Baradine WTP

Filter Inspection

NSW Health / Warrumbungle Shire Council

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1 Background

1.1 Project Scope

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

The filter inspection at Baradine Water Treatment Plant (WTP) was included as a deliverable for this project by an approved variation.

This inspection report provides an overall assessment of filter health and examines any likely causes of water quality issues.

The data reviewed and assessed in this report includes:

1. Chemical dose rates and conditions
2. Filtration rate
3. Filter outlet control
4. Air scour rates, duration and distribution
5. Filter backwash triggers
6. Backwash rates, duration and distribution
7. Filter headloss accumulation rate
8. Filter ripening period
9. Visual filter backwash observation
10. Backwash water turbidity profiling
11. Filter media height and configuration, including backwash water trough level
12. Filter media loss
13. Filter media condition including sludge analysis, visual inspection and sizing analysis
14. WSAA Good Practice Guide checklist for filtration.

1.2 Plant Overview

Baradine WTP is a 1 ML/d conventional water treatment plant which services the nearby township and surrounding properties.

The plant's process treatment train can be listed:

- Raw water pumping from bore adjacent to WTP
- Aeration for soluble iron and limited manganese oxidation
- pH correction using soda ash
- Coagulation with aluminium chlorohydrate (ACH) and rapid mixing
- Flocculation with flocculation aid polymer (LT20)
- Sedimentation using a circular upflow clarifier
- Filtration using one dual media open gravity filter
- Disinfection using chlorine gas
- Fluoridation using sodium fluoride
- Clear water tank and pumping to Baradine reservoir.

Washwater produced from filter backwashing is directed to the sludge lagoons. Two sludge lagoons exist on-site, with only one operational while the other remains offline. The sludge lagoons are alternated approximately every six months.

A schematic demonstrating Baradine WTPs physical and chemical processes are shown in Figure 1-1.

Figure 1-1: Baradine Water Supply System (AECOM, 2014)

Note: WSC to confirm bypass arrangement exists as shown above.

1.3 Existing Filter Design

Table 1-1 presents the known elements of the existing filter configuration. Data is sourced from the WTP O&M manual unless otherwise noted.

Table 1-1: Existing Filter Design Criteria

Design Criteria	Units	Value	Comment
DESIGN FLOW CRITERIA			
Plant Maximum Design Flowrate	L/s	19	Based upon design flowrate of 1.5 ML/d over 22.5 hours of runtime.
Plant Operating Flowrate	L/s	13	Typical flowrate indicated by site operator.
Plant Flowrate During Backwash	L/s	0	Plant is taken offline when the filter is backwashed.
FILTER DESIGN			
Number of Filters		1	
Number of Filter Cells per Filter		1	
Diameter (single filter)	m	3	
Filter Area (single filter)	m^2	7.1	Cross sectional area of filter.
Lateral Design			
Type			Plenum floor with long stem filter nozzles
Filter Nozzle Density	nozzles/m^2	64	~64 nozzles per filter area.
Nozzles per filter	No.	460	
Maximum Filtration Rate			
Maximum Filtration Rate	m/h	9.7	At max flowrate of 19 L/s.
Operating Filtration Rate	m/h	6.6	At typical flowrate of ~13 L/s.
Unit Filter Run Volume (UFRV) – continuous operation	ML in 22 h	1.55	Operating for 22 h/d at design flowrate of 19 L/s, and is backwashed everyday
FILTER MEDIA CONFIGURATION			
Filter Coal			The media and support layers listed here are those specified within the operational manual, but the configuration could not be verified on site due to excessive manganese build up on the media.
Depth	mm	1000	~495mm of Filter Coal measured on site with lots of media found in lagoons which had been washed out of the filter.
Effective Size	mm	1.25 -1.35	
L/d ratio	-	769	
Filter Sand			
Depth	mm	200	
Effective Size	mm	0.6 – 0.7	
L/d ratio	-	307	Fine sand.

Design Criteria	Units	Value	Comment
Design Combined L/d (coal and sand)	-	1077	Typically target >1250. Includes coal and fine sand.
Actual Combined L/d (coal and sand)	-	~688	Significant loss of filter coal observed
Supporting Sand			
Depth	mm	100	
Size Range (coarse sand)	mm	1 - 2	
Supporting Gravel			
Depth	mm	75, 75, 75	Three layers of supporting gravel; fine, medium and large, respectively.
Size Range	mm	1.5 – 3.0, 3.0 – 6.0, 6.0 – 12.0	Three graded layers of gravel
WASHOUT LAUNDER			
Design Media Distance from Launder	mm	210	
Actual Media Distance from Launder	mm	~1020	Measured during site inspection.
No. of Launders per Filter	No.	1	One V shaped launder
Launder Dimensions			
Length	mm	2380	Length of each launder arm
Width	mm	300	
Depth	mm	450	
Total launder volume	m^3	~0.70	Included two V arms and the central outlet section

Overall, the filtration rate is considered acceptable due to the original design being based on typical filtration rates (<10 m/h) at the maximum design flowrate. Typically, the industry standard L/d ratio requirement is >1250 however the typical design filtration rate is also 8-10 m/h. The Baradine filters are treating ground water (low turbidity) and are only operating typically around 6.6 m/h, therefore the original design L/d ratio is considered reasonable. Although filtration performance may suffer at maximum instantaneous rates which occurs each summer.

However, whilst on site a significant amount of filter media was missing and was observed to have been washed out of the filter due to the incorrect placement of the draindown level float switch (which was rectified whilst onsite). This had caused filter coal to be washed into the sludge lagoons. The missing filter media has therefore resulted in an inadequate L/d ratio of approximately ~688. This is likely impacting filtered water quality.

It is also however advised that individual filtered water online monitoring is installed and then the data is examined to confirm if the original design L/d ratio is adequate given at times the plant is operated at the full design instantaneous flowrate. Another issue with filters with low L/d ratios is the lowered solids holding capacity, which results in the filters requiring more frequent backwashes.

The Filter structure is made of GRP or FRP and is currently 19 years old (installed in 2001). GRP tanks typically have a design life of 25 years. Therefore, the filter is approaching its expected end of design life.

2 Filter Operational Data Review

2.1 Data

Historical operational data for Baradine WTP has been provided for the period between January 2015 and November 2019. Operational data was available only as daily WTP grab sample monitoring data. There are no online water quality analysers at Baradine WTP and therefore no SCADA trends were available to analyse. Hunter H2O recommends that online water quality monitoring is considered. This is being assessed through a different Safe and Secure Water Program funded project however as part of a wider council scheme.

Daily grab sample monitoring data included the following:

- Raw water turbidity and pH
- Aerated pH
- Settled water turbidity and pH
- Treated water turbidity, free chlorine and pH.

The provided grab sample monitoring data has numerous gaps for individual parameters, including:

- Raw water turbidity is only recorded between September 2019 and November 2019
- Settled water turbidity is only recorded between October 2019 and November 2019.

Treated water turbidity is the only parameter that remains consistent for the entire January 2015 to November 2019 period.

2.2 Data Assessment Summary

Daily monitoring data has been used to investigate the filtration performance. Unit Filter Run Volume (UFRV), Clean Bed Headloss (CBHL) and filter ripening period could not be determined as there is no online data available. The assessment results are provided in Table 2-1. For comparison purposes the turbidity data for raw, settled and treated are also included.

Table 2-1: Turbidity Data Summary for Filtered, Raw, Settled and Treated Water (January 2015 and November 2019)

Parameter	Count	Min NTU	Avg NTU	Max NTU	5%ile NTU	25%ile NTU	50%ile NTU	75%ile NTU	90%ile NTU	95%ile NTU
Raw Water	65	0.03	0.08	0.16	0.04	0.06	0.07	0.09	0.1	0.108
Settled Water	52	0.16	0.33	0.67	0.18	0.23	0.28	0.41	0.59	0.61
Treated Water	1774	0.01	0.13	0.92	0.01	0.03	0.07	0.18	0.37	0.48

It can be seen from Table 2-1 that the treated water 95%ile turbidity of 0.48 NTU (grab sample) is above the Australian Drinking Water Guidelines (ADWG) target of <0.2 NTU for reduction of chlorine resistant pathogens.

To ensure the filter is an effective barrier against protozoan pathogens, conventional filtration should be continuously monitored (online monitoring of individual filtered water turbidity) and operating with a filtered water turbidity target of <0.15 NTU - <0.3 NTU (depending on the catchment risks). However, given that the raw water sourced for Baradine comes from a deep bore (~216 m), assuming that the bore head and the aquifer are confined then the focus on chlorine resistant pathogens should not be of great concern. However, the Drinking Water Management System (DWMS) workshop undertaken in 2014 identified and documented pathogens as a risk for Baradine. Therefore, this report assumes that the risk assessment undertaken and the subsequent CCPs are correct and the target is as per the guidance noted above. It is critical however to confirm the bore head is adequately protected. It is also always prudent to test the raw water for *E.coli* and or turbidity regularly during and after rainfall to confirm there is no evidence of surface water intrusion.

It is recommended that online filtered water turbidity monitoring is installed to confirm the performance of the filter and overall plant performance continuously via SCADA tending (with alarming). Implementation of online filtered water turbidity monitoring should be considered as an effective, long term solution of online water quality review and exercise.

To enable effective online water quality monitoring of the whole plant, it is recommended to undertake continuous data monitoring and storage via SCADA of the following parameters:

- Raw water flow, pH and turbidity
- Aerated water pH
- Coagulation pH
- Settled water turbidity
- Individual filtered water turbidity and headloss
- Treated water pH, turbidity, chlorine and fluoride
- Backwash flowrate and timing.

Filtration performance can be often impacted by the upstream pre-treatment systems effectiveness. Controlling aeration, coagulation, flocculation and sedimentation processes are important to enable consistent quality and volume of water supplied to the filter to enable effective filter performance. Key parameters that can affect coagulation performance are pH, turbidity, true colour and flow.

Jar testing should be used regularly to optimise pH adjustment and coagulant dose rates when the raw water quality experiences changes in turbidity, true colour or pH and also iron and manganese.

Continuous collection of the above listed online water quality monitoring parameters will allow WSC to assess filtration performance through:

- Filter ripening phase directly after backwash
- Impacts of filter headloss on turbidity
- Filtration performance during normal operation and high turbidity raw water events.

2.3 Commentary on Filtration Critical Control Point

Critical Control Points (CCP) for Baradine WTP prior to June 2018 are demonstrated in Figure 2-1, along with corresponding monitoring and action procedures in Figure 2-2.

