Optimising the resilience of water treatment systems against extreme events of high manganese

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Abstract

Greater Western Water (GWW) services a diverse and growing region in Victoria, sourcing water from the Melbourne system and local catchments including Merrimu and Rosslynne reservoirs. During summer, local reservoirs often experience elevated manganese levels, which can cause unpleasant taste and staining in household plumbing. Manganese is typically treated through filtration and chlorination. While chlorine oxidises soluble manganese for removal, it also forms manganese oxide (MnO) particulates that can accumulate in pipework, leading to discolouration in the water. High manganese concentrations in catchments may require increased chlorination, promoting further manganese oxide precipitation and increasing the risk of brown or black water events.

To mitigate these aesthetic impacts, the use of a sequestering agent prior to chlorination is being investigated. Calgon T (sodium hexametaphosphate), a food-safe chemical with polyphosphate compounds can bind soluble manganese ions through strong electrostatic charges, preventing precipitation during chlorination. A series of jar testing and a site trial at the Rosslynne Water Treatment Plant (WTP) is being conducted to assess the effectiveness and operational implications of introducing Calgon T. This paper reviews the relevant literature, outlines the testing methodology and results, and discusses the change management considerations associated with implementing a new chemical treatment process within GWW.

Acknowledgement of Country

Greater Western Water respectfully acknowledges the Traditional Owners of the lands and waters upon which we work and operate, the peoples of the Kulin Nations. We pay our deepest respects to their Elders past and present who continue to forge the way ahead for their emerging leaders.

1.0 Introduction

1.1 Manganese in Drinking Water Treatment (Rosslynne Water Treatment Plant)

Manganese is an important parameter in water quality to monitor for, especially at concentrations exceeding 0.05 mg/L where it could leave an undesirable taste in water and stain plumbing fixtures and laundry (US EPA 2024a, cited in NHMRC 2011). The Australian Drinking Water Guidelines 6, Version 4.0 June 2025 (NHMRC 2011) states the concentration of manganese in drinking water should not exceed:

- 0.1 mg/L based on health consideration.
- 0.05 mg/L based on aesthetic consideration.

GWW's Rosslynne WTP treatment process to lower manganese concentration involves:

- Potassium Permanganate dosing
- Dissolved air flotation and filtration (DAFF)
- Chlorination

In chlorination, the free chlorine oxidises the soluble manganese for removal, but while manganese concentrations are lowered, the reaction will also precipitate manganese oxide deposits that can form scaling in the pipework, causing nuisance for maintenance crews to clean the "black ooze" off and further staining in customers' plumbing fixtures.

GWW's Rosslynne catchment sees occurrences of high manganese concentration in water typically at the offtake from the reservoir at lower levels during the summer season when water demand is high. As manganese concentration gets extremely high, the chlorination process gets used to a higher extent, increasing the risk of MnO precipitation and staining in the pipework.

Rosslynne WTP has an existing Potassium Permanganate (Pot Perm) dosing treatment prior to filtration to oxidise manganese, however it will still leave low concentrations of soluble forms of manganese, potentially due to competitive chemistry in the water.

1.2 Calgon T – Sodium Hexametaphosphate

One method of controlling manganese's aesthetic effect is using a sequestering agent that keeps manganese in soluble form preventing precipitation. Calgon T (or Calgon), a sodium hexametaphosphate product contains soluble compounds in water called polyphosphates. Polyphosphates tend to be bonded in long chains with strong electrostatic charges, which holds metal ions in solution as well as keeping it from reacting with other ions (Van Newenhizen 1998, cited in Sullivan 2007).

Christodoss (1990) has found in his tests that "manganese was not oxidised by hypochlorite and produced no discoloration for a period of 10 days [in the presence of polyphosphates]". However, Sullivan (2007) has found in her tests that polyphosphate is not effective in manganese sequestration due to potential competitive chemistry and other conditions in the trialled West Boylston Drinking Water plant. Overall, there is very little literature on the Calgon T product and the application of sodium hexametaphosphate in water treatment. However, back in the former Western Water days, Calgon has previously been used at Lancefield WTP to manage the quality of the bore water. Furthermore, applications of Calgon have been utilised by other water authorities like Gippsland Water, Barwon Water and Wannon Water. Nevertheless, this project will investigate the application and effectiveness of sodium hexametaphosphate in manganese management.

