day with much less demand. Hence reticulations storage and balancing would be expected to have enabled the WTP to survive these events. The average plant flowrate is also 0.6 ML/d. Therefore, increasing the plant capacity beyond 1.5 ML/d is not considered necessary within the next 30 year period. However, a Peak Day Demand analysis should be undertaken to confirm this. In addition, the current plant bottle neck is the clarifier and treated water storage. Hence replacement of these process units is required to secure the 1.5 ML/d plant capacity.

Therefore, if the 1.5 ML/d capacity is sufficient the upgrades will largely encompass rectification of the current plant deficiencies. These upgrades could be grouped into the following key process upgrades:

- Clarifier capacity upgrade and replacement (~$1.3M)
- Filter replacement (~$200k – ~$300k) or full refurbishment (~$100k - ~$150k)
- New TWS (~$250k - ~$350k)
- Plant automation (instrumentation and monitoring), chemical dosing system and control system upgrades (including new MCC) (~$1.9M)
- Building refurbishment (~$160k).

Therefore, the total refurbishment cost would be expected to be in the order of approximately $3.9M – $4.1M.

Given the extent of the issues uncovered at Baradine WTP through recent investigations and studies commissioned by Council and supported by DPIE and NSW Health, the justification for a new WTP presents itself as a long term, holistic approach to addressing each major issue at the WTP. In comparison, upgrade of individual process units would result in a more complex treatment system with a mix of old and new infrastructure.

The order of magnitude of costs for refurbishment are estimated to be in the order of approximately ~$4M. While based on Hunter H2O's benchmarking cost database, for a 1.5 ML/d WTP, it could be expected that a new WTP may be procured for a similar cost in the order of ~$3M - ~$6M. In recent times, however, there has been a wide variation between small WTP costs for a new greenfield plant.

Hunter H2O's observations of this range from site specific constraints or sloping sites which can result in quickly escalating costs, however Baradine WTP would not be affected by this. In addition, any customisation away from suppliers' standard packages brings about a premium for the small WTP range. Hence if Council is willing to adopt standard packages from contractors then the cost of a new WTP could be on the lower end of the range. However, there is a risk that any movement away from those standards could easily push the overall cost into the high range.

Note: the costs mentioned above are high level costs and should be reviewed in more detail once a decision is made and funding is identified or confirmed.

Therefore, Hunter H2O recommend that Warrumbungle Shire Council consider approaching DPIE to extend the existing SSWP funding to enable a complete replacement of the WTP given its age and the extent of the issues identified through recent reports. Pursuing a refurbishment approach would not be ideal given the age of the WTP and the fact that government funding opportunities are few and far between.

The proposed new WTP may consider similar process units. However, there are improvement opportunities to be considered, such as, combining the TWS and backwash storage tanks and combining the clarifier and filter into a single package. Further opportunities may exist and could be investigated through a value management exercise and further investigation.

5 References

Bligh Tanner. (2016). *WSC Drinking Water Management System Implementation Report.*

CWT. (2019). *Warrumbungle C.t. Review Summary.*

Hunter H2O. (2014). *Baradine WTP Clarifier Ultrasonic Testing of Steel Plate Thickness Report.*

Hunter H2O. (2015). *Baradine WTP Clarification Options Assessment.*

Hunter H2O. (2020). *Baradine WTP Filter Inspection.*

Hunter H2O. (Jun 2020). *WSC WTP Automation and Process Instrumentation Audit.*

Hydrosphere Consulting. (2018). *Warrumbungle Shire Council Integrated Water Cycle Management Strategy.* Warrumbungle Shire Council.

NHMRC, NRMMC. (2011). *Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy.* Commonwealth of Australia, Canberra: National Health and Medical Research Council, National Resource Management Ministerial Council.

Warrumbungle Shire Council (WSC). (2020). *Pollution Incident Response Management Plan (PIRMP) for the Baradine Water Treatment Plant - Revision 3.1.*

Water Treatment Australia (WTA). (2001). *Baradine Water Treatement Plant Operation and Maintenance Manual.* Coonabarabran Shire Council.