CCP ID	Critical Control Point	Hazard	Control Parameter	Target	Alert Level	Critical Limit
BDN1	Filtration	All pathogens	Turbidity	<0.6 NTU	>0.8 NTU	>1.0 NTU

Figure 2-1: Baradine WTP Filtration CCP (prior to June 2018)

Water Supply System	Baradine
CCP ID	BDN1
What is the control point?	Filtration
What are the hazards?	All pathogens
What is being monitored?	Turbidity
What will initiate response?	High turbidity reading (online or from grab sample)

Target <0.6 NTU	Alert Level >0.8 NTU	Critical Limit >1.0 NTU
Monitoring Systems Monitoring parameter: Turbidity Monitoring location: Outlet of filter Monitoring frequency: Daily grab sample - Calibration of instruments - Visual inspection of filters - Routine monitoring program - Backwashing filters (time based/on high turbidity read) - Testing raw water - Coagulation/sedimentation/clarification monitoring (daily sampling) - Hose down filter whilst backwashing - Pressure cleaning of filters annually - Check media annually - Visual inspection of clarifier floc and inspection of the blowers	**Corrective actions** - Check settled water turbidity * check dosing * jar tests * adjust dose accordingly - Check filter operation * check headloss * check time since last backwash - Instigate backwash * recheck headloss * resample and test	**Corrective actions** - Follow all AL corrective actions - Notify Manager Warrumbungle Water (Ph. 0409 896 452) - Dump clarifier water - Reduce flow rate through filters - Call PHU (Ph. 0407 551 548) and NOW (Ph. 0458 268 453) - Check reticulation for chlorine residual and turbidity - Microbiological sampling and testing - Dose with chlorine - Consider instigating a boil water alert

Figure 2-2: Baradine WTP CCP procedures (prior to June 2018)

The current CCP, however, for Baradine WTP filtered water turbidity was implemented on the basis of turbidity targets recommended by the DWMS implementation report completed by Bligh Tanner (Bligh Tanner, 2016). The Filtration CCP limits outlined in the DWMS implementation report were effective at WSC from June 2018 and are presented in Figure 2-3, along with corresponding monitoring and action procedures in Figure 2-4.

CCP ID	Critical Control Point	Hazard	Control Parameter	Target	Alert Level	Critical Limit
BDN1	Filtration	All pathogens	Turbidity	<0.2 NTU	>0.4 NTU	>0.8 NTU

Figure 2-3: Baradine WTP Filtration CCP (effective June 2018)

Water Supply System	Baradine
CCP ID	BDN1
What is the control point?	Filtration
What are the hazards?	All pathogens
What is being monitored?	Turbidity
What will initiate response?	High turbidity reading (from grab sample)

Target <0.2 NTU	Alert Level >0.4 NTU	Critical Limit >0.8 NTU
Monitoring Systems Monitoring parameter: Turbidity Monitoring location: Outlet of filter Monitoring frequency: Daily grab sample • Backwashing filters (time based) • Visual inspection of filters (daily) • Hose down filter whilst backwashing (as required) • Pressure cleaning of filters (annually) • Calibration of turbidity meter (annually) Associated routine checks: • Coagulation/clarification monitoring (daily) • Visual inspection of clarifier floc and inspection of the blowers	**Corrective actions** • Resample and test • if resample fails, instigate backwash • Check filter operation (visual) • Check settled water turbidity - check dosing - jar tests (as necessary) - adjust PACl/electrolyte dose accordingly • Notify Technical Officer (immediately on 0428 005 730 should problem persist, otherwise, via weekly operating sheet) • Technical officer to log details, and inform Manager Warrumbungle Water as required.	**Corrective actions** • Immediately notify Manager Warrumbungle Water (0428 949 450) • Follow all AL corrective actions • Investigate cause (e.g. poor clarification) • Follow directions from Manager, such as - reduce flow rate through plant - check reticulation for chlorine residual and turbidity - Increase chlorine dose - Microbiological sampling • Manager Warrumbungle Water call - PHU (0407 551 548), - Director Technical Services (0417 464 438)

Figure 2-4: Baradine WTP CCP procedures (effective June 2018)

Current Filtration CCP limits were determined on the basis of assessing the water quality risks of Baradine WTP's raw water source. Baradine WTP sources groundwater, therefore, the likelihood of protozoa contamination is minimal and the prime consideration is effective disinfection (Bligh Tanner, 2016).

Hunter H2O provide the following commentary and recommendations on the current Filtration CCP in the context that the current DWMS identifies pathogens as a risk for Baradine due to "agricultural inputs due to surface water ingress" (AECOM, 2014):

- The CCPs are considered a little higher that what should be expected from an effective filtration process given pathogens have been identified as a risk in the catchment. CCPs should also be incorporated into WTP online water quality monitoring and result in plant shutdowns if critical limits are exceeded.
- The BDN1 CCP target is adequate
- The BDN1 CCP alert level should be reduced to >0.3 NTU
- The BDN1 CCP critical limit should be lowered to >0.5 NTU in line with other WTPs.

2.4 Filter Performance Data

Operational monitoring data was provided to Hunter H2O by WSC to develop an understanding of current filter performance and to assess how the filter is satisfying operational capability. The provided data has been analysed to determine filter performance for each of the following parameters and relationships:

- Filter outlet turbidity (treated water turbidity)
- Raw and settled water turbidity influence on filter performance
- Filter ripening.

Please note that within the operational monitoring data provided by WSC, turbidity data prior to June 2018 had been categorised on the basis of the redundant Filtration CCPs identified in Figure 2-1. The filter performance data analysis for turbidity presented in this report however has presented turbidity readings prior to June 2018 by categorising them against the updated CCPs identified in Figure 2-3.

2.4.1 Filter Outlet Turbidity

Filtered water turbidity recorded from January 2015 to November 2019 is presented in Figure 2-5 and has been plotted with the target, action and critical limit CCPs.

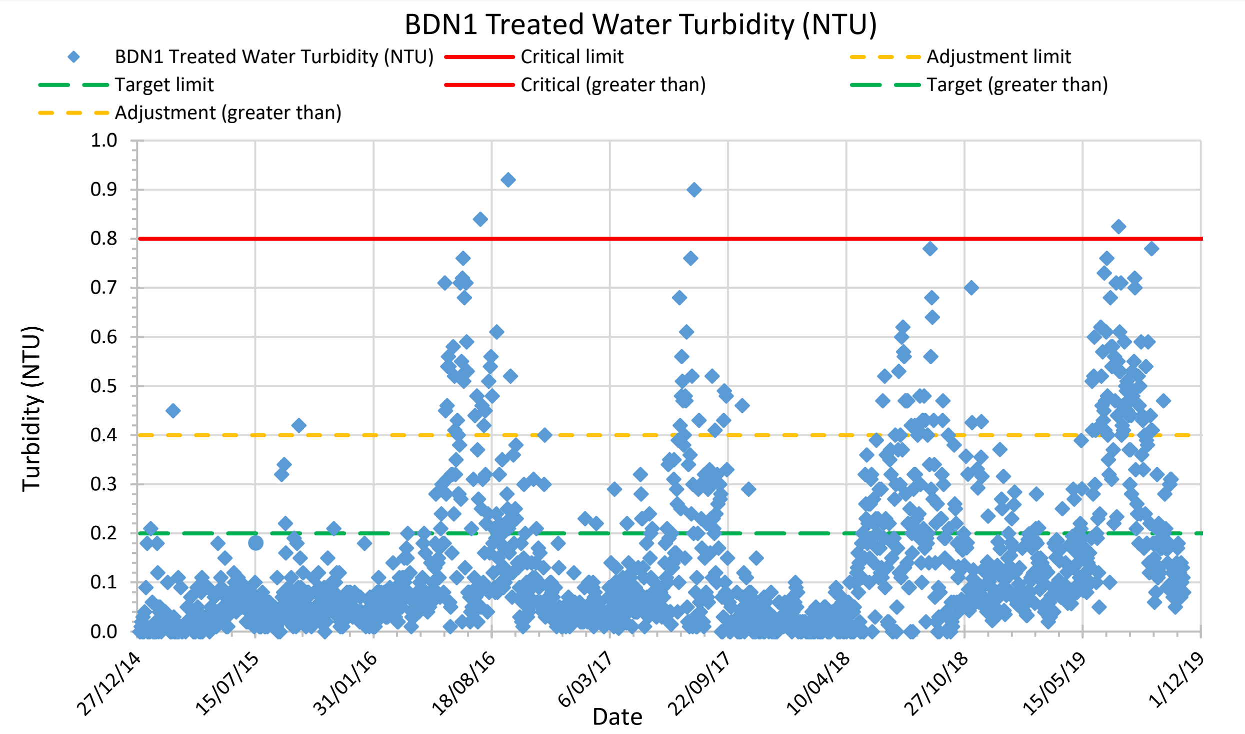

Figure 2-5: Filtered Water Turbidity (January 2015 - November 2019)

It can be seen from Figure 2-5 that filtered (treated) water turbidity periodically increases during winter months, implying that during spring – autumn, lower turbidities are typical, while during winter the plant experiences higher turbidities. It is also of note that the winter of 2015 did not see the same increase in filtered water turbidity compared to 2016 through to 2019. There has also been an increase in filtered water turbidity during spring to autumn in 2018-2019 compared to previous years. This could suggest that some variable has changed which is now resulting in poor filtered water quality at times, with greater variability observed in winter months.

The data exhibits a wide variability in the turbidity results especially in the winter months. Therefore, the root cause of the high turbidity cannot be confirmed given the lack of data. Likely causes could be:

- sampling techniques or times
- sample temperature causing fog on the sample vial and overinflated readings
- overdosing of ACH and post flocculation issues
- cold water affecting coagulation and thus 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 (refer below discussion).

Further targeted investigation in this area is therefore required.

Manganese and iron are a raw water quality issue for Baradine WTP (refer Figure 2-6). During winter, with colder water temperatures, coagulation and precipitation reactions occur more slowly, therefore iron and manganese oxidation could be impaired if the filtration process is not optimised to capture the precipitate. During the site visit it was found that a significant amount of filter media was missing from the filter and had been backwashed into the lagoon inlet. Therefore, following the event that resulted in the media loss it could be possible that filtration performance was therefore negatively affected. In addition, a large amount of build-up (likely manganese) was observed on the filter media. This indicates that the filter may be operating, or has been operating, with a natural manganese oxide coating on the filter media which assists with removal of manganese. A natural coating could develop on the filter media (as was found at Binnaway WTP) likely due to the dissolved oxygen provided by the aerator and the high pH (50%ile of ~7.9) of the coagulated water. With shorter bed depths this manganese removal process could potentially be affected. This suspicion however would need to be confirmed through additional data collection with a focus on iron and manganese data throughout the WTP (including the raw water).