2.0 Jar Tests – Methodology, Results & Discussion

2.1 Summary and Hypothesis

A series of jar tests of the Calgon T stock solution (20%w/v), procured from IXOM, and sodium hypochlorite has been conducted in 2024 and 2025 at Rosslynne WTP. The main hypothesis for these jar tests was that if the soluble manganese matches with the total manganese while, the Calgon is having a desired impact on the water, as it would be successful in sequestering the manganese from precipitation during oxidation with free chlorine. The jar tests were conducted by Jacki Dunn, Water Treatment Engineer, and Samuel Leong, Treatment Planning Engineer.

A summary of jar tests completed and selected for discussion on this paper are as follows:

1. Dose range: 0.5-3 mg/L – in low Mn water (April 2024)
2. Manganese, Mn^{2+} spiking v. 2 mg/L Calgon dose (August 2025)
3. Calgon v. Without – 2 weeks contact time (August 2025)
4. pH range 6.5-8.0 & 2 weeks contact time (September 2025)

Other jar tests ie. blending different water sources with Calgon-dosed water, were done but not selected for discussion as testing methods were unorthodox and may produce inaccurate results.

2.2 Jar Test #1 – Calgon dose range: 0.5-3 mg/L in Rosslynne's Catchment with low manganese levels (April 2024)

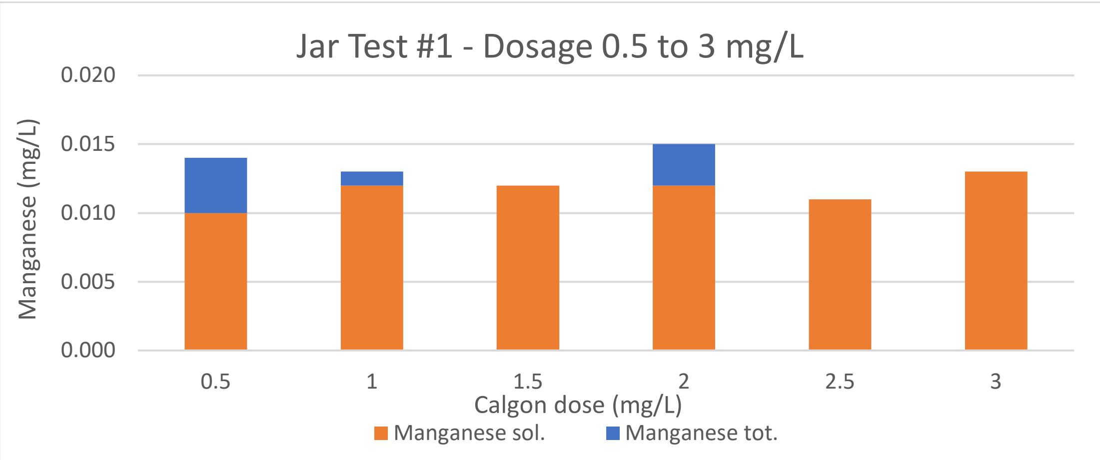

Figure 1 – Jar Test #1 – Dosing Calgon T in Rosslynne's raw water between 0.5 to 3 mg/L

Jar Tests #1 aimed to observe the effects of Calgon in the Rosslynne raw water catchment. Variability of results is reflective of the relatively low levels of Manganese in the raw water, along with inaccuracies in the test method as results show soluble Mn higher than the total. Regardless, the test demonstrates that the Calgon treatment is effective in keeping Mn in solution, avoiding oxidation by chlorine, with dosage of Calgon at optimal effectiveness between 1.5 to 2 mg/L.

