To:	Cornelia Wiebels Manager Warrumbungle Water Warrumbungle Shire Council	From:	Michael Carter Senior Process Engineer Hunter H2O
CC:	Kevin Tighe	Date:	11/01/2019

Subject: Baradine WTP – Review of Clarification Options

1 Background

Baradine Water Treatment Plant (WTP) is a conventional treatment plant consisting of aeration, coagulation, flocculation, clarification, gravity filtration, chlorine disinfection and fluoride dosing. The plant principally sources water from an onsite bore and has a maximum design capacity of ~1.0 ML/d.

A condition assessment of the existing clarifier structure was undertaken in 2014, using an ultrasonic thickness gauge, which found severe pitting corrosion throughout the structure. The extent of pitting corrosion to the existing clarifier requires that either refurbishment or replacement of the clarifier is necessary.

Previous investigations indicated that delaying the refurbishment or replacement of the existing clarifier for 12 – 18 months runs a very real risk of asset failure along with safety concerns with the structure itself. Rehabilitation is no longer considered viable as the extent of the pitting corrosion may prove to be practically too difficult, and therefore replacement is required.

Following the Section 60 approval guidance, Warrumbungle Shire Council engaged Hunter H2O to undertake an options study to assess the refurbishment options against two replacement options (lagoon sedimentation and inclined plate sedimentation). Once the options study was completed, a concept design was undertaken on the preferred option. During the completion of the concept design and specification and prior to Council going to tender, DoI Water advised that endorsement would not be provided.

In the spirit of collaboration and to progress the project, Warrumbungle Shire Council has requested that Hunter H2O provide technical assistance to compare the two clarification options further by identifying key issues, advantages and disadvantages between each option at a high level, to ensure that Council is undertaking the required due diligence to ensure the most appropriate solution is found for the community at Baradine. This information is then to be provided to DoI Water for endorsement of a preferred option.

2 Water Quality Risks

2.1 Drinking Water Quality Risk Assessment

In 2014 Warrumbungle Shire Council in conjunction with NSW Health undertook a drinking water quality risk assessment (AECOM, 2014) through a series of workshops to identify water quality risks in each WTP catchment. The workshops were well supported by various stakeholders including 13 of council staff, 2 NSW Health representatives, a NSW Office of Water representative (now DoI Water) and three attendees from the engaged specialist consultant AECOM. In the case of Baradine, the following raw water quality hazards were identified during the workshops along with the hazardous events:

- Cryptosporidium - Pathogens from agricultural inputs due to surface water ingress.
- Iron and Manganese - Groundwater can contain naturally occurring iron and manganese
- Pathogens – Incorrect dosing of coagulant, wildlife cross contamination or clarification failure.

It should also be noted that the workshops also identified risks for Coonabarabran, Binnaway and Mendooran in regards to their existing sedimentation lagoon processes. The identified water quality risks were turbidity and colour with flooding, short-circuiting and wildlife access leading to remobilisation of sediments.

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2.2 Iron and Manganese

The raw bore water at Baradine WTP has very high concentrations of iron with typical concentrations of 6 – 8 mg/L and maximum values recorded at 10 mg/L. Manganese concentrations are also relatively high with concentrations typically around 0.2 – 0.3 mg/L. Due to these high concentrations, for Baradine WTP in particular, it is therefore likely that there is a real risk that iron or manganese could be released from sludges stored in the future sedimentation lagoons. Currently this would not present itself as an issue, at Baradine WTP, as an above ground clarifier is used.

Extensive investigations into the release of manganese from sludges into the surrounding water bodies is available in the literature, with the following reports stating:

1. Occurrence of Manganese in Drinking Water and Manganese Control, (AWWA Research Foundation, 2006):
    a. *"Mn removed in sedimentation and filtration processes is ultimately directed to plant residuals. Mn and iron associated with sludge will be released from sludge blankets if anaerobic conditions develop, which often happens in manually cleaned sedimentation basins, and the resulting total Mn concentrations applied to the filters can exceed that of the raw water"*
2. *Recycle Stream Effects on Water Treatment,* (AWWA Research Foundation, 1993)*:*
    a. *"Manganese was evaluated at a number of facilities, which all showed similar results – the sludges contained high concentrations of manganese."*
    b. *"Studies conducted on manually cleaned sedimentation basins showed that as the sludge accumulated in the basins, the manganese levels in the clarified water gradually increased."*
    c. *"The potential of manganese release was evaluated at a number of facilities, and several types of waste streams were evaluated. Evaluations were also conducted at two plants to determine if manganese was released from sludge stored in manually cleaned sedimentation basins. Some of the possible effects of sludge storage in sedimentation basins have previously been reported by Hoehn et al. (1987). They reported significant releases of manganese, iron and total organic carbon from sludges held in manually cleaned sedimentation basins."*
    d. *"Data showed that the dissolved manganese concentrations leaving the sedimentation basin containing accumulated sludge was continually rising and was consistently higher than the manganese concentrations leaving the continuously cleaned basin. In fact, the dissolved manganese level in the settled water leaving the manually cleaned basin was higher than the level in the water entering the basin, indicating a release from the stored sludge in the basins effluent. Dissolved oxygen profiles for the manually cleaned basin ….. showing that anaerobic conditions existed within the sludge blanket."*
    e. The data presented in the report indicated that anaerobic conditions were found within the manually cleaned sedimentation basins examined with less than 1m of sludge. In addition, the laboratory testing confirmed that collected sludge samples released manganese continually with significant increases in manganese detected in the clarified water after 4-5 weeks while concentrations continually increased over time. In regard to the Baradine situation, the proposed lagoons are currently sized to accommodate around 1 m of sludge and rotate every ~12 months.

As a result, it is widely known and accepted within the water industry that soluble manganese can be released from anoxic or anaerobic conditions commonly found in sludges, such as within manually cleaned sedimentation basins or lagoons. For these same reasons, when manganese is a raw water quality risk, it is common for a WTP sludge handling system to either avoid returning supernatant to the head of the plant or to have a dedicated treatment system to ensure that the manganese returned to the raw water does not impact the treatment system. Further these concentrations can present a higher challenge as compared to the raw water, as the manganese continually increases within the closed loop system (until the sludge is removed manually).

3 Clarification Options Review

Two clarifier replacement options were assessed during the Baradine WTP Clarification Options Report (Hunter Water Australia, 2015). These options include Sedimentation Lagoons and Inclined Plate Sedimentation Tanks

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which are described and compared in the following sections. The Sedimentation Lagoon option described below is however based on the 1991 Public Works design and not that described in the Baradine WTP Clarification Options Report (Hunter Water Australia, 2015).

3.1 Sedimentation Lagoons

Sedimentation lagoons have been used throughout NSW regional towns for decades, initially introduced as an innovative low capital cost clarification option for small regional communities. The success of the sedimentation lagoon then saw an increase of their construction across NSW, due to them being a low-cost treatment process during a period of time when there was a greater focus of maintaining water supply rather than achieving stringent water quality targets. As the Australian Drinking Water Guidelines become increasingly more stringent the occurrence of sedimentation lagoons has become less popular, with more water utilities opting for more innovative and robust processes which provide better performance and reliability.

Effective flocculation is required to produce a settleable flocc and is critical to a sedimentation lagoons performance. Following flocculation, the flocculated water enters the sedimentation zone which allows for particles to settle under gravity and the settled water is then pumped to the filters. Traditional sedimentation processes are required to be large to provide the large surface area required for settling. Sludge is stored within the lagoons for longer periods, typically for 6-18 months depending on sludge accumulation rates.

The original 1991 Public Works sedimentation lagoon design for Baradine was intended to operate with a common dedicated hydraulic flocculation tank which diverts the flocculated water to each online lagoon. Settled water would be collected and pumped to the filter. Generally, flocc would build up within the sedimentation lagoons until carry over becomes problematic and operations staff are alerted to the need to organise the lagoons to be changed over.

Examples of sedimentation lagoons can be seen in Figure 3-1. These examples show that floating sludge and flocc is a common issue encountered with sedimentation lagoons as is weed growth. Floating flocc can cause excessive headloss accumulation when transfer to the filters while also increasing the risk of mudball formation.

Figure 3-1: Examples of sedimentation lagoons (from left to right – Top – Binnaway, Coonabarabran and Mendooran WTP's in 2014, Bottom – Binnaway 2018, Mendooran 2017 and Coonamble 2018).

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3.2 Inclined Plate Sedimentation Tanks

Inclined plate sedimentation processes have been in existence since the 1970's. Ongoing technological advancements have resulted in the technology becoming cost effective in recent years. The popularity of inclined plates has been increasing with the introduction of the technology into Australia in the early 2000's.