Parameter	bore no 1		bore no 2	
	Min.	Max.	Min.	Max.
Iron	1.2	8	6.2	10
Manganese	0.28	0.29	0.24	0.26

Figure 2-6: Iron and Manganese defined in the 1999 Baradine WTP Design Specification (DPWS, 1999)

As mentioned earlier though, the data exhibits a wide variability in the turbidity results. Therefore, the root cause of the high turbidity cannot be confirmed given the lack of data.

Note: WSC to confirm that during winter months the WTP is running when the samples are collected. Sample collection could be resulting in the high variability in results.

If sampling collection times and methods are confirmed to be suitable and not the cause of the variability in the turbidity results, then it may be possible that the filtration performance was affected following the winter of 2016, due to significant media loss and subsequent reduction in media with an oxide coating within the filter. If this was the cause, then the filtered water manganese concentration could have increased. Increased filtered water-soluble manganese can result in increased turbidity upon chlorination and oxidation of the soluble manganese. However, given the variability in sample results, further investigation is required to confirm why there are some good results in winter while the majority are much worse. Based on the data provided, the root cause of the filtered water spikes is unclear.

The filtered water turbidity data has also been manipulated into a percentile graph (demonstrated by Figure 2-6). This was achieved by dividing the sequential number of turbidity recordings by the total number of data points. For example, in a data set of 1000 data points, when sorted from smallest to largest the 900th data point would become the 90th percentile (900/1000 x 100).

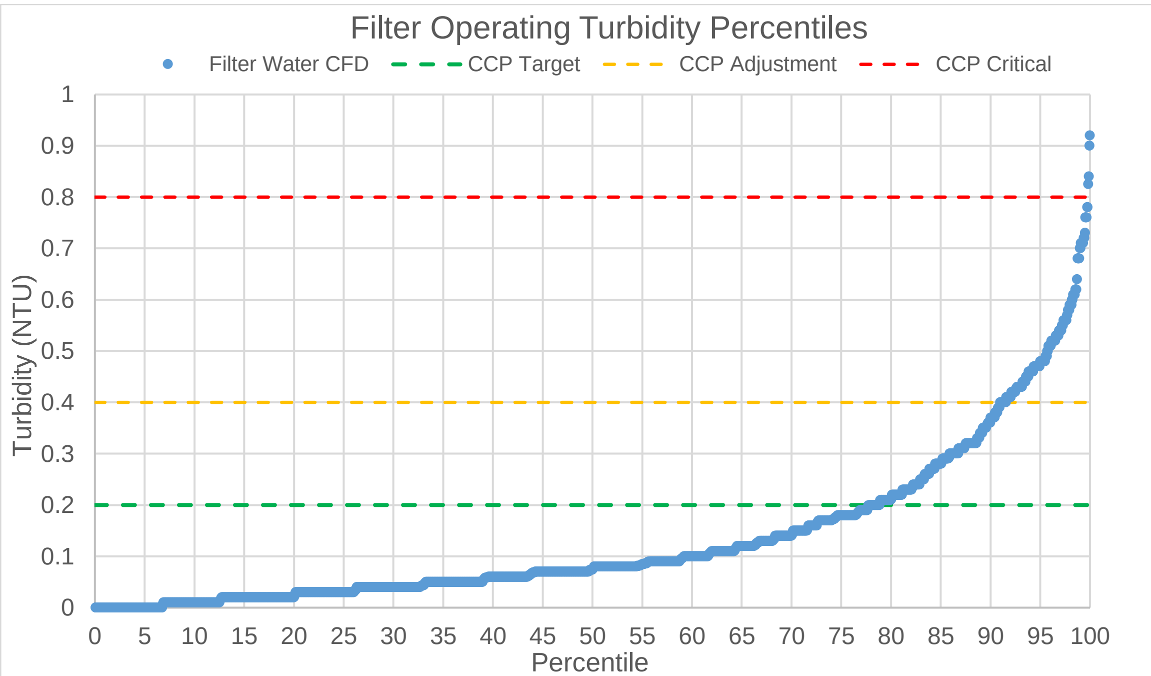

Figure 2-7: Filtered Water Turbidity Profiles (January 2015 – November 2019)

It can be seen from Figure 2-6 that approximately 10% of filtered water turbidity results exceeded the CCP of 0.4 NTU (including turbidity readings pre-June 2018), while ~77% of results remained below 0.2 NTU within the safe range specified by ADWG.

2.4.2 Raw and Settled Water Turbidity Influence on Filter Performance

No online filtered water turbidity data was available for assessment, therefore, raw and settled water turbidity grab samples were analysed to identify any impact or relationship with filtered water turbidity. Figure 2-7 presents the comparison between raw, settled and filtered water turbidity.

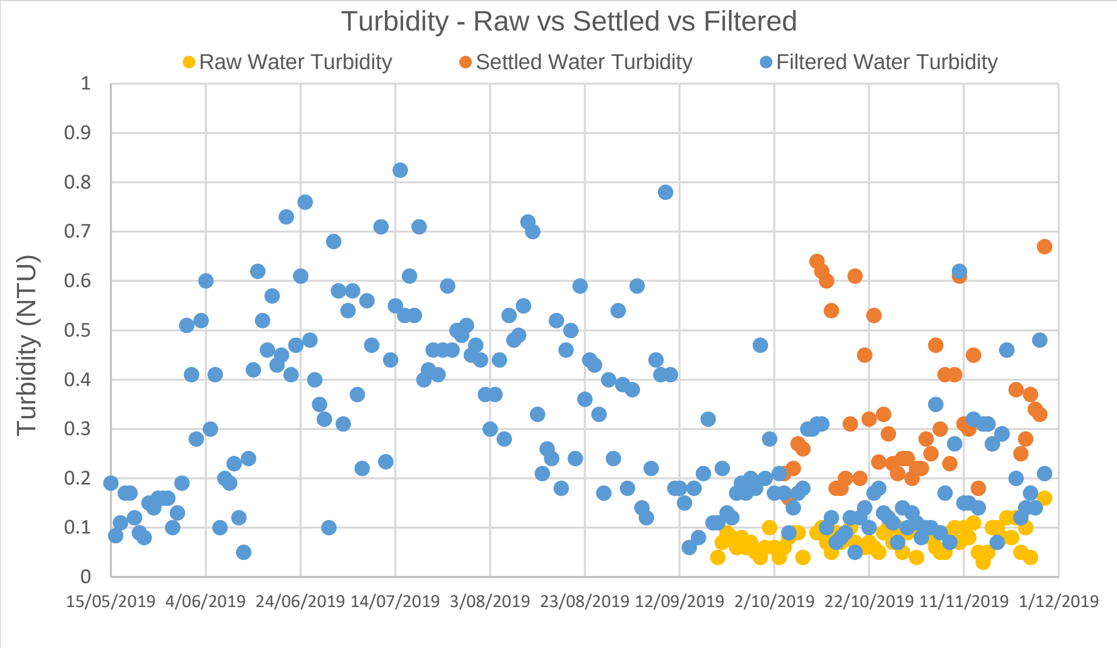

Figure 2-8: Turbidity Comparison for Raw, Settled and Filtered Water

It can be seen from Figure 2-7 that raw and settled water turbidity data prior to September 2019 has not been provided or does not exist, therefore, any effect on filter performance could assessed. The raw water turbidity appears to be stable (based on grab sample data) and is lower than the settled water turbidity. It can however be seen from Figure 2-7 that raw water turbidity is generally lower than settled water, maintaining <0.2 NTU, while settled water exceedances >0.4 NTU have been observed. This is likely due to iron and manganese oxidation via aeration at a high pH. This is expected and the filter would have been designed to remove the remaining precipitate and solids remaining in the settled water quality. However, filter media loss is likely contributing to elevated filtered water turbidities.

The high variability in sample results is concerning and therefore a focus on process optimisation and or sampling regime should be considered and investigated further. Sampling daily at different times of the day or at different durations after the WTP has been running can alter the results and thus make root cause analysis difficulty. Online instrumentation enables trending of data which can then be used to identify issues and determine the root cause more easily.

2.4.3 Filter Ripening

Filter ripening is the period of elevated turbidity immediately after a backwash or plant start-up. This could not be considered as there is no recorded online monitoring data of the filtered water quality.

Filter-to-waste is where filtered water is diverted away from treated water for a period. Without filter-to-waste, the period of improving turbidity after a backwash and on start-up is critical to the overall performance of filtration. Filter-to-waste is usually also considered if a filter is unable to produce filtered water below the maximum percentile targets.

It is therefore important to monitor the filtered water turbidity continuously so that the filter ripening period can be examined and monitored in future.

2.4.4 Data Performance Summary

The data analysis summary based on the provided daily monitoring data is outlined below:

- The 95%ile filtered water turbidity of 0.48 NTU is significantly higher than the recommended ADWG target of <0.2 NTU, for effective reduction of chlorine resistant pathogens.
- Comparison of recent data (2015 - 2019) shows that filter performance degrades during winter months likely due to manganese breakthrough in the filter due to media loss and reduction in filter media bed depth.
- Raw water turbidity appears to be stable (based on grab sample data) and is lower than the settled water turbidity. This is likely due to the iron and manganese that is oxidised following the aeration and high pH coagulation stages. Not enough data exists to enable a correlation to be established between raw, settled and filtered water turbidity.
- Insufficient data was provided for analysis of historical:
  - Flow on filter performance
  - Backwash frequency
  - Drain down rate
  - Filter outlet control valve oscillation and hydraulic surging.

2.5 Health Based Targets

Baradine WTP sources water from a bore on-site, therefore, is treating a groundwater source. Groundwater sources are known to have an inherently lower risk of pathogen contamination, but an increasing risk of metal contamination.

As part of a multibarrier approach to pathogen reduction, effective filtration plays a critical role. A well operated and maintained filter serves to form a barrier to particles, including pathogens, that if not removed would result in poor disinfection, dirty water complaints and increased disease burden through exposure to chlorine tolerant protozoans. It is noted that even though the WTP sources ground water from a deep bore (~216 m) the raw water risk assessment undertaken in 2014 identified pathogens as a concern.

Baradine WTPs previous Filtration CCPs prior to June 2018 were considered slightly higher than the ADWG recommendations for target, alert and critical level CCPs. The ADWG (NHMRC, 2016) recommends filtered water turbidity of <0.2 NTU for effective reduction of chlorine-resistant pathogens. The ADWG (NHMRC, 2016) also recommended a turbidity of <1 NTU for effective disinfection.

Baradine WTP currently adopts a filtered water target CCP of <0.2 NTU which satisfies the recommendation of ADWG target NTU.