Appendix A Capacity Review Spreadsheets

Baradine WTP

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Plant Flows							
Raw Water Flowrate	ML/d	1.54	1.24	0.63		Based on production rate minus clarifier desludge and filter backwash waste volumes	
Instantaneous Raw Water Flow	L/s	19.0	16.0	13.0		O&M Manual 2001 states 19L/s or 1.5 ML/22.5 h, Percentile flows from operational spreadsheet data	
Instantaneous Raw Water Flow	m3/h	68.4	57.6	46.8			
Plant Operation	h/d	22.5	21.6	13.5		O&M Manual 2001 states 22.5 hour day for design, percentile operation hours calculated from above	O&M Manual for design, Operational spreadsheet data for plant flows for percentiles (2015-2020 data), Clarification Options Assessment report 2015
Plant Efficiency	%	97.5	93.4	87.0		Calculated from production and raw water flowrates	
Plant Production Flowrate	ML/d	1.5	1.16	0.55		Design flowrate from O&M Manual, Production flowrate percentiles from Operational data	
Instantaneous Treated Water Flow	L/s	18.5	14.9	11.3			
Instantaneous Treated Water Flow	m3/h	66.7	53.8	40.7			
Aerator						No water quality data avaiable to assess performance or capacity	
Coagulation & Rapid Mixing							
Inline Rapid Mixer Pot							
Diameter	m	0.39					WAE Drawings 2001
Depth	m	0.55				Based on water level mark in site photo	Site photo and WAE Drawings 2001
Water Volume	m^3	0.06					
Rapid Mixer						SEW Eurodrive Model R17DT63L2, 521 rpm, 0.37 kW	O&M Manual 2002
Mixing Impeller Diameter	m	0.25				ST'D WTA 250 DIA IMPELLER	WAE Drawings 2001
Revolutions per minute	RPM	521.00					WAE Drawings 2001
Revolutions per second	rev/sec	8.68					
Kt (Lower and Upper Range)		0.16	0.32			Note: Value of 0.32 is not for 95%ile flow. A value of 0.32 assumes 4 baffles at 10% of tank diameter, so range of 0.16-0.32 has been used to account for uncertainty. Baffles are recommened in mixing tanks to prevent vortexing.	Physicochemical Treatment Processes Vol 3 Textbook Table 1 p27: propeller, pitch of 1, 3 blades
Water Power P (Range)	W	102.12	204.23			Range - based on Kt uncertainty. See G Value Calc Equations Sheet	
Rapid Mixing Energy / Velocity Gradient G (Range)	s-1	1257.28	1778.07			Range - based on Kt uncertainty. See G Value Calc Equations Sheet	
Detention Time	s	3.41	4.04	4.98		Detention Time based on volume of mixing chamber and instantaneous flowrate.	

Report Tables

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Rapid Mixing Energy	s-1	1257-1778	N/A	N/A	500 - 2000
Detention Time	s	3	4	5	10 - 60

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Flocculation							
Tank design		1 Compartment					
No. of trains	no.	1					Site visit notes/photos
No. of compartments	no.	1					Site visit notes/photos
Depth	m	4.57				Water depth starting 1ft below top of flocc tank	Baradine WTP Drawing - Flocc Tank and Baffles
Length	m	2.75					Baradine WTP Drawing - Flocc Tank and Baffles
Width	m	2.75					Baradine WTP Drawing - Flocc Tank and Baffles
Flocculation volume (per compartment)	m3	34.6					
Flocculation volume (per train)	m3	34.6					
Flocculation time (per compartment)	min	30.32	36.00	44.3		Based on instantaneous raw water flow	
Flocculation time (per train)	min	30.3	36.0	44.3		Based on instantaneous raw water flow	
Mechanical Mixing Compartment 1							
Mixing Impeller Diameter	m	2.20				Estimate relative to tank width based on drawings	Baradine WTP A1 Drawings - Flocculator and Drive
Paddle width	m	0.23					
Number of paddles	No	4					
Cd	unitless	1.16					
Area of Paddles	m2	1.98					
Water Density	kg/m3	1000					
Vr	m/s	0.55				Assumed based on 6 RPM (1 turn per 10 seconds) of paddles	
Water Power	W	194.12					
Flocculation Mixing Energy (Compartment 1)	s-1	75.00					

Report Tables

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Flocculation Mixing Energy (Compartment 1)	s-1	75.0			30 - 80
Flocculation time (total)	min	30.3	36.0	44.3	>30