2.3 Jar Test #2 – Manganese Spiking v. Calgon at 2 mg/L dose (August 2025)

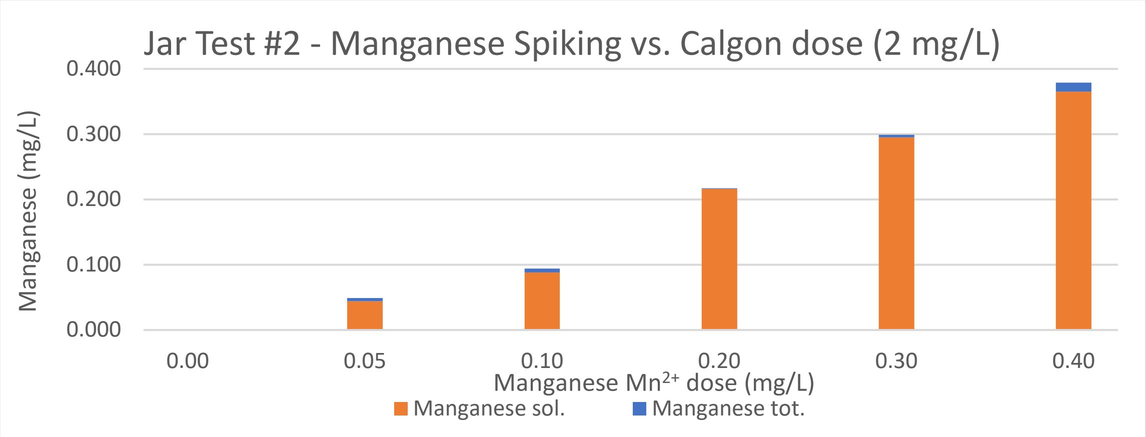

Figure 2 – Jar Test #2 – Mn Spiking - Graph show results 15-20 minutes after dosing Calgon.

As the jar tests conducted in 2024 were using the filtered water from Rosslynne Water Filtration Plant that had low manganese during those periods, the following tests involve spiking the filtered water with a Manganese Mn^{2+} standard solution. From the last test, the optimal Calgon dose is observed between 1.5 to 2 mg/L. Keeping the Calgon dose at 2 mg/L across the 6 jars, this test aimed to observe the resilience of Calgon's effectiveness in environments where manganese concentration is at a high 0.4 mg/L. Allowing the sodium hypochlorite dosage 15 minutes contact time to oxidise with the manganese, this test shows that Calgon at 2 mg/L can sequester most of the manganese concentration before in contact with the free chlorines.

2.6 Jar Test #3 – Calgon v. Without –2 weeks contact time (August 2025)

This test only involves 2 jars with the aim to observe the comparison of Calgon dosage against no Calgon in the filtered water dosed with 0.1 mg/L manganese and with hypochlorite. A contact time of 2 weeks was observed on the 2 jars. After 1 week since dose, the "No Calgon" jar showed a 95% drop – indicating 95% of the soluble manganese has been oxidized by the hypo dosage while "Calgon" retained 25% manganese as soluble. After 2 weeks since dose, the "No Calgon" jar showed discolouration with 5% of the manganese remaining soluble, whereas the "Calgon" jar remained clear with 25% manganese remaining soluble, shown in Figure 3 and 4 below. The "Calgon" jar saw a 92% reduction in manganese concentration in 2 weeks.

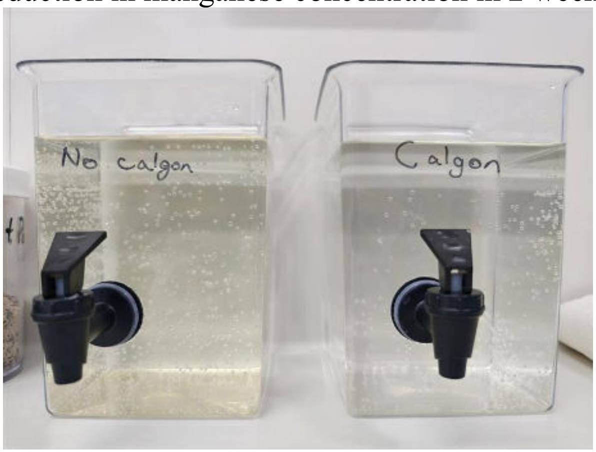

Figure 3 – Comparison of Jars after 2 weeks post-dose (Left: without Calgon; Right: Calgon dosed)