If considering guidance from the WSAA Manual for the Application of Health Based Treatment (HBT) Targets (Water Services Association of Australia, 2015) a monthly 95th percentile of <0.15 NTU is the highest target with <0.2 NTU being the second tier target for claiming log removal credits from a media filter which is preceded by effective coagulation, flocculation and sedimentation (or flotation).

Process	Log reduction value			Process critical limits
	Bacteria	Virus	*Cryptosporidium*	
Conventional Treatment [3 & 4]	2.0	2.0	3.0	Individual filter turbidity ≤ 0.3 NTU for 95% of month and not > 0.5 NTU for ≥ 15 consecutive minutes Combined filtrate turbidity < 0.2 NTU for 95% of the month and not > 0.5 NTU for 15 consecutive minutes. [5]
	2.0	2.0	3.5	Individual filter turbidity ≤ 0.2 NTU for 95% of month and not > 0.5 NTU for ≥ 15 consecutive minutes
	2.0	2.0	4.0	Individual filter turbidity ≤ 0.15 NTU for 95% of month and not > 0.3 NTU for ≥ 15 consecutive minutes

Figure 2-9: WSAA Log Credit and Performance Requirements

2.5.1 WSAA Good Practice Checklist

A high-level checklist assessment was undertaken of the filtration process against the recommendations in the Water Services Association of Australia (WSAA) guideline 'Good Practice Guide to the Operation of Drinking Water Supply Systems for the Management of Microbial Risk' (Water Services Association of Australia, 2015).

The Media Filtration Table from the WSAA Good Practice Guide (Water Services Association of Australia, 2015) was used as a checklist to assess the Baradine WTP filters and filter operations.

A summary of the non-conformances is provided in Table 2-2 while the full details of the assessment are provided in Appendix A.

Table 2-2: WSAA good practice guideline non-conformances

No.	Non-Conforming Measure	Comment
46	Approved (USEPA 180.1 or ISO 7027) turbidimeters are provided for each filter (Mosse et al. 2009; AwwaRF 2002; AWWA 2001) and operated according to specifications.	There is no online monitoring at the WTP.
47	Once triggered for backwash, the filter is shut down automatically and placed in a backwash queue.	There is no automatic backwash trigger.
49	During drain down, prior to backwashing, controls are in place to ensure the filtration rate does not increase.	There is no control over the filter drain down rate.
51	Media depths in all filters are within specifications.	Based on the onsite measurement the media is approximately ~500mm lower than specified. Excessive media loss has occurred and was found to be in the offline lagoon.
52	Filter operations must be optimised to remove pathogens, as measured by post-filter turbidity.	There is no logged continuous online filtered water quality monitoring. Filter grab sample data indicates a 95%ile value of 0.48 NTU. Filtered

No.	Non-Conforming Measure	Comment
	Examples of post-filter turbidity performance which would deliver known log removal credits for the removal of Cryptosporidium (WSAA 2014) are given below: Individual filter turbidity ≤0.15 NTU for 95% of the month and not >0.3 NTU for ≥15 consecutive minutes. (4.0 log removal for conventional treatment 3.5 log removal for direct filtration) Individual filter turbidity ≤ 0.2 NTU for 95% of the month and not > 0.5 NTU for ≥15 consecutive minutes. (3.5 log removal for conventional treatment 3.0 log removal for direct filtration)	water is above 0.2 NTU for a portion of the time (only ~22% of samples are greater than 0.2 NTU).
53	Backwashes are triggered automatically by turbidity, head loss and run time (Kawamura 2000).	There is no automatic backwash trigger.
54	Clean bed head loss (CBHL) is monitored during operation and trended.	The headloss meters were no set up properly and there is no recording or trending of CBHL.
58	In plants without filter to waste, the ripening period after backwashing does not exceed the critical limit for any longer than: 0.5 NTU 30 min (3 log credit) 0.5 NTU 15 min (3.5 log credit) 0.3 NTU 15 min (4 log credit)	There is no online monitoring at the WTP.
59	Continuous recording and display of turbidity, filter flow, head loss and filter level or filter outlet valve position, is provided on the plant SCADA.	There is no online monitoring at the WTP.

3 Filter Inspection

3.1 Overview

A site inspection was undertaken by Michael Carter, Anthony Blair and Joshua Tarjanyi from Hunter H2O on 26 and 27 November 2019 with the purpose of:

- Undertaking the '15-point' filter inspection check;
- Meet with operators to discuss and plan the filter entry procedures and coordinate emergency retrieval equipment;
- Familiarised themselves with WTP systems and assets;
- Observed a filter backwash;
- Entering the filters to collect media samples for sizing and sludge analysis;
- Undertook sludge volume tests on filter media samples from the filter ;
- Measuring the turbidity of washwater during the backwash;
- Discussing preliminary site visit findings with operators and Council; and
- Gathering additional operational data and procedures.

Philip Hensby (WTP Operator) and Andrew Milford (WTP Team Leader) from WSC were present during the inspection.

3.2 General observations

The following general observations were made on site:

1. The plant is not flow paced and changes to chemical dose rates relating to operation of the raw water flow or raw water quality must be made manually.
2. There is no online, continuous monitoring of plant operation or performance due to the design of the plant control system.
3. Visual inspection of the filter in operation revealed that there was air entrainment in the water leaving the clarifier and entering the filter. This turbulence may result in flocc shear (break up) impacting any remaining flocc that is leaving the clarifier and thus make it harder to capture within the filter due to the smaller flocc size.
4. The filters water level had some slight wave action occurring which was impacting on the filter outlet valve control to a small degree via the Trimod besta level controller. This may have been a result of the air entrainment causing the surface disturbance or the wind on the day of the inspection as the filter is located outdoors (unsheltered).
5. Visual inspection of the filter during a backwash identified that the draindown level float switch used to stop the filter drain down, open the washwater outlet valve and start the air scour after a short delay, was higher than it was designed to be (due to the cord being wrapped around a support bracket). Therefore, the water level was still at the top of the washwater launder when the air scour started. Filter media loss was observed.
6. A significant amount of filter media was observed to have washed out of the filter and was piling up at the sludge lagoons inlets.
7. Visual inspection of filter media revealed intermixing of the support gravel with filter media. This infers disturbance of the filter bed.
8. Visual inspection of the filter indicated that the plenum floor was compromised evidenced by scouring along the side walls of the filter and filter media being present in large quantities in the underdrain. This indicated that the filter may be bypassed around the side walls and also that some filter nozzles may be compromised due to the filter media placement within the underdrain.
9. Process disturbances relating to failure of equipment may not be recognised by plant systems or plant operators until significant process disturbance has occurred (e.g. loss of coagulation due pre-pH failure or incorrect ACH dose rate setting will not be automatically detected and alarmed). The first indication that an incident like this occurs would be customer complaints.
10. The main switchboard/MCC is located within the room where the clear water tank has potential to overflow.

3.3 Pre-treatment chemical dose rates and conditions

Raw water flow at the time of the visit was approximately 18 L/s.

Chemical dose rates observed during the site inspection are demonstrated in Table 3-1.

Table 3-1: Observed Chemical Dose Rates

Chemical	Units	Dose Rate	Comment
Soda Ash	mg/L	~96	Dosed to the aerator outlet
ACH	mg/L	~15	
LT20 Polymer	mg/L	~0.14	

3.4 Filter Operation

3.4.1 Filter Backwashing

Discussing filter backwash operations with the site operator indicated that backwashing is activated manually at the operator's discretion. Typically undertaken daily during the daily clarifier drain down task.

Table 3-2 presents the current filter backwashing sequence.

Table 3-2: Filter Backwash Sequence (manually initiated)

Filter Operation	Units	Design Criteria	Comment
Backwashing			
Filter to level	First step involves the WTP operator shutting down the WTP and the filter feed subsequently stops. The backwash process is initiated via the filter backwash control panel. The water level drops to the backwash level over a ~7 minute period.		
Filter level at start of Backwash	Top of washwater launder. This was fixed whilst on site by lowering the draindown level float switch down to its original position.		
Air Scour Duration	mins	~3	
Air Rate	m^3/h	425	Based on air scour blower rate of 118 L/s.
Equivalent to	m/h	60	
High flow wash rate	m^3/h	316	Based on backwash flowrate of 88 L/s
High flow wash rise rate	m/h	~45	
Duration	mins	~7-8	
Return to service	Return to service is through filling the filter with settled water from the clarifier.		

3.4.2 Backwash Turbidity Profile

A backwash was manually initiated during the site visit. Sample vials were used to manually collect washwater dropping from the filter washwater launder at regular intervals. The results of this analysis are presented graphically in Figure 3-1, and the sample order of turbidity readings undertaken can be seen in Figure 3-2.

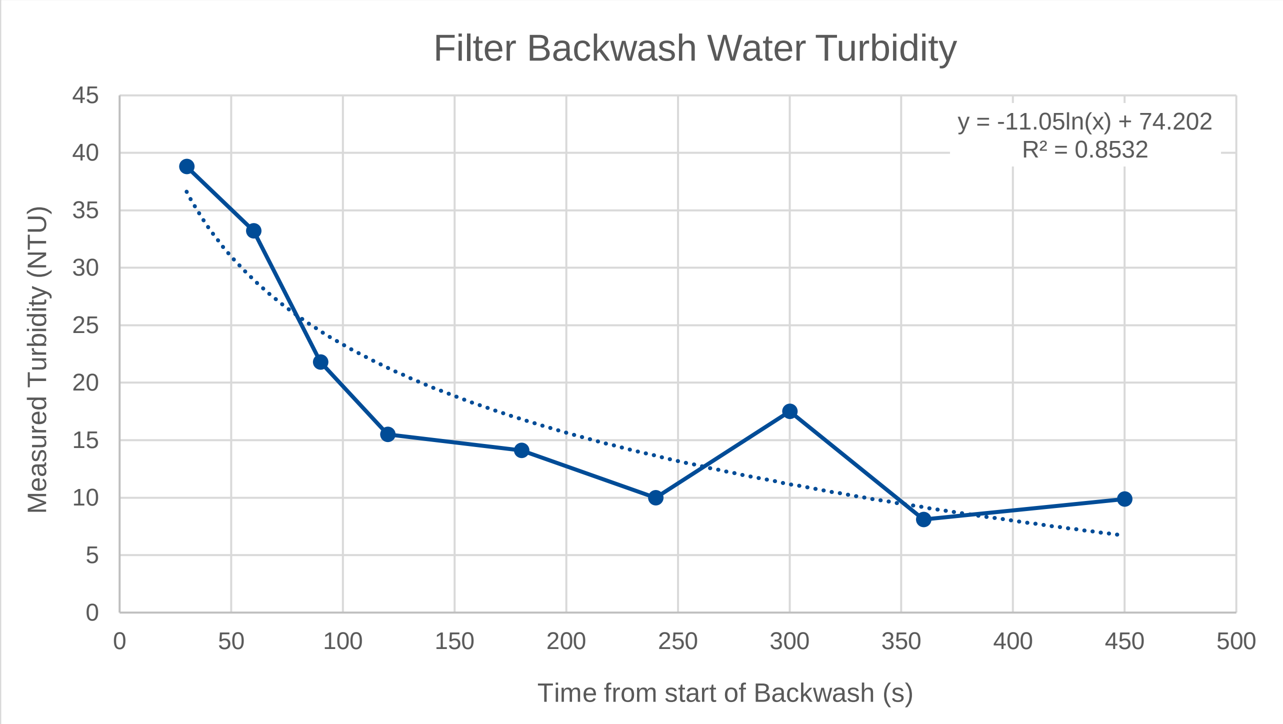

Figure 3-1: Filter backwash turbidity profile

In considering the turbidity profiling of the backwash from Figure 3-1, the turbidity of the washwater reached ~10 NTU between 4 - 7.5 minutes of high flow washing. There is an outlier value of 17 NTU captured at five minutes which does not seem to fit the trend. Using the trend line however would indicate that 10 NTU is achieved after ~5.8 minutes.