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Clarifier							
Tank design		1 Cylindrical/Conical Clarifier Tank					
No. of trains	no.	1					Site photos, drawings, O&M Manual
Depth to the beginning of incline	m	1.52				Water level depth starting 1ft below top of tank	Baradine WTP A1 Drawings
Inclined Wall Length	m	7.32					Baradine WTP A1 Drawings

Baradine WTP

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Depth from beginning of incline to base	m	6.5				Calculated from pythagoras theorem	
Depth from beginning of incline to vertex of an equivalent extended cone	m	7.1				Calculated using similar triangles ratio of sides, for use in tank volume calculation	
Upper Diameter	m	7.52					Baradine WTP A1 Drawings
Diameter at base	m	0.69					Baradine WTP A1 Drawings
Total Tank Volume	m3	173				Calculated based on volume of upper cylinder and lower cone, with smaller ("chopped off") base cone subtracted	
Clarifier Volume without flocc tank (per train)	m3	138				Flocc Tank Volume (centrewell) subracted from clarifier tank volume	
Settling surface area (per train)	m2	36.9				Subtracts the flocculation centrewell area	
Detention time	h	2.0	2.4	3.0			
Surface loading rate	m/h	1.9	1.6	1.3			
Clarifier Sludge Scour duration	min/day	13.4	37.0	37.0			Site Visit Notes
Clarifier Sludge Scour wastage volume (daily)	m3/d	12.6	34.9	34.9		Based on assumed 100mm pipe	

Report Tables

Parameter	**Units**	**Design Flow**	**95%ile Flow**	**50%ile Flow**	**ISDV**
Surface loading rate	m/h	1.9	1.6	1.3	1.3 - 1.9
Detention time	h	2.0	2.4	3.0	1.0 - 3.0

Filtration

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Filter Design		1 Gravity Filter					
No. of filters	No.	1					O&M Manual 2001
Total media bed depth (design)	m	1.525				O&M Manual has Coal (1000mm), Fine Sand (200mm), Coarse Sand (100mm), Fine Gravel (75mm), Medium Gravel (75mm), Large Gravel (75mm) = 1.525m	
Total media bed depth (actual)	m	1.02				Filter media was previously lost during backwashing.	Filter Inspection Site Measurement
Filter Diameter	m	3					O&M Manual 2001
Filter Height	m	4.3					O&M Manual 2001
Area per filter	m2	7.1				Based on filter diameter.	
Total filtration area	m2	7.1				Only 1 filter.	
Filtration rate	m/h	9.7	8.1	6.6		Based on instantaneous raw water flow.	
Elapsed time between backwashes	h	24	24	24		Filter is backwashed once a day.	Site notes
Unit Filter Run Volume	m3/m2	217.7	175.8	89.5		Based on 22.5 hours per day plant operation.	O&M Manual 2001
Design Capacity Dual Media Filter						Design Values Based on the	
Effective Size (ES) - Coal	mm	1.3				1.25-1.35 mm	O&M Manual 2001
Bed depth - Coal	m	1					O&M Manual 2001
Effective Size (ES) - Fine Sand	mm	0.65				0.6-0.7 mm for fine sand	O&M Manual 2001
Bed depth - Fine Sand	m	0.2					O&M Manual 2001
Design L/d ratio - combined (coal and sand)	-	1076.9				Only considering coal and fine sand - not including coarse sand and gravel supporting layers	
Actual Capacity Dual Media Filter (Lost media)						Media was lost from the filter, values here calculated on the actual media depth at site visit	Filter inspection site visit.
Effective Size (ES) - Coal	mm	1.3					O&M Manual 2001
Bed depth - Coal	m	0.495				Assumes all the media lost was from the top coal layer	Filter Inspection Site Visit Measurement of filter bed depth
Effective Size (ES) - Fine Sand	mm	0.65					O&M Manual 2001
Bed depth - Fine Sand	m	0.2				Assumes all the media lost was from the top coal layer	O&M Manual 2001
Actual L/d ratio - combined (coal and sand)	-	688.5				Only considering coal and fine sand - not including coarse sand and gravel supporting layers	

Report Tables

Parameter	**Units**	**Design Flow**	**95%ile Flow**	**50%ile Flow**	**ISDV**
No. of filters	No.	1.0	N/A	N/A	>3
Filtration rate	m/h	9.7	8.1	6.6	<10-12
Elapsed time between backwashes	h	24	N/A	N/A	>24
Unit Filter Run Volume	m3/m2	218	176	89	>250-500
Design L/d ratio - combined (coal and sand)	-	1077	N/A	N/A	>1250
Actual L/d ratio - combined (coal and sand)	-	688	N/A	N/A	>1250