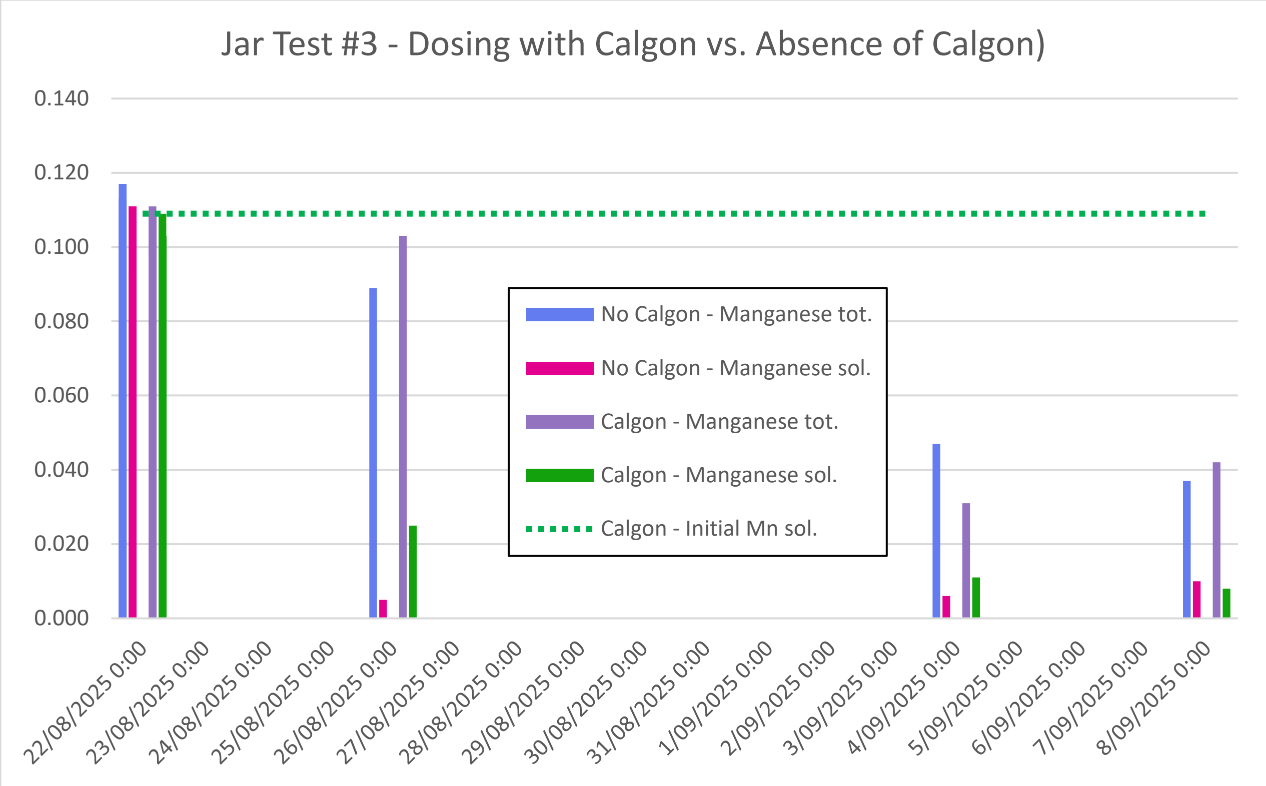

Figure 4 - Jar Test #3 – 2-week span of Mn concentrations after dosing one jar with Calgon and keeping one jar with no Calgon. Results show Calgon effect preventing soluble Mn oxidising and precipitating.

2.7 Jar Test #4 – pH range 6.5-8 & 2 weeks contact time (September 2025)

The aim of this jar test is to observe 2 weeks of contact time of Calgon in a pH range of 6.47 to 8.03. Results have highlighted the low pH of 6.47 hinders both the oxidation and sequestration of manganese over the span of 2 weeks contact. However, this jar test results and other jar tests involving pH range not included in this paper indicated that any higher pH will not optimise the Calgon dosage's sequestration of manganese.