A common problem with having a very low turbidity at the end of the backwash cycle is that the filter may take a long time to ripen during which time the turbidity leaving the filter will be high. The ripening period is unknown, however as there is currently no individual filtered effluent turbidity analyser. If filter ripening was confirmed to be an issue, then there may be an opportunity to reduce the backwash duration marginally to assist filter ripening.

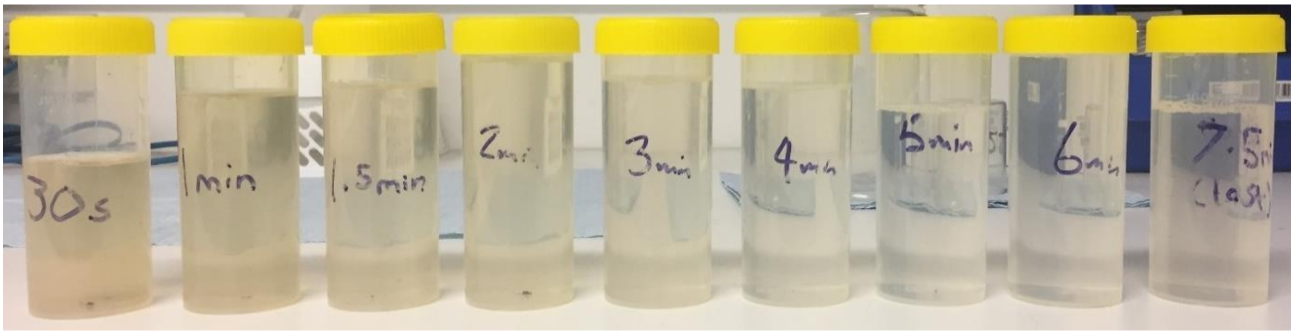

Figure 3-2: Filter backwash samples collected for turbidity profiling

3.4.3 Backwash Observations

The filter was observed from the viewing platform next to the aerator during the drain-down, air scour and backwash sequences. The turbidity of the washwater stream dropped to acceptable levels with 4 – 7.5 minutes of analysis indicating that backwash time and intensity is likely acceptable. Discussion with operators indicated that backwashing protocols are maintained consistently throughout the year. Washwater rates should generally be adjusted throughout the year as changing water temperatures may significantly alter filter bed expansion due to changes in water viscosity (if bed expansion is too high then media loss can occur). As such, opportunities exist to optimise the backwash procedure pending further analysis by operational personnel. This should be considered given the low free board between the design filter media level and the launder. Typically, 300 mm is the freeboard allowance, from the top of the filter media to the underside of the washwater launder, used to prevent media loss.

The following key observations were made during the backwash inspection:

- The filters did not drain down past the top of the washwater launder. It was found that the draindown level float switch was raised above its normal position and thus the water level was at the top of the washwater launder when the air scour sequence started. This caused media to bubble over into the washwater launder and is the likely cause of the previous filter media loss.
- The washwater launders were able to carry all flows without flooding.
- Air scour and water wash distribution appeared to be good overall. No ‘dead spots’ and volcanoes were observed. However, as the water level was at the top of the launders the whole air scour pattern could not be completely observed.
- Washwater discharged to the sludge lagoons was observed to cause significant disturbance at the sludge lagoon inlet which resulted in sludge being resuspended and carried towards the lagoon outlet end.

3.5 Media Condition

Filter media condition was assessed visually and by collecting samples from entering the filter and digging into the coal layer of the filter. Three samples at various locations and depths were collected and sent to the lab for media particle size analysis. Two alternate locations in the filter were also selected to undertake a sludge volume index (SVI) test. Figure 3-3 demonstrates where each sample was collected from to undertake SVI testing and media particle size analysis.

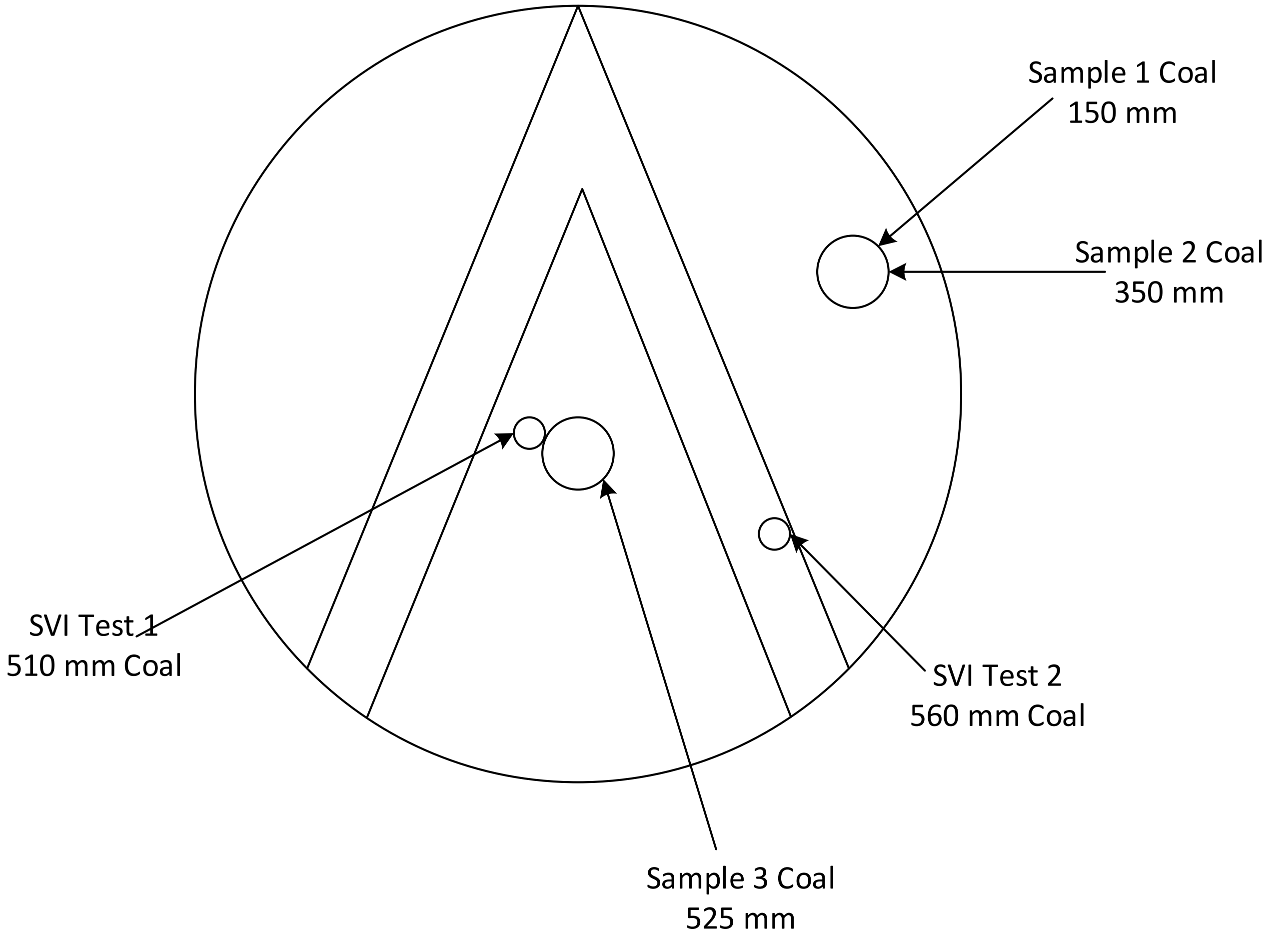

Figure 3-3: Filter Media Sampling Locations

While digging through the filter media at the sampling points, no mudballs were identified and there was minimal to zero fines situated on the top layer of the filter coal. The filter coal media looked angular in shape with low deterioration. However there was plenty of algae and flocc/sludge that had sloughed off from the filter walls which was present on top of the filter media (Figure 3-4). It can also been seen in Figure 3-4 that there were scouring marks at various points across the filter wall which indicate potential high washwater velocity points along the filter walls. This suggests that the plenum floor may have separated from the filter wall in sections causing filter washwater to exit at high velocity through the compromised sections. This would also allow the filter to be bypassed in certain sections in filtration mode.

