Rainfall and its impacts on Water Treatment Amid Alkalinity Changes

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ABSTRACT

Although rainfall is a regular occurrence in Mackay between the months of November to April every year. Some bouts of rainfall tend to have a greater impact on the treatability of the water. This paper is an analysis of data collected over the eight days from the 11th to the 19th of January 2023, which averaged rainfall of 80 mm per day. It covers how Mackay operators of the Nebo Road Water treatment plant responded to these events and the challenges this water brings, including pH changes, high turbidity, high organics and loss of alkalinity.

Analysing this data, it is then a question of interpreting the effectiveness of Caustic soda and Sodium Bicarb and their necessity in the treatment process?

As this report determines how to deal with the changes of water and its effects on the treatment process, how does this analysis help the Mackay water treatment operators understand and respond to future water changes and impacts to water quality?

1.0 INTRODUCTION

Located in west Mackay, Nebo Road Water Treatment plant was officially opened March 1982. Having filter upgrades in the early 2000's. Nebo Road has the capability 58ML/day of river water and an additional 21ML/day of bore water. This gives the plant a total capacity of 79 ML/day.

Sourced from the local Pioneer River, River water is picked up right at the Dumbleton Weir which is then pumped 13 km to Nebo Road WTP. This can take anytime from 6 to 8 hours.

The plant operates in a conventional process where it runs through the dosing tank allowing contact time to dose powder activated carbon and pH correction. Coagulant in the form of Poly Aluminium Chlorohydrate (PACl) is added before the sedimentation clarifiers. Iron and Manganese can be oxidised by potassium permangenate which is then filtered out by the multimedia filters. Filtered water is chlorinated with gaseous chlorine before being distributed to one of the main reservoirs in Mackay.

In Mackay, rainfall is a regular occurrence during the months of November to April every year. Often referred to as the wet season. On occasion there are bouts of rainfall which tend to have a greater impact on the treatment process. How much water can be treated, how much chemical is used, how often the operator's control and regularly monitor processes and equipment supplying the data.

This paper will focus on an example of these conditions which happened over 9 days from the 10th to the 19th of January 2023 where rainfall averaged 80 mm per day with a peak rainfall of 140mm in one day. This paper delves into the immediate impacts, then the long-term impacts of this event.

2.0 NTU Increases and peak.

As rainfall continues, runoff from the land increases the flow and level of the river which greatly impacts the river water quality. Increases in Turbidity, colour, Iron, Manganese, organics and loss of Alkalinity tend to be the leading contributors to water treatment challenges. Fortunately thanks to the turbidity meter at the Dumbleton pump station. Nebo Road Operators have a pre warning of high turbid water up to 6 to 8 hours ahead, which allow them time to prepare for Jar testing and ensure that chemicals are batched and storage is sufficient.

To put these results into perspective **Figure 1** represents a trend for the 5 days leading up to the rain event from the 6th to the 10th of January. The raw water turbidity was very consistent around 2.5 NTU.

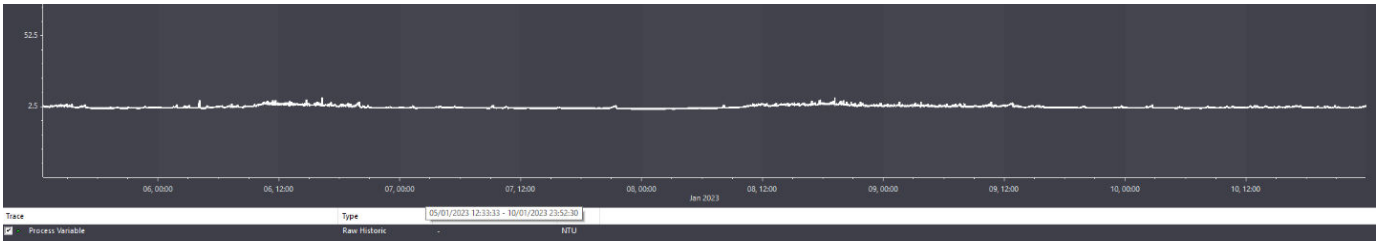


Figure 1. *Raw water NTU from the 6th to the 10th January 2023 – Note NTU consistency.*