Backwash

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Air scour duration	mins	3	3	3		"About 3 minutes" - Stated in O&M Manual	O&M Manual 2001
Air scour flow rate	L/s	118	118	118		Normal Air Scour Flow = 118 L/s @ 55kPa	O&M Manual 2001
Air scour rate	m/h	60.1	60.1	60.1		Based on filter area.	
Water wash duration	mins	5	9	9			O&M Manual 2001
Water wash flow rate	L/s	88	88	88		This was using old backwash tank that ran under gravity, unknown if this is the same with the new ground level backwash tank. (Normal backwash water flow = 88 L/s)	O&M Manual 2002
Water wash rate (per filter area)	m/h	44.82	44.82	44.82		Based on filter area.	
Bed expansion		22%	22%	22%		Estimated using assumed bed parameters and software.	Hunter H2O backwash bed expansion estimation tool.
Wash water volume (single filter)	m3	26.4	47.5	47.5		Calculated from flowrate and duration	O&M Manual 2001
Wash water volume (single filter)	# Bed volumes	3.7	6.6	6.6		Based on capacity estimation and current media depth, including supporting layers (accounting for recent media loss)	Filter Inspection Site Visit
Backwash Supply Tank Capacity	m3	56.5	56.5	56.5		Estimations made from site photos and gioogle earth -> D=6m, H=2m	Site photos, estimation
Backwash Supply Tank Capacity	# Bed volumes	7.84	7.84	7.84		Based on capacity estimation and current media depth, including supporting layers (accounting for recent media loss)	Filter Inspection Site Visit

Baradine WTP

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Backwash Supply Tank Capacity	No. of backwashes	2.14	1.19	1.19		Based on capacity estimation and current media depth, including supporting layers (accounting for recent media loss)	Filter Inspection Site Visit

Report Tables

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Air scour duration	mins	3.0	3.0	3.0	>3
Air scour rate	m/h	60.1	60.1	60.1	>60
Water wash duration	mins	5.0	9.0	9.0	>5
Water wash flow rate	m/h	44.8	44.8	44.8	>45
Bed expansion	%	22%	22%	22%	>20
Wash water volume (single filter)	# Bed volumes	3.7	6.6	6.6	>3.5
Backwash Supply Tank Capacity	# Bed volumes	7.8	7.8	7.8	>7.7
Backwash Supply Tank Capacity	No. of backwashes	2.1	1.2	1.2	>2

Disinfection and Treated Water Storage

M.Carter 17/07/2020 - Found original WAE 1962 drawings and updated tank capacity and baffle factor based on dimensions