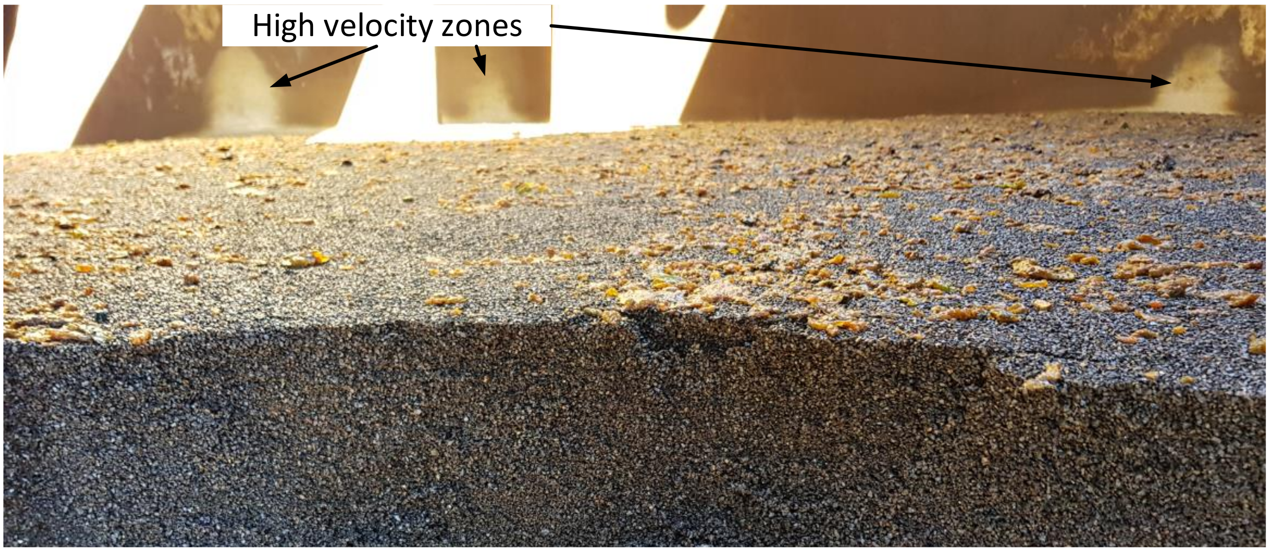

Figure 3-4: View from filter access hole across filter media surface with wall scouring observed.

Immediately prior to collecting filter sample 2 at 350 mm, support gravel was encountered and observed to be mixed with the coal and sand layers. No filter sand was encountered throughout both sampling points in the filter until it was realised that the sand had a manganese oxide coating (refer Section 3.5.1).

At filter sample point 3 it was observed that coal or coated black sand had been mixed with support gravel. Underdrain filter nozzles were also observed to be exposed at the depth (~525 mm) of sample 3 (demonstrated by Figure 3-5).

Figure 3-5: Filter nozzle exposed with coal with gravel and media intermixing

Filter sampling and SVI test locations are summarised in Table 3-3.

Table 3-3: Filter media sample types and depths

Filter Sample	Sample Type	Sample Depth (mm)
Filter Sample 1 (S1)	Coal Layer	150
Filter Sample 2 (S2)	Coal Layer	350
Filter Sample 3 (S3)	Sand/Coal Layer?	525
SVI Test 1	Coal Layer	510
SVI Test 2	Coal Layer	560

3.5.1 Manganese Oxide Coating

When first digging through the filter media it was thought that there was no filter sand layer installed as all the filter media appeared at first glance to be black and similar in size. It was not until excavation down to the gravel layers occurred, that it was discovered that the filter sand and support sand had in fact turned black (with a likely manganese oxide coating). The suspected manganese coating had resulted in the filter sand increasing in size (looking similar to the coal) and this was found to be intermixed throughout the filter coal and support layers.

No allowance was made for manganese coating analysis for this project as this was not originally expected at Baradine WTP. However, during the site inspection, it was suspected that a manganese coating had developed on the sand layers. A sample was therefore collected and washed with acid (dilute hydrochloric acid) whilst onsite, then rinsed with water as seen in Figure 3-6.

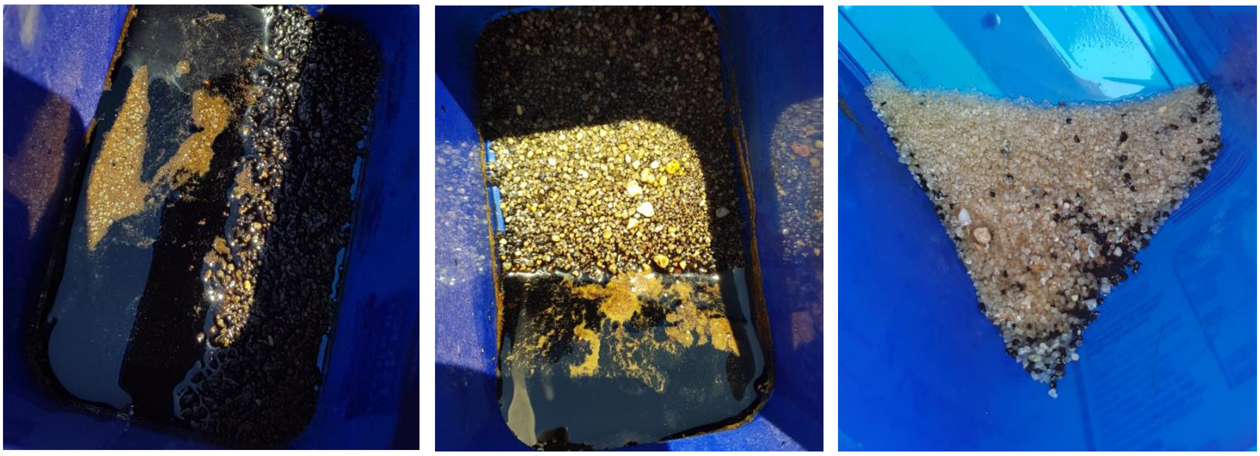

Figure 3-6: Filter media soaked and washed with acid (left to right: beginning to end of washing)

It can be seen from Figure 3-6 that the filter sand was black before the acid soak and washing and then clean following rising. The acid also turned black indicating manganese. In addition, once the acid was added to the media there was an exothermic reaction occurring which further supports this finding. It is unclear if a manganese coating had developed on the coal, however this is also suspected to have occurred to some degree. The manganese coating was not excessive or built up to the point where it could be broken off the filter media when applying pressure from fingers, as was seen at Binnaway WTP during the filter inspection in 2017. Manganese staining was also visible und her underdrains and on the filter walls.

3.5.2 Media Loss and Underdrains

Prior to entering the filter, confined space entry of the underdrain was undertaken with the aim of assessing the plenum floor and filter nozzles. It was observed upon entry that a large quantity of sand was present on the underdrain floor (Figure 3-4). Filter media present in the underdrain suggests either broken nozzles or a disturbance of support gravel layers which has allowed sand and coal to migrate to and through the nozzles. The filter nozzle slot size (measured to be ~1.6mm on site) is also large and this would allow filter sand (0.55 – 0.65 mm) to pass through to the underdrain if a disturbance of the support layers occurs, which has occurred at some point in the past.

Figure 3-7: Filter sand and coal found in filter underdrain

Large quantities of filter coal were also identified at the inlet of the empty sludge lagoon (Figure 3-8).

Figure 3-8: Filter media in sludge lagoon

The large volume of filter media found in the sludge lagoon supports the finding that draindown level float switch was positioned too high which was contributing to filter coal loss during the air scouring process. The media lost during each filter backwash would have then been carried to the lagoons by the high rate backwash flows.

The damage to the underdrain (previously mentioned) was also confirmed by visual inspection of the underdrains which revealed similar scouring points along the join between the plenum floor and filter wall, evidenced by clean white sections (with no manganese build up due to scouring effects). In addition, water was also observed leaking and dripping through these compromised sections (refer Figure 3-9). Visual inspection also revealed hair line cracks and damage on and around the joints (floor and wall). There was therefore sufficient evidence of wall to floor joint failure and cracking suggesting potentially bypassing of filter media.

Figure 3-9: Underdrain floor joint failure and cracking

3.5.3 Sludge Volume Index Testing

Media samples were taken from the surface layer of the filter bed for Sludge Volume Index (SVI) testing:

- Each sample was collected by firstly scraping away the top few centimetres of filter media using a shovel, then collecting a composite sample from a depth as detailed in Table 3-3 through to the top of the filter media (with the top few centimetres scraped away)
- ~500mL of each sample was placed in 1L measuring cylinder and topped up with clean tap water
- The sample was then shaken vigorously to dislodge any sludge from the media
- The measuring cylinder was then left undisturbed to allow sludge to settle.

Figure 3-10: SVI testing for SVI1 (left) & SVI2 (right)

The test undertaken at the SVI 1 and SVI 2 sample locations did not produce any visible sludge layer after the water had settled, as both tests produced very fine floc that did not settle. No sludge layer formed on top of the media and thus the observed SVI was considered to be quite low. A SVI of <5% is generally acceptable as being ‘good’ (Murray, 2005).

3.5.4 Filter Media Sizing

Filter media samples were sent to River Sands Pty Ltd, QLD, for filter media sieve analysis for determination of the filter media effective size (ES) and also the uniformity coefficient. Results of the analysis are summarised in Table 3-4 while the laboratory test results can be found in Appendix B.

Table 3-4: Filter Media Sizing Results

Filter Sand Samples	Sample Type	Effective Size (mm)	Uniformity Coefficient (-)
Original Design – Coal	-	*1.25 - 1.35*	*1.35*
Original Design – Sand (Fine)	-	*0.6 – 0.7*	*1.35*
Sample 1 (S1)	Coal/Sand? Layer	0.78	*2*
Sample 2 (S2)	Coal/Sand? Layer	0.79	*1.85*
Sample 3 (S3)	Coal/Sand? Layer	0.83	*1.88*

The filter media configuration was found to be different to the design specification. Given the large amount of missing media and the difficulty in determining the interface between sand and coal layers, it was hard to define if coal or sand was captured in the filter media samples. This indicated that either there was a large amount of filter media intermixing that had occurred (which was observed), or that the sand layer effective size had increased due to a manganese coating on the filter media (also observed).

3.6 Filter outlet flow control

The filter level control is maintained via a trimod besta proportional level controller. Operations staff indicated that the fluoride flowmeter (filtered water outlet flowmeter) can at times fluctuate by a few L/s. This was not observed during the site visit however the trimod besta level controller was seen to be adjusting back and forth just before the filter was put into backwash based on the small waves on the water surface within the filter. This may have been caused either by wind or the bubbles entering the filter through the inlet due to air entrainment. These small changes in the level controller are expected to result in slight changes in the filtered flowrate. Sudden changes in filtration rate should be avoided. Hence further investigation into the cause of the fluctuation should be undertaken. Hunter H2O recommend that Council install a new stilling tube similar to that used at Coonabarabran WTP to mitigate against water surface disturbances and then reassess the issue.

4 Conclusions & Recommendations

On Tuesday and Wednesday of the 26 and 27th November 2019, Hunter H_2O attended Baradine WTP to meet with Warrumbungle Shire Council staff and assess the condition of the filtration system. Philip Hensby, the site operator, and Andrew Milford from WSC attended the inspection.

4.1 Summary of Data

Data analysis indicated that the water quality leaving the existing clarifier is of generally good quality (50%ile of 0.28 NTU), however the filtered water quality is exceeding the current filtration target CCP (<0.2 NTU) for ~23% of samples tested. The 95%ile filtered water turbidity of 0.48 NTU is significantly higher than the recommended ADWG target of <0.2 NTU, for effective reduction of chlorine resistant pathogens.