Over the 8 days from the 10th to the 18th of January. The trends in **Figure 2.** show the significant fluctuations of turbidity each day**.** The first thing Nebo Road operators do in any wet weather event is reduce the water plant to its lowest flow of 300 L/S, this aids treatment processes by increasing contact and sedimentation time.

According to this trend, at its peak Nebo Road had a turbidity of 350 coming into the plant. However, laboratory results on several samples gathered from the 17th of January have confirmed raw water turbidity having peaked at 483 to 500 NTU

These same sampling results also showed that Nebo was able to treat this water at its peak and still achieve a treated water turbidity of 0.3 and 0.6.

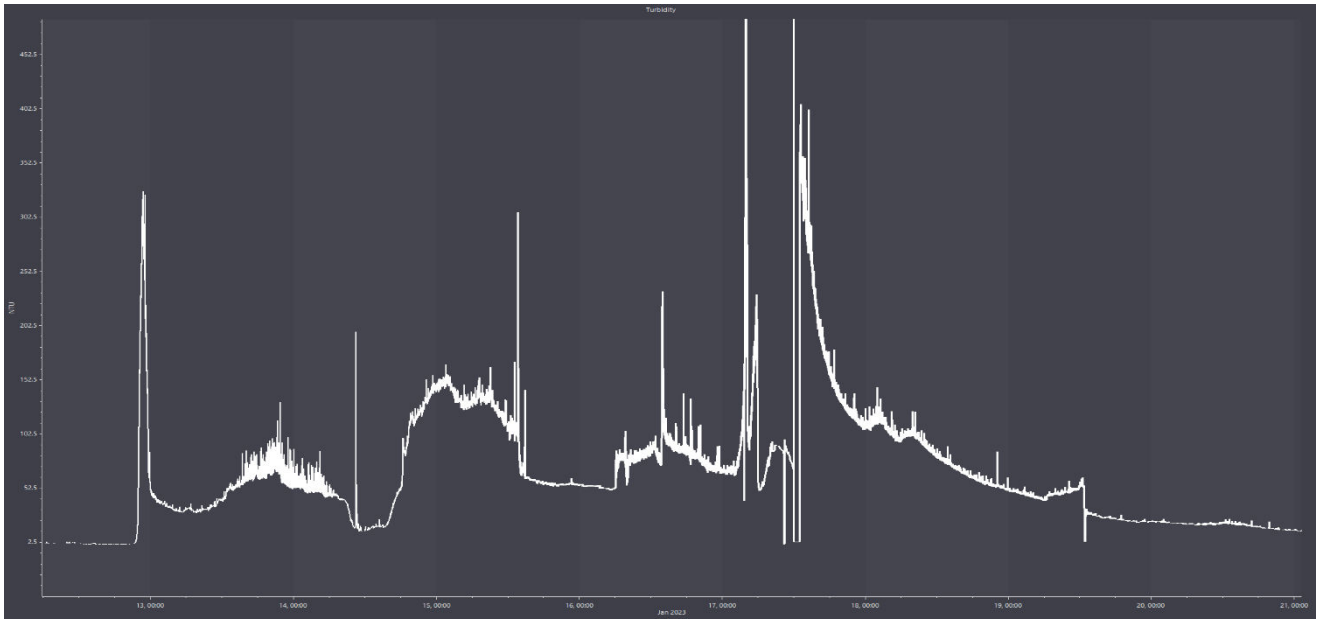
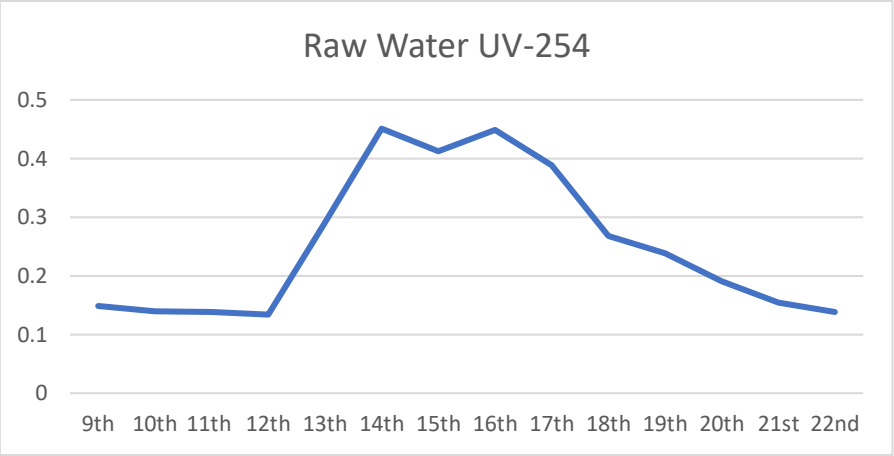