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	Comments	Source
Tank design		1 Rectangular Underground TWS				
No. of Storages		1			Several customers are connected on way to the Res, so can only consider TWS tank for Ct	
Contact Volume: Rectangular TWS						
Length	m	5.18			Based on 17 ft dimension stated on 1962 WAE GA	1962 WAE Baradine WTP GA Drawing W35/284/1
Width	m	5.18			Scaled from dimension drawing and determined to be 17 ft dimension	1962 WAE Baradine WTP GA Drawing W35/284/1
Depth	m	0.9144			Based on 3 ft dimension stated on 1962 WAE GA	1962 WAE Baradine WTP GA Drawing W35/284/1
Volume (max)	m3	24.6			Maximum volume capacity of TWS tank.	
Minimum TWS tank level	%	65%			Assumed, based on a previous report	WSC Drinking Water Management System Implementation Report 2016 - Bligh Tanner
Minimum TWS tank volume	m3	16.0			Minimum filled volume of the reservoir.	
Additional Storage Volume: Town Reservoir						
Reservoir Volume	m3	1100.00			1.1 ML town storage reservoir	
Total Storage Volume	m3	1124.6			TWS tank + reservoir. This is only used for total storage time calculations and NOT for C.t.	
CCPs						
Free Cl2 residual (min)	mg/L	1			CCP Critical Limit	Warrumbungle DWMS Annual Report 2019
Free Cl2 residual (lower target)	mg/L	1.4			CCP Target Range Lower Boundary	Warrumbungle DWMS Annual Report 2019
Free Cl2 residual (upper target)	mg/L	1.9			CCP Target Range Upper Boundary	Warrumbungle DWMS Annual Report 2019
Ct Calculations for Baffle Factor = 0.1					Uncertainty regarding baffle factor, two sets of Ct calculations are carried out with baffle factors 0.1 and 0.2.	Site visit notes, operator discussions
Baffling factor (T10/T)	-	0.1			Assuming no baffling in the TWS tank.	
Effecitve Contact Volume (max)	m3	2.5			Takes into account baffling factor, based on estimated maximum capacity of TWS tank	
Effective Contact Volume (min)	m3	1.6			Takes into account baffling factor, based on minimum TWS tank level assumption	
Storage Time (max)	hours	16.87	20.91	27.63	Based on instantaneous treated water flow through TWS AND reservoir, does not take into account baffle factor.	
Contact Time (max)	hours	0.04	0.05	0.06	Based on instantaneous treated water flow, takes into account baffle factor, used for Ct max calculations below.	
Chlorine Ct (max) - Lower CCP Target	mg.min/L	3.1	3.8	5.1	Based on max contact time and lower boundary of chlorine CCP target.	
Chlorine Ct (max) - Upper CCP Target	mg.min/L	4.2	5.2	6.9	Based on max contact time and upper boundary of chlorine CCP target.	
Contact Time (min)	hours	0.02	0.03	0.04	Based on instantaneous treated water flow, takes into account baffle factor, used for Ct min calculation below.	
Chlorine Ct (min)	mg.min/L	1.4	1.8	2.4	Based on min contact time and critical chlorine CCP limit.	
Ct Calculations for Baffle Factor = 0.2					Uncertainty regarding baffle factor, two sets of Ct calculations are carried out with baffle factors 0.1 and 0.2.	Site visit notes, operator discussions
Baffling factor (T10/T)	-	0.2			Assuming "some" baffling in TWS tank, with low efficiency	
Effecitve Contact Volume (max)	m3	4.9			Takes into account baffling factor, based on estimated maximum capacity of TWS tank	
Effective Contact Volume (min)	m3	3.2			Takes into account baffling factor, based on minimum TWS tank level assumption	
Storage Time (max)	hours	16.87	20.91	27.63	Based on instantaneous treated water flow through TWS AND reservoir, does not take into account baffle factor.	
Contact Time (max)	hours	0.07	0.09	0.12	Based on instantaneous treated water flow, takes into account baffle factor, used for Ct max calculations below.	
Chlorine Ct (max) - Lower CCP Target	mg.min/L	6.2	7.7	10.1	Based on max contact time and lower boundary of chlorine CCP target.	
Chlorine Ct (max) - Upper CCP Target	mg.min/L	8.4	10.4	13.8	Based on max contact time and upper boundary of chlorine CCP target.	
Contact Time (min)	hours	0.05	0.06	0.08	Based on instantaneous treated water flow, takes into account baffle factor, used for Ct min calculation below.	
Chlorine Ct (min)	mg.min/L	2.9	3.6	4.7	Based on min contact time and critical chlorine CCP limit.	

Report Tables

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	
Baffling factor (T10/T)	-	0.1-0.2			>0.1	Values Reported as a range over baffling factors 0.1-0.2

Baradine WTP

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Storage Time (max)	hours	16.9	20.9	27.6	>12		
Chlorine Ct (max) - Lower CCP Target	mg.min/L	3.1-6.2	3.8-7.7	5.1-10.1	>15		
Chlorine Ct (max) - Upper CCP Target	mg.min/L	4.2-8.4	5.2-10.4	6.9-13.8	>15		
Chlorine Ct (min)	mg.min/L	1.4-2.9	1.8-3.6	2.4-4.7	>15		