More recently the technology has advanced, and plate settlers are proving to be a cost effective and competitive settling solution. This realisation within the industry, along with the simplicity, robustness and efficiency associated with plate settlers, has further increased their popularity.

The efficiency of particle removal in horizontal water flow depends on the surface area available for settling. Therefore, the efficiency can be improved by increasing the surface area. Inclined plates are commonly used for this purpose. Inclined plate settling units can be inserted into a traditional sedimentation tank to increase the settling capacity of the flocculated water and hence increase the hydraulic rate through the process unit, commonly conveyed as the surface loading rate (m/h), which is the volumetric flow rate (m^3/h) divided by the tank surface area (m^2). Therefore, the inclined plate settling sedimentation tanks can be reduced in size relative to traditional sedimentation tanks due to their higher hydraulic capacity which is achieved through an increase in effective surface area. Sludge can be collected by either gravity sludge hoppers, vacuum sludge collection systems or typical scraper and sludge pit type arrangements.

Plate settlers effectively operate at a number of sites with loading rates of 7 - 8 m/h compared to the current clarifier design of ~1.9 m/h. Tube settlers typically operate in the order of 3 - 5 m/h, however have replacement cost issues. Plate settlers therefore can result in real savings in real estate and construction costs. Further as there are no moving parts, maintenance regarding plate settlers are virtually non-existent.

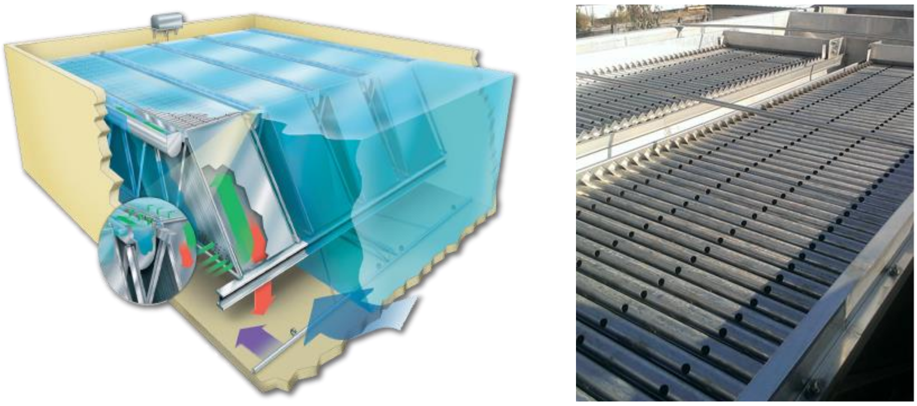

Figure 3-2: Inclined Plate Settler (Meurer Research, 2018).

3.3 Comparison of Risks and Issues

A comparison of risks and issues for both options are presented in Table 1.

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Table 1: Clarification Options Comparison