Figure 2. *Raw Water NTU 11th to the 18th January 2023 – Note various fluctuations of NTU*

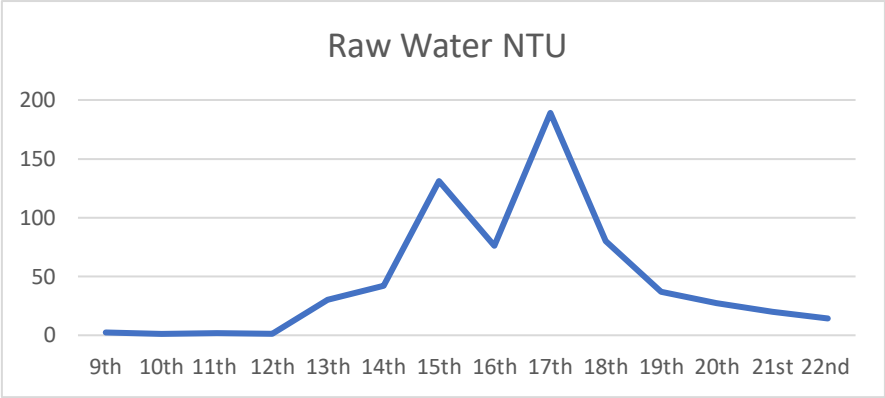
2.1 Affects on UV-254

At Nebo Road UV-254 is the water test conducted to measure organic matter in the water. UV 254 is a quick and convenient measure of dissolved organic compounds. Operators at have found measuring UV-254 quite helpful when it comes to setting water quality targets for dosed water before the filters. Also, in understanding or preparing for sudden increases in chlorine demand of treated water. UV-254 is often used to dictate dose rates after conducting jar tests. For example, the operator would compromise a slightly higher turbidity for a lower UV absorbance. This would lower the organic matter in the water which would in turn help with less cl2 consumption thereby reducing likelihood of cl2 by-products in the treated water.

Using data that is collected every morning **Graph 1** represents UV-254 results on Raw water over a 14 day period. As shown for the first 3 days, results staying reasonably consistent around 0.15 UVA then spiking up to 0.451 at its peak. During winter when wet weather isn't as prevalent Nebo Road WTP generally has UVA results sitting under 0.05. Comparing **Graph 1 & 2** turbidity does recover more quickly than UV-254. This can cause further problems later when there is still quite a bit of UVA but very little NTU therefore primary coagulant dose rates have to remain relatively high.