Comparison of recent data (2015 - 2019) shows that filter performance degrades during winter months. The data exhibits a wide variability in the turbidity results especially in the winter months. Therefore, the root cause of the high turbidity cannot be confirmed given the lack of data. Likely causes could be sampling techniques or times, sample temperature causing fog on the sample vial and overinflated readings, overdosing of ACH and post flocculation issues, cold water affecting coagulation and this causing elevated aluminium and hence post flocculation issue or potentially insufficient contact time with soluble manganese due to the decreased filter media bed depth. Further targeted investigation in this area is required.

The raw water turbidity appears to be stable (based on grab sample data) and is lower than the settled water turbidity. Higher settled water turbidity is due to ACH dosing and iron and manganese oxidation following the aeration and high pH coagulation stages. Not enough data exists to enable a correlation to be established between raw, settled and filtered water turbidity. It is therefore unclear if the clarifier also performs poorly in winter or if this is only related to the filter performance.

In summary the data reviewed suggests that there is a reoccurring issue with filtered (treated) water turbidity occurring each winter. This could either be attributed to the poor filter condition identified or the upstream pre-treatment systems. Pre-treatment optimisation (jar testing to confirm coagulant dose rate and optimise pH etc) should be investigated along with rectification works for the filter to improve filter performance.

4.2 Summary of Filter Inspection

In summary, the filter appeared to be in relatively poor condition with a significant amount of filter media missing and structural issues concerning the plenum floor. Filter media found in the underdrain suggested either broken nozzles or a disturbance of support gravel layers which has allowed sand and coal to migrate to and through the filter nozzles. Visual inspection confirmed evidence of plenum floor to filter wall joint failure and cracking suggesting potentially bypassing of filter media.

The original filter media design depth and media configuration itself was considered reasonable but not ideal. Overall, the filtration rate is considered acceptable due to the original design being based on typical filtration rates (<10 m/h) at the maximum design flowrate. Typically, the industry standard L/d ratio requirement is >1250 however the typical design filtration rate is also 8-10 m/h whereas the Baradine WTP filter design L/d ratio was 1077. The Baradine filters are treating ground water (low turbidity) and are only operating typically around 6.6 m/h, therefore the original design L/d ratio is considered reasonable although not ideal. Hence filtration performance may suffer at maximum instantaneous rates which occurs each summer.

The filter backwashing appears to be effective in removing sludge from the filters and the remaining filter media was in good condition. Sludge (SVI) testing found very little to no sludge in the media and this was supported by visual observation of the media and turbidity profiling of the backwash. In considering the turbidity profiling of the backwash, the turbidity of the washwater was less than 10 NTU after almost ~4 – 7.5 minutes of high flow washing.

The filter sand had a visible manganese coating which was confirmed through onsite acid washing. Inspection of the filter media surface did not reveal any problems, however subsequent entry into the filter and inspection of the underdrains confirmed issues with the underdrains (plenum floor to filter wall join) and nozzles. There were multiple points along the filter wall which appeared to confirm plenum floor to filter wall joint failure. The Filter is made of GRP and is currently 19 years old (installed in 2001), while GRP tanks typically have a design life of 25 years. Therefore, the filter is approaching its expected end of design life and could be expected to start deteriorating as was observed.

A significant amount of filter media was missing and was observed to have been washed out of the filter due to the drain down level float switch which was higher than it should have been (which was immediately rectified whilst onsite). This had caused filter coal to be washed into the sludge lagoons. The missing filter media has therefore resulted in an inadequate L/d ratio of approximately ~688. This is likely impacting filtered water quality.

The filter level control was found to be somewhat problematic causing slight fluctuations in the filtered water flowrate. Hunter H2O recommended that Council install a new stilling tube similar to that used at Coonabarabran WTP to mitigate against water surface disturbances and then reassess the issue.

In general, as per the data, the filter inspection demonstrated that the filters are not performing well and appear to be at risk. This is supported by the review of filter operation against the WSAA Good Practice Guide where the filters were found to have 9 non-conformances out of 15 measures. The key issues have been summarised below:

- L/d ratio less than ideal (especially given the reduction in filter media depth)
- Filter media loss
- Plenum floor to filter wall joint failure and cracking
- Filter media intermixing and migration to underdrain
- Filter flow control.

4.3 Recommendations and Opportunities

The following key recommendations and opportunities have been identified for Baradine WTP;

1. Filter Upgrades:
    i. Refurbish the existing GRP filter (19 yrs old) by removing filter media, replacing filter nozzles with finer slot nozzles, cleaning, patching and rectifying the plenum floor to filter wall joint failures and installing new filter media ($100 – 150k); or
    ii. Replace the existing filter with a new stainless steel filter to improve design issues and rectify all other refurbishment issues (~$200 - 300k).
2. Install a new stilling tube similar to that used at Coonabarabran WTP to mitigate against water surface disturbances.
3. nstall an online filtered water turbidity analyser on the outlet of the filter and enable trending of and storage of the data collected
4. Following on from individual turbidity analysers being commissioned, analyse the logged data and review filter ripening performance.
5. Undertaken a pre-treatment optimisation investigation to optimise coagulant dose rates and coagulation pH for manganese removal.
6. Investigate sampling methodology, sample collection timing and commence turbidity, pH, iron and manganese testing on raw, settled and filtered water.
7. Undertake a plant wide monitoring, instrumentation and automation audit and scoping study. (currently underway)
8. Data loggers/SCADA to enable online water quality monitoring trending of data;
9. Perform ongoing annual filter inspections;
10. Reduce the filtered water turbidity automatic backwash trigger to 0.3 NTU once the filtered water turbidity can be improved and lowered consistently.
11. Consider reducing the BDN1 CCP Alert level to >0.3 NTU.
12. Consider reducing the BDN1 CCP Critical level to >0.5 NTU once the filtered water quality is lowered more consistently following upgrades to the filter.
13. Varying backwash duration to minimise ripening and rate in response to seasonal (water temperature) changes.

5 References

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Appendix A: WSAA Good Practice Guide Checklist

Table A-5-1: WSAA Good Practice guide checklist for Filtration

Good Practice Guide Checklist - Filtration							
No.	**Measure**	**Category (best fit)**	**Rationale**	**Frequency of Assessment**	**Required Result**	**Actual Result**	**Comment**
45	The design filtration rate is known and the plant operates within the design specifications.	Process & Operations	Exceeding the design specifications is likely to result in poorer performance of the process element and consequently poorer pathogen removal.	One off Review annually. Could be calculated continuously and alarmed in the SCADA system.	Complies	Compliant	Although the design filtration rate is 9.7 m/h when operated at design plant flow of 19 L/s, typically the WTP is operated at 13 L/s which results in a filtration rate of 6.6 m/h. Even so both filtration rates are below the industry standard of 10 m/h.
46	Approved (USEPA 180.1 or ISO 7027) turbidimeters are provided for each filter (Mosse et al. 2009; AwwaRF 2002; AWWA 2001) and operated according to specifications.	Process Control	Allows assessment of individual filter performance and detection of poorly performing filters.	One off Should be reassessed after any major refurbishment or capital works.	Present	Does not comply	There is currently no online monitoring at the WTP
47	Once triggered for backwash, the filter is shut down automatically and placed in a backwash queue.	Process	Any filter showing turbidity breakthrough must not be allowed to continue filtering. Log removal of pathogens at this stage is very low.	Annually Also after any major refurbishment, capital works or PLC modifications.	Complies	Does not comply	There is no automatic backwash trigger.
48	Combined air scour low rate wash if present is < 15 m/hr.	Process	The combination of high rate water wash and air scour can result in damage to the filter under drain systems and displacement of the support gravels.	Annually Flow rate assessment needs to be repeated if modifications are made to backwash system or controls.	Complies	Compliant	Air scour rate is ~60 m/h. (O&M Manual)
49	During drain down, prior to backwashing, controls are in place to ensure the filtration rate does not increase.	Process	Any increase in flow through a filter particularly at the end of a filter run results in particle and pathogen shedding.	Annual Review Also after any major refurbishment, capital works or PLC modifications.	Complies	Does not comply	There is no control over the filter drain down rate.
50	A full filter inspection (including, where relevant, the plenum space) is carried out at least once per year (Kawamura 2000) or after significant dirty water events.	Process & Operations	Filter media and underdrains can deteriorate significantly and compromise filter performance. Details of a full filter inspection can be found in Mosse and Murray (2009).	Annually Also to be done after a significant dirty water event.	Complies	Compliant	This report fulfils this item for this year.
51	Media depths in all filters are within specifications.	Process & Operations	Loss of media in any filter increases the risk of turbidity and pathogen breakthrough.	Quarterly For each filter Distance to top of media x 100 Specified distance to top of media Alternatively, the media depth can be assessed based on lines painted on the walls of the filter indicating the specified bed depth.	< 115% >90%	Does not comply	Based on the onsite measurement the media is approximately ~500mm lower than specified. Excessive media loss has occurred and was found to be in the offline lagoon.
52	Filter operations must be optimised to remove pathogens, as measured by post-filter turbidity. Examples of post-filter turbidity performance which would deliver known log removal credits for the removal of Cryptosporidium (WSAA 2014) are given below: Individual filter turbidity ≤0.15 NTU for 95% of the month and not >0.3 NTU for ≥15 consecutive minutes. (4.0 log removal for conventional treatment 3.5 log removal for direct filtration) Individual filter turbidity ≤ 0.2 NTU for 95% of the month and not > 0.5 NTU for ≥15 consecutive minutes. (3.5 log removal for conventional treatment 3.0 log removal for direct filtration)	Process & Operations	Maximum removal of pathogens requires the lowest possible filtered water turbidity. The available evidence is that pathogen removal is decreased if the filtered water is greater than 0.2 NTU. Water from individual filters should consistently produce water that has a turbidity of <0.2 NTU. The ADWG contains target values for post filter turbidity. The actual target values for post filter turbidity that will be applicable for an individual WTP will depend on the source water assessment (WSAA 2014).	Monthly No. observations < target NTU x 100 Total number of observations No. observations < critical NTU x 100 Total number of observations	≥95% < target NTU value 100% < critical NTU value	Does not comply	There is no logged continuous online filtered water quality monitoring. Filter grab sample data indicates a 95%ile value of 0.48 NTU. Filtered water is above 0.2 NTU for a portion of the time (only ~22% of samples are greater than 0.2 NTU).
53	Backwashes are triggered automatically by turbidity, head loss and run time (Kawamura 2000).	Process	All three triggers should be enabled to provide adequate protection against the passage of pathogens. Triggers are sometimes turned off for “convenience”.	Monthly Check backwash triggers.	Complies	Does not comply	There is no automatic backwash trigger.