Issue/Risk	Sedimentation Lagoon	Inclined Plate Sedimentation
Contamination	• The potential for contamination of the sedimentation lagoon water via surface runoff (nearby diesel tanks, chemical storage area and chemical sprayer washdown area), pathogens from the nearby paddock (horses within <7m from western lagoon), vermin ingress (due to the natural attraction to wildlife) is greatly increased • Dirty filter washwater is returned untreated and in one go while the plant is offline to a location after the point of coagulant addition. Therefore, any contaminates introduced into the system are returned to the process and continually build up until sludge is removed annually and the sudden rapid flowrate used for filter backwashing would disturb the sludge in the lagoon. This would not be an issue for the Inclined Plate Sedimentation option. This practice does not follow the WSAA Good Practice Guidelines or the USEPA's Filter Backwash Recycling Rule which both recommend that the dirty filter washwater should be returned at a rate less than 10% of the raw water flow entering the plant. • Inundation: - The whole Baradine WTP site can be subject to flash flooding as described in the Baradine Flood Study (Lyall & Associates Consulting Water Engineers, May 2012). - The sedimentation lagoons are located within the 1 in 100-year flood area which is inundation to above-floor level. The site is also near the 1 in 20-year flood level related to inundation to floor level. - Contamination due to flooding/inundation has a high chance of introducing pathogens, pesticides, hydrocarbons and other water related risks due to the nearby workshop site and surrounding farm land. • Baradine WTP has high concentrations of iron and manganese in the bore water, therefore iron and manganese build up in the sludge is likely to eventually increase the manganese in the treated water (refer Section 2.2). • The existing sludge lagoons are known to leak however the extent of the leakage has not been investigated. The lining has therefore been compromised and requires replacement to prevent seepage and sub surface flow ingress too (if any). Subsequent yearly desludging of the lagoons presents a risk of damaging the lining and thus the integrity resulting in similar seepage and sub surface flow ingress (if any) that the lagoons currently experience.	• Contamination risks are minimised as the inclined plate sedimentation lagoon is raised above the ground and is a smaller tank which provides less opportunity (surface area) for wildlife contamination.
Design	• The existing sludge lagoons (to be used as Sedimentation lagoons) are shallow and, are the 1999 design has a short overflow weir. High weir loading rates and convection currents in the lagoons are likely to reduce overall sedimentation performance. Even with optimisation of the sedimentation lagoon operation, performance is likely to be less than that compared to a purpose-built above ground clarifier. • A common hydraulic flocculation tank limits the ability to adjust plant flowrates to meet demand as lowering flowrates impacts on the flocculation mixing energies which can compromise the performance of the sedimentation lagoons. This was experienced at Nundle WTP which resulted in an typical filtered water turbidities of around 0.5 - 1 NTU for many years. • Settled water pumps will shear remaining flocc carryover which can then impact on the filter performance as the smaller flocc is more difficult for the filter to remove. This phenomenon has been experienced during a pilot plant investigation undertaken at Wagga Wagga WTP where filter ripening issues were found to be linked to flocc shearing through the settled water pumps. • Sludge accumulation within the base of the sedimentation lagoons may still create problems such as solids "rafting" to the surface. • The WTP can be more difficult to optimise given the significant detention time provided by the sedimentation lagoons such that changes to the coagulation chemistry may take some time to have a measurable effect	• The package inclined plate sedimentation tank has a dedicated flocculation tank with mechanical mixers to enable optimisation of mixing and also enable a range of water flowrates to be treated while not compromising the flocculation mixing energies (unlike hydraulic flocculation) • The package inclined plate sedimentation tank has automatic desludge capabilities to prevent sludge build-up and eliminate risks of iron and manganese releases associated with aged sludges with low DO concentrations.
Performance	• Sedimentation lagoons can often turn over, and flocc clumps can rise as seen in Figure 3-1. Flocc carry over to the filters can be problematic especially if clumps of flocculated material enter the media filter, which can increase the risk of mudball formation. • Due to the large volumes, surface area and retention time within the sedimentation lagoons which is required for flocc settling, perfect conditions for algae growth exist if sufficient nutrients are available. Plant growth would use some of the nutrients, however Wellington WTP was dosing chlorine into the inlet of their sedimentation lagoons for years in order to prevent algae growth. More recently at Mendooran WTP, an algae bloom occurred within the lagoon which impacted filtered water turbidity as the bloom occurred after the point of coagulation. The risk for Baradine WTP is lower however as	• 98-99% solids removal efficiency indicated by suppliers under maximum conditions, therefore should be suitable for solids loads up to 250 NTU to maintain settled water quality of maximum 2 NTU. While up to 25 NTU should achieve less than 2 NTU. • Very little chance of sludge turnover due to frequent automatic sludge removal sequences.