Graph 1. *Increases in organic matter as a result of successive heavy rainfall.*



Graph 2. *Raw Water NTU as a result of successive rainfall.*

The initial challenge for the water treatment operators was to find a way to treat this water. Mackay water consumption was averaging 30ML per day. With the bores at the time restricted to producing 15 ML per day. To produce the other 15 ML/Day and match declining water levels in reservoirs throughout town. The water treatment operators had to figure out how to manage the incoming raw water in order to successfully treat it.

2.2 pH and effects of Alkalinity

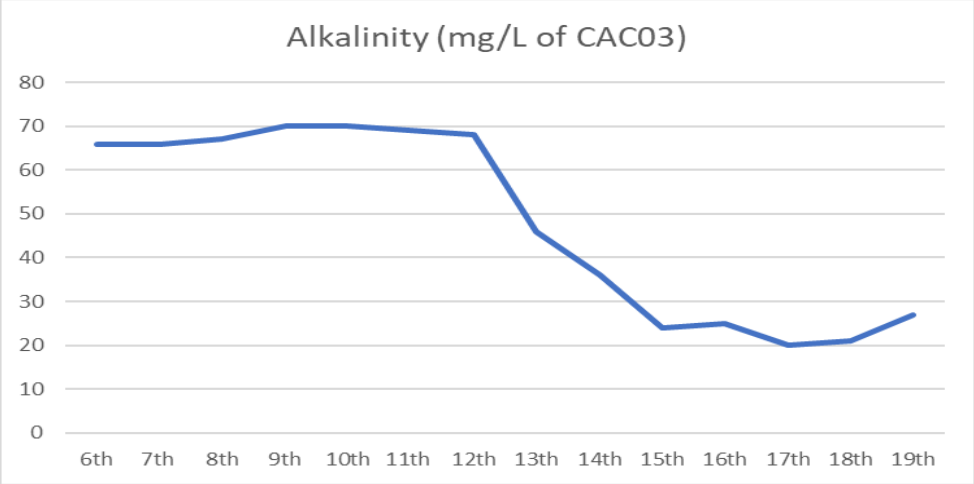
For all chemicals to be most efficient and effective the operators have found the pH range from 7 to 7.5 to be the "sweet spot." The Pioneer River water tends to naturally sit around 7.2. During these 9 days this water averaged a pH of 7.0. While this is still fine, the operators primary concern with how unstable this figure is and potential further loss of alkalinity.

With using pH correction, care needs to be taken to avoid raising the pH too high. If the raw river water were to be inadvertently dosed to a pH above 8 there would be a massive detrimental effect to the effectiveness of the primary coagulant likely deeming the water untreatable. If this happens, the operator will have no choice but to release dosed water into the runoff lagoon.

Alkalinity is expressed as the buffer to resist change in pH if an acid or alkali is added. Under normal conditions the raw water coming into the plant has a healthy level of 70 mg/L of Calcium Carbonate (CaCO3)

Nebo Road WTP operators have found over several rain events that an alkalinity less than 25 will deem the water untreatable. Once again requiring the operator to release dosed water in the runoff lagoon.
During this rain event as shown in **Graph 2** the raw water alkalinity dropped to 20 mg/L over two days.

Graph 2: *Alkalinity Drop over the rain event duration in January 2023*



2.3 Trying to hold onto Alkalinity

Whilst the pH of the raw water was sitting at an average of 7.0 over the course of this event Nebo Road WTP operators maintained a Dosed water average of 7.4. This was done by adding Alkalis chemicals, in particular Caustic Soda. Caustic soda is the water treatment plants primary pH correction chemical due to its effectiveness and ability to store a bulk quantity of it to last several months. Using a 50% caustic soda (sodium Hydroxide) solution, operators were dosing from 4 up to 10 mg/L throughout the 9 days.

What operators found though, was dosing caustic wasn't enough. Particularly on January 17th there was a period of time where Caustic was holding the pH but the alkalinity was not there and pH was still highly susceptible to change. The need for alkalinity is crucial as primary coagulants like ACH theoretically consume up to 0.29 mg/L of CaCO3.