Good Practice Guide Checklist - Filtration							
No.	**Measure**	**Category (best fit)**	**Rationale**	**Frequency of Assessment**	**Required Result**	**Actual Result**	**Comment**
54	Clean bed head loss (CBHL) is monitored during operation and trended.	Process Control	Any sustained increase in CBHL indicates fouling of the media and likely poor log removal efficiency.	Monthly For a given filter flow rate, the clean bed head loss (after backwash) should remain within a target of 5% of original CBHL.	100 % within 5% of original CBHL	Does not comply	The headloss meters were no set up properly and there is no recording or trending of CBHL.
55	Backwashing of dual media filters should achieve >15% expansion of the filter coal, and fluidisation of the full filter media depth (AwwaRF 2002; AWWA 2001).	Process	Poorly backwashed filters result in reduced plant capacity and pathogen removal. Methods for measurement of fluidisation and expansion can be found in Mosse and Murray (2009).	Monthly For each filter Media fluidisation depth >95% Coal expansion >15%	Complies	Compliant	Based on site observations >15% bed expansion is more than likely to occur. This is supported by backwash rate of ~44.8 m/h which typically achieved greater than 15% bed expansion in theory.
57	During backwashing, any increase in flow to those filters remaining on-line during the backwash is <20%.	Process	Removal of a filter for backwashing without a reduction in plant flow results in sudden increases in flow rate through the remaining filters, resulting in shearing of floc and possibly the passage of pathogens through the filter.	Monthly No. backwashes where flow increase <20% x100 Total backwashes	100% backwashes	Compliant	There is only one filter so the WTP shuts down when the filter is backwashed.
58	In plants without filter to waste, the ripening period after backwashing does not exceed the critical limit for any longer than: 0.5 NTU 30 min (3 log credit) 0.5 NTU 15 min (3.5 log credit) 0.3 NTU 15 min (4 log credit)	Process	Any increase in turbidity represents increased risk to consumers. The ripening period is generally associated with a lower log removal of pathogens. The ripening period is defined as the time from the start of the filter run after backwashing until the target turbidity is consistently achieved.	Monthly Turbidity alarms should be set on filtrate turbidity according to guideline numbers. Number of ripening periods < target x100 Total number of ripening periods	> 95%	Does not comply	There is no online monitoring at the WTP.
59	Continuous recording and display of turbidity, filter flow, head loss and filter level or filter outlet valve position, is provided on the plant SCADA.	Process Control	Essential for filter optimisation and problem diagnosis.	Daily review of trends. Annual review of SCADA set up.	Present	Does not comply	There is no online monitoring at the WTP.
60	Air scouring is required where polymer is employed in the treatment process.	Process	Polymer residual can carry over to filters and bind filter media. Air scouring is necessary to break the bonds between the floc polymer and the media. Air scouring may also be required in some plants not using polymer, eg Iron (Fe) and Manganese (Mn) removal plants.	One Off At time of commissioning of filters.	Present	Compliant	There is air scour ability.

Appendix B: Filter Media Analysis Results

RIVER SANDS PTY LTD

Test Certificate

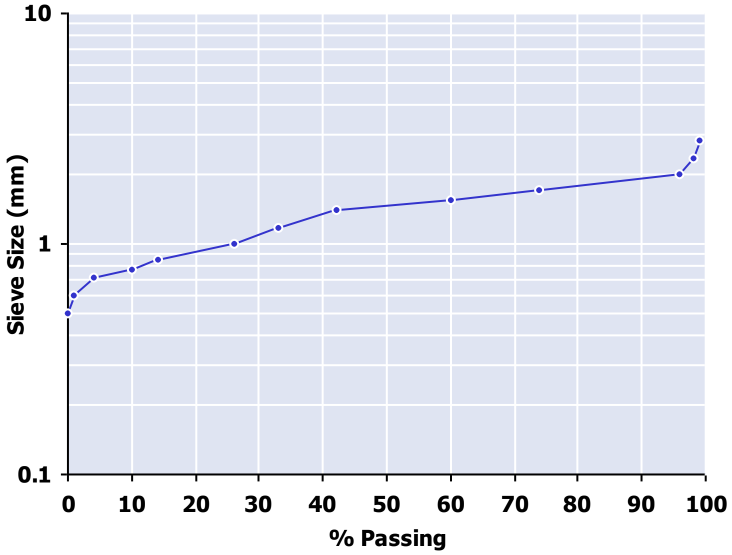
NATA ACCREDITED FOR TECHNICAL COMPETENCE Registration #10470

S1 150mm

16 December 2019
Report No. 6390
Page 1 of 1
Tested by S.Arnold
Received 06-Dec-19
Analysed 12-Dec-19
Sieve Std AS 1141.11.1
Sampling Std AS RECEIVED

Client
Hunter H2O
19 Spit Island Close
Mayfield West, NSW, 2304

Job No LWR 11593
Product Supplied Media
Sample No Sample



Aperture (mm)	US Std E11 Mesh	Percent Retained	Percent Passing	Indicative grading
2.800	7	0	100	
2.360	8	1	99	
2.000	10	2	96	
1.700	12	22	74	
1.400	14	32	42	
1.180	16	9	34	
1.000	18	7	26	
0.850	20	11	15	
0.710	25	10	5	
0.600	30	3	1	
0.500	35	1	0	
PAN		0	0	

D10/ES (mm)	0.78	Above mm (%)	N/A
D60 (mm)	1.56	Below mm (%)	N/A
UC	2.00		

Approved Signatory

(D.Wirth)

RIVER SANDS PTY LTD

Test Certificate

NATA ACCREDITED FOR TECHNICAL COMPETENCE Registration #10470

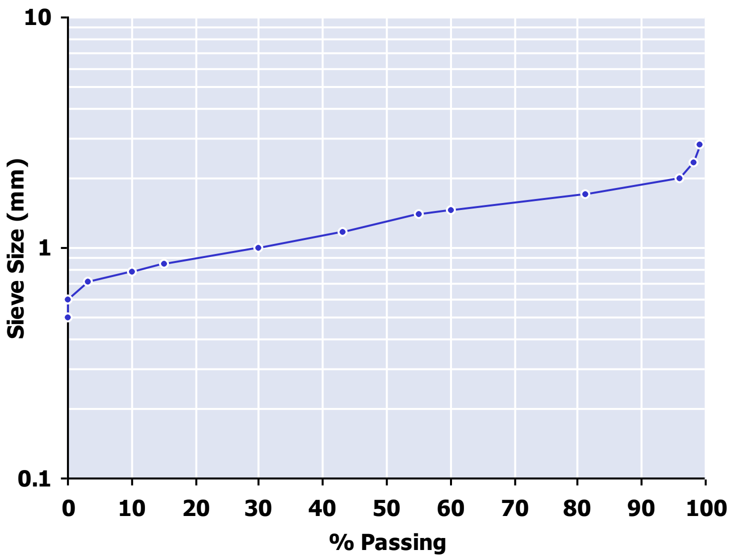
S2 350mm

16 December 2019
Report No. 6391
Page 1 of 1

Client
Hunter H2O
19 Spit Island Close
Mayfield West, NSW, 2304

Job No LWR 11593
Product Supplied Media
Sample No Sample

Tested by S.Arnold
Received 06-Dec-19
Analysed 12-Dec-19
Sieve Std AS 1141.11.1
Sampling Std AS RECEIVED



Aperture (mm)	US Std E11 Mesh	Percent Retained	Percent Passing	Indicative grading
2.800	7	1	99	
2.360	8	1	99	
2.000	10	2	96	
1.700	12	14	82	
1.400	14	27	55	
1.180	16	12	43	
1.000	18	12	31	
0.850	20	16	15	
0.710	25	12	3	
0.600	30	3	1	
0.500	35	0	0	
PAN		0	0	

D10/ES (mm)	0.79	Above mm (%)	N/A
D60 (mm)	1.45	Below mm (%)	N/A
UC	1.85		

Approved Signatory

(D.Wirth)

RIVER SANDS PTY LTD Test Certificate

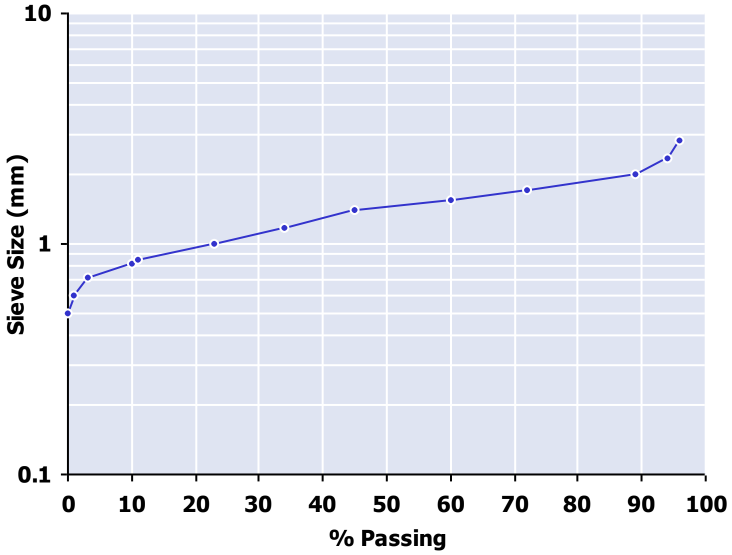
NATA ACCREDITED FOR TECHNICAL COMPETENCE Registration #10470

S3 525mm

16 December 2019
Report No. 6392
Page 1 of 1
Tested by S.Arnold
Received 06-Dec-19
Analysed 12-Dec-19
Sieve Std AS 1141.11.1
Sampling Std AS RECEIVED

Client
Hunter H2O
19 Spit Island Close
Mayfield West, NSW, 2304

Job No LWR 11593
Product Supplied Media
Sample No Sample



Aperture (mm)	US Std E11 Mesh	Percent Retained	Percent Passing	Indicative grading
2.800	7	3	97	
2.360	8	3	94	
2.000	10	5	89	
1.700	12	17	73	
1.400	14	27	46	
1.180	16	12	34	
1.000	18	11	23	
0.850	20	12	11	
0.710	25	8	3	
0.600	30	2	1	
0.500	35	1	0	
PAN		0	0	

D10/ES (mm)	0.83	Above mm (%)	N/A
D60 (mm)	1.55	Below mm (%)	N/A
UC	1.88		

Approved Signatory

(D.Wirth)