Chemical Dosing Systems

Megapac 23 (ACH)	Units	Design Flow	95%ile Flow	50%ile Flow	Comments	Source
					Changed from PACL to ACH	Site visit notes
Bulk storage capacity	L	10000				O&M Manual 2001, site phots
Batch Strength/Supplied Strength	% w/w	23%			23% as Al2O3, 40% as Al2(OH)5Cl	IXOM Product Specification
Supplied SG		1.34				IXOM Product Specification
Typical Dose (Median)	mg/L	12.8			Median of daily measurements 2015-2020	Operational monitoring data 2015-2020
Average consumption	L/h	0.653	0.55	0.45		
Average consumption	L/d	14.70	11.87	6.04		
Maximum Dose	mg/L	20.2			Max from daily measurements 2015-2020	Operational monitoring data 2015-2020
Maximum consumption	L/h	1.0	0.9	0.7		
Maximum consumption	L/d	23.2	18.7	9.5		
Bulk chemical storage @ average dose	weeks	97.2	120.4	236.5	@ average dose and max plant flow	
No. of duty transfer pumps		1				Site photos
No. of standby transfer pumps		0				Site photos
Dosing pump standby capacity	%	0%				
Maximum duty pump capacity	L/h	90				Site visit notes
Maximum dosing capacity	%	8729%	10365%	12757%	Based on Maximum Duty Pump capacity and Maximum Dose	

Report Tables

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Bulk chemical storage @ average dose	weeks	97.2	120.4	236.5	>4
Dosing pump standby capacity	%	0%			100%
Maximum dosing capacity	%	8729%	10365%	12757%	>110%

Polymer Flocc Aid - Polyacrylamide (LT20)	Units	Design Flow	95%ile Flow	50%ile Flow	Comments	Source
Intermediate Batch Storage Capacity	L	1000			2 x 500 L mixing and storage tanks	O&M Manual 2001, site photos
Bulk storage capacity	kg	25			No powder currently stored on site, there is easily room for one 25 kg bag in the polymer dosing room. However it is believed that Council store their polymer at a different site.	Site visit photos
Batch Strength/Supplied Strength	% w/w	0.15%			Polymer batched to 0.15%	Site visit notes
Supplied SG		1			Based on SDS	SDS Sigma Aldrich
Typical Dose (median)	mg/L	0.154			Median of daily measurements 2015-2020	Operational monitoring data 2015-2020
Average consumption	L/h	7.0	5.9	4.8	Takes into account batch strength	
Average consumption	L/d	158.0	127.6	64.9		
Maximum Dose	mg/L	0.191			Max from daily measurements 2015-2020	Operational monitoring data 2015-2020
Maximum consumption	L/h	8.7	7.3	6.0		
Maximum consumption	L/d	196.0	158.2	80.5		
Intermediate Batch chemical storage @ max dose	days	6.3	7.8	15.4	Storage at average dose and corresponding plant flow.	
Bulk chemical storage @ average dose	weeks	12.1	105.4	207.0	Based on the assumption of 1 x 25 kg bag stored in the polymer batching room.	
No. of duty transfer pumps		1				O&M Manual 2001, site photos
No. of standby transfer pumps		0				O&M Manual 2001, site photos
Dosing pump standby capacity	%	0%				
Maximum duty pump capacity	L/h	18.93			Duty: 18.93 L/h at 7 bar at 50/60 Hz	Site photos
Maximum dosing capacity	%	217%	258%	318%	Based on Maximum Duty Pump capacity and Maximum Dose	

Report Tables

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV
Intermediate batch storage @ max dose	days	6.3	7.8	15.4	1 - 2
Bulk chemical storage @ average dose	weeks	12.1	105.4	207.0	>4
Dosing pump standby capacity	%	0%			100%
Maximum dosing capacity	%	217%	258%	318%	>110%

Chlorine Gas	Units	Design Flow	95%ile Flow	50%ile Flow	Comments	Source
Bulk storage capacity	kg	210			3 x 70 kg gas cyclinders, room for more if required	Site photos
Typical Dose (Median)	g/h	130			Median from daily measurements 2015-2020, assuming that the "Dosing - Chlorine" column in the operational data spreadsheet is the dose actually applied and not the residual measured.	Operational monitoring data 2015-2020
Average Dose	mg/L	1.95	2.42	3.19	Based on instantaneous treated water flow and median dose data.	Operational monitoring data 2015-2020
Average consumption	kg/h	0.13	0.10	0.08	Based on instantaneous treated water flow and median dose data.	Operational monitoring data 2015-2020
Minimum Dose	g/h	50			Minimum recorded from daily measurements 2015-2020, assuming that the "Dosing - Chlorine" column in the operational data spreadsheet is the dose actually applied and not the residual measured.	Operational monitoring data 2015-2020
Maximum Dose	g/h	180			Maximum recorded from daily measurements 2015-2020, assuming that the "Dosing - Chlorine" column in the operational data spreadsheet is the dose actually applied and not the residual measured.	Operational monitoring data 2015-2020
Minimum Dose	mg/L	0.75	0.93	1.23	Based on instantaneous treated water flow and minimum dose data above.	Operational monitoring data 2015-2020
Maximum Dose	mg/L	2.70	3.35	4.42	Based on instantaneous treated water flow and maximum dose data above.	Operational monitoring data 2015-2020