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Issue/Risk	Sedimentation Lagoon	Inclined Plate Sedimentation
	the only expected route of nutrient ingress would be due to surface water flows during intense rainfall or floods or contamination through vermin ingress. This risk is mostly eliminated if an above ground clarification unit was used however.	
Desludging	• The desludging operation can be a labour intensive and costly exercise with some regional councils reporting costs in the range of $3k - $10k at various frequencies of between 6 – 18 months. Hence it is often avoided until clarified water is compromised, and issues occur at the water treatment plant. For Baradine WTP it is estimated that the lagoons may potentially require desludging every ~6 - 12 months due to the high concentrations of iron in the bore water. • While a lagoon is offline and drying, the period required to dry the sludge can be extended due to wet periods. Therefore, the risk of solids carry over in the online lagoon is increased as the lagoon cannot be taken offline or desludged whilst still in operation.	• Desludging is an automated process which occurs multiple times on a daily basis to prevent any risk of iron or manganese releases from the stored sludge.
Operability	• Good - chemical dose rates require modification to adapt to changing conditions. • Simple process to control, few variables other than chemical dosing. • Sedimentation lagoon change over, desludging and relining required every 6 - 18 months.	• Good - chemical dose rates and wasting require modification to adapt to changing conditions. • Regular hose down of plates.
Treatment risks and knowledge gaps.	• Process has been used for many years. Undocumented issues related to solids carry over and inadequate flocculation conditions common at some WTPs. E.g. Nundle WTP replaced sedimentation lagoons with a reactivator clarifier due to issues with flocculation and sedimentation performance impacting on filtered water turbidity.	• Proven process over a wide range of turbidity and applications around the world, including Australia.
Maintenance	• Operations staff often highlight that lagoons are easy to operate and maintenance is low. This is because in most instances operations staff leave the lagoon rotation to a 12 monthly activity or longer. Sometimes much longer than first anticipated by the designer. • Kumbucah weed and other plant growth is a common issue encountered with sedimentation lagoons as seen in Figure 3-1. Plant growth can be problematic and also introduce points of contamination. Plant removal is generally labour intensive and presents additional WHS risks as the weeds have to be removed manually. • Settled water pumps and instrumentation (E.g. level instruments etc).	• Flocculation mixers. • Inclined plate sedimentation instrumentation (E.g. level instruments etc) • Actuated valves used for automatic desludging
WHS Risks	• Sedimentation lagoons present similar issues to that of sludge lagoons with access and the risk of slips and falling into lagoons. • There are additional associated risks with operation of heavy machinery required to desludge lagoons.	• Package inclined plate sedimentation units are designed to comply with all of the latest Australian Standards in regard to WHS issues. Platforms and stairs are included to allow operations staff to access area's as required for sample collection etc.
Key disadvantages	• Iron and manganese releases from sludge and impacting treated water quality. • Potential for short circuiting • Introduces additional water quality risks • Filter washwater is returned after the point of coagulation at a rapid rate (potential to resuspend settled sludge) • WSC operations staff were concerned that the quantity of sludge generated at Baradine WTP would exceed the capacity of the lagoons at their current size and thus lagoon rotation could be required to occur on a more frequent basis than theoretical calculations indicate. Thus, requiring increased operational staffing time. • Potential for algae blooms to occur.	• Higher capital cost
Key potential advantages.	• Lower capital cost • Simple operation	• Simple and robust operation • No risk of potential iron, manganese or aluminium resolubilisation • Retains the sludge lagoons as per existing arrangement
High Level Capital Cost	• Generally, a cheaper option to construct as a general earthworks contractor would be engaged to undertake the work, however this presents issues in terms of reliability achieving performance guarantees in the longer term. • Estimated Capital Cost for Baradine WTP: ~$440k	• Estimated Capital Cost for Baradine WTP: ~$705k (304SS option) • An epoxy coated mild steel option may result in a cost reduction in the order of ~$50k.
High level whole of life cost	• Estimated Whole of Life Cost for Baradine WTP: -$695k (30yr NPV @4%)	• Estimated Whole of Life Cost for Baradine WTP: -$800k (30yr NPV @4%)

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Although both the Sedimentation Lagoon and Inclined Plate Sedimentation options have similar hazards regarding to water quality risks, such as introducing a contamination point or the potential for release of iron or manganese from sludges, the likelihood of the hazard occurring is vastly increased with the Sedimentation Lagoon option due to larger ground level surface areas and long-term retention of sludge within the process. While in some instances the above risks and issues are eliminated when adopting an Inclined Plate Sedimentation or alternative above ground clarification process.

Therefore, the risks associated with Sedimentation Lagoons are much greater than that compared to an Inclined Plate Sedimentation process or other above ground clarification option with regular automatic sludge discharges.

In providing this comparison, Hunter H_2O continues to endorse the basis and outcomes of the original multi-criteria assessment (MCA). Given the numerous water quality risks identified by multiple stakeholders and the reduced risk profile of the Inclined Plate Sedimentation option, the Inclined Plate Sedimentation presents an innovative fit for purpose option that is robust and simple to operate. In the spirit of collaboration, Hunter H_2O hopes that Council's decision to elect an inclined plate sedimentation process as the preferred option for the Baradine community is considered and accepted by DoI Water.

Kind Regards,

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4 References

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