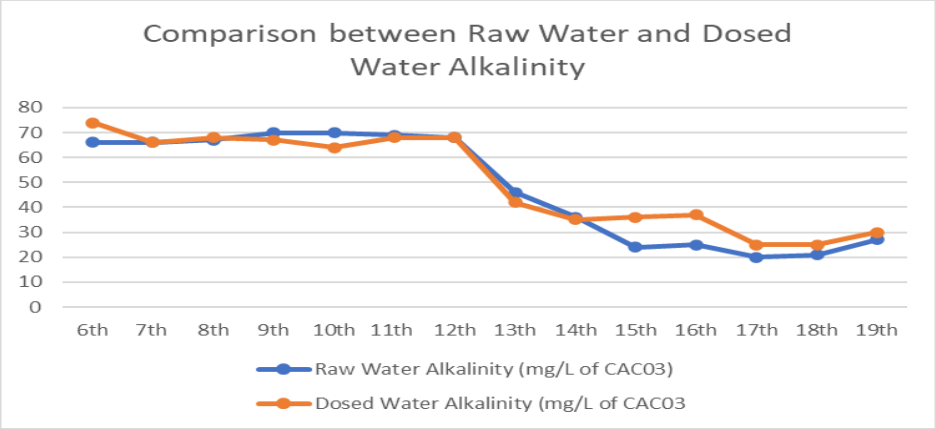
The conundrum is that the more alkalinity is increased, the more that pH rises as well. Using a

second alkali chemical which has less effect on pH but more on alkalinity would be the ideal counter to this problem. This is where the operators were finding success in using Sodium Bicarbonate to supplement Caustic Soda. Sodium bicarb is dosed as a 10% solution.

In the past twelve months several tests have been conducted by the operators to find how much sodium bicarb increases Alkalinity. Results of testing the plant at 300 L/s using a 50mg/L of sodium bicarb and Coagulant dose rate of 5 mg/L Alkalinity was increasing 16mg/L.
Doing the same test in a jar test Alkalinity was increasing 20mg/L CaCO3.

As shown in **graph 3** early morning on January 17 the alkalinity dropped below 25 mg/L the primary coagulant became ineffective, and the water was untreatable requiring the plant to be temporarily shut down. The operator on shift set the Caustic Soda dose rate to 7mg/L supplementing this with a sodium bicarbonate dose rate of 50mg/L, which successfully kept the alkalinity around 25 to 30 mg/L over the following 7 hours. All whilst keeping the pH below 8 ensuring no detrimental effects to the coagulation process.

Fortunately, in this event the raw river water alkalinity recovered quickly over the course of the day. Recovering enough that dosing caustic soda by itself was sufficient to maintain an alkalinity above 25 mg/l CACO3.



Graph 3. *Comparison of Raw River water and Dosed water alkalinity after being treated with Caustic soda. Bicarb was also dosed from the 17th January*

Figure 3 shows the NTU of dosed water over the 17th January. The operator on call shut the plant down at 4 am as dosed water turbidity had exceeded the critical control point of 4 NTU and was rising quickly, the plant was restarted around 4:30 am. untreatable water was sent off to the runoff lagoon for another two to three hours. At 6 am Nebo Road operators decided to start dosing sodium bicarb (the shaded sections) noticing a considerable improvement over the first hour and a half it was run.

At 10 am the operator noticed that the bicarb dosing had stopped. Over the following two hours it was found that the inline filter for the dose pumps had clogged up with sodium bicarb sediment stopping the flow. The operator cleaned the filter and got the dose pump running for another 2 hours. The trend shows the reaction that losing alkalinity for 2 hours likely had an influence for the dosed turbidity to spike. Dosing of bicarb continued until 2 pm, after which caustic soda managed to maintain an alkalinity of 25 overnight.