Baradine WTP

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Maximum consumption	kg/h	0.18	0.15	0.11		Based on instantaneous treated water flow and maximum dose data above.	Operational monitoring data 2015-2020
Bulk chemical storage @ average dose	weeks	10.26	12.71	16.80		Storage at average dose and maximum plant flow. Based on 22.5 hr/day operation.	
No. of duty chlorinators		1				Capacity: 4 kg/h	Site visit photos
No. of standby chlorinators		1				Capacity: 2 kg/h	Site visit photos
Chlorinator standby capacity	%	100%				Standby chlorine vacuum regulator only has 2 kg/h capacity, whereas duty has 4 kg/h capacity, however, these are both higher than the chlorinator capacity of 0.2 kg/h	Site visit photos
Maximum duty pump capacity	kg/h	0.2				Chlorinator rotameter shows 0.2 kg/h maximum capacity	If operated in duty/standby. Operating in duty/assist will increase capacity if hydraulics allow.
Maximum dosing capacity	%	111%	138%	182%		Based on Maximum Duty chlorinator capacity and Maximum Dose	

Report Tables

Parameter	**Units**	**Design Flow**	**95%ile Flow**	**50%ile Flow**	**ISDV**
Bulk chemical storage @ average dose	weeks	10.3	12.7	16.8	>4
Chlorinator standby capacity	%	100%			100%
Maximum dosing capacity	%	111%	138%	182%	>110%

Soda Ash

Parameter	Units	Design Flow	95%ile Flow	50%ile Flow	ISDV	Comments	Source
Intermediate Batch Storage Capacity	kg	450				9000 L at 0.05 kg/L (In Batching/Storage Tank)	Site photos
Bulk storage capacity	kg	2000				2 x 40 x 25 kg (Bags stored on two pallets - there is space for two pallets on the raised platform inside the main buidling)	Site photos
Batch Strength Concentration	g/L	50				50 kg / 1000 L - site notes from operator records	Site photos
Purity	%	99.8%					
Supplied SG		1.09				Based on SDS	SDS Halliburton
Typical Dose (median)	mg/L	142.49				Median from daily measurements 2015-2020.	Operational monitoring data 2015-2020
Average consumption	kg/h	9.8	8.2	6.7		takes into account batch strength	
Average consumption	kg/d	219.7	177.4	90.3			
Maximum Dose	mg/L	187.95				Max from daily measurements 2015-2020.	Operational monitoring data 2015-2020
Maximum consumption	kg/h	12.9	10.8	8.8		takes into account batch strength	
Maximum consumption	kg/d	289.8	234.0	119.1			
Intermediate Batch Storage Capacity (@Max Dose)	days	1.6	1.9	3.8		@ Maximum dose and corresponding flows, based on intermediate storage above	
Bulk chemical storage @ average dose	weeks	1.3	1.6	3.2		@ average dose and corresponding flows, based on bulk storage above	
No. of duty transfer pumps		1					Site photos
No. of standby transfer pumps		1					Site photos
Dosing pump standby capacity	%	100%					
Maximum duty pump capacity	L/h	255				255 L/h at 50Hz	Site photos
Average consumption	L/h	195.3	164.5	133.6			
Average dosing capacity	%	131%	155%	191%		Based on average dose	
Maximum consuption	L/h	257.6	217.0	176.3			
Maximum dosing capacity	%	99%	118%	145%		Based on Maximum Duty Pump capacity and Maximum Dose	

Report Tables

Parameter	**Units**	**Design Flow**	**95%ile Flow**	**50%ile Flow**	**ISDV**
Intermediate batch storage @max dose	days	1.6	1.9	3.8	>4
Bulk chemical storage @ average dose	weeks	1.3	1.6	3.2	>4
Dosing pump standby capacity	%	100%			100%
Maximum dosing capacity	%	99%	118%	145%	>110%

Appendix B Filter Inspection Report