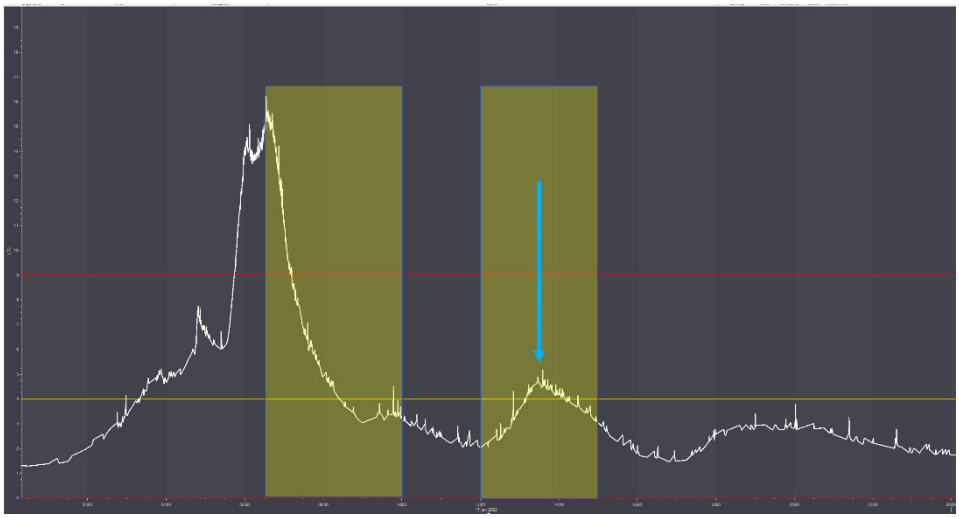


Figure 3. *Dosed water NTU over the 17th January. Note – Yellow shading indicate operation of sodium bicarb dosing at 50mg/L. Blue arrow indicating peak of turbidity after dosing was offline for 2 hours*

2.4 Identifying the shortfalls.

Over the past two years the Nebo Road WTP process engineers have been pushing to great effect, the installation of many needed upgrades. From new powder activated carbon dosing pumps to setting up potassium permanganate dosing pre filters. The most significant upgrade has been completely overhauling the multi-media filters with new air scour roses and fresh filter media.

All these things have given operators a fighting chance to handle impactful water conditions more economically, by significantly reducing the need to discharge water to the runoff lagoons. Reducing unnecessary waste of all dosing chemicals used in instances of untreatable water.

Having identified alkalinity loss as one of the most significant problems remaining for Nebo Road. There have been several upgrades under deliberation. Sodium bicarb dosing, although proven to be useful, if not managed carefully still has a high risk of overshooting the pH of 8. Another negative is the duration that bicarb can be run. Due to the limitation of the batching tank size, to continuously run a dose rate of 50 mg/L the sodium bicarb will only run up to 20 hours between batches. One potential upgrade is to update the sodium bicarb dosing system to a more modern setup which would include newer, more accurate dosing pumps which may increase the time between batching. Additionally regular maintenance checks of pumps and the batching tank to ensure sodium bicarb remains at the correct concentration.

The second and more likely upgrade is to install an additional inlet to the dosing tank so bore water can be blended into the raw water inlet tank. The bore water at Nebo Road water treatment plant maintains an alkalinity of 120 mg/L CACO3. This blending of bore and river water will increase alkalinity at the dosing tank, reducing the need for as much pH correction.

3.0 CONCLUSION

The residents of Mackay can be reassured that even when there are one or two of these rain events occurring each year, the water teams are endeavouring and succeeding to produce good quality safe drinking water. It is also important for operators to understand that all chemicals in the plant have a role to play, even ones rarely used. To regularly verify the dosing capabilities of these chemicals and to ensure that all chemicals are routinely checked and tested for correct dose rates and concentrations. Mackay council's operation and management team continue to seek improvements to Nebo Road to ensure a constant supply of water, even in times of poor quality.

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