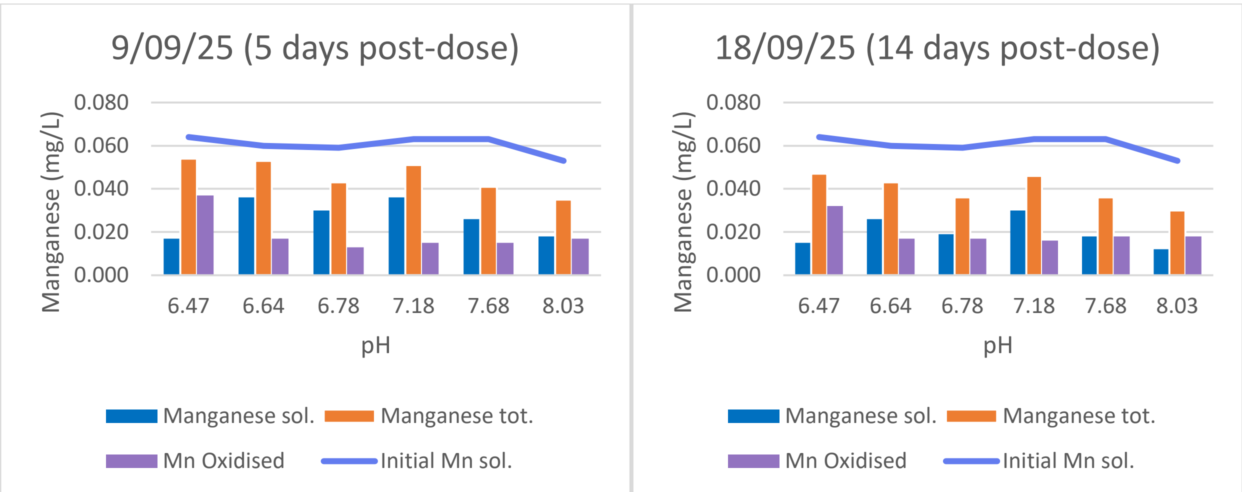

Figure 5 - Jar Test #4 – Testing the effectiveness of Calgon in various pH range (between 6.5 to 8)

3.0 Further works: Site Trial and Jar Tests

3.1 Preparation for Site Trial

A site trial is being prepared at the Rosslynne Water Treatment Plant utilising a prefabricated IBC dosing system. As this will be a site trial, this asset is useful for the temporary and portable setup for the Calgon T dosing, skipping the need to build an additional dosing site with a storage tank and bunding while there are insufficient data and evidence in the application and effectiveness of the chemical product.

This project involved the procurement of the IXOM Cube pre-fab IBC dosing skid product, the installation of the dose piping and electricals, and the management of change process to approve the dosing of Calgon T as part of the Rosslynne water treatment process and its effect on the water supply system. At the time of writing this paper, the Calgon dosing asset is being commissioned for the Rosslynne water supply system.

Figure 6 - Setup of site trial to dose Calgon T in Rosslynne WTP post-filtration and pre-chlorination

3.2 Limitations & Challenges

There are limitations and challenges throughout the project including:

- Periods of time when Rosslynne catchment water quality and the plant conditions where the manganese concentrations were low.
- Potential human error in the unorthodox jar testing so some results may not as accurate as expected.
- Extensive Management of Change processes for the preparation of the site trial as it will change the Rosslynne water treatment process and hence, the water supply system for affected townships.

3.3 Further Jar Testing works

Additional jar testing is being considered for additional scenarios including:

- Blending different water sources (to simulate the water supply switch from GWW's local catchment to Melbourne Water's supply)
- Potential softening of MnO particulates that form scaling around the pipework.
- Further validation of Calgon T vs. Without testing.

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4.0 Conclusion

Key observations and concluding takeaways from this project so far are:

- The jar tests showed desirable results with high fraction of soluble manganese to total, implicating that the polyphosphates in Calgon T can sequester and keep the soluble manganese from precipitating to manganese oxide deposits.
- Optimal dosing range is between 1.5 to 2.0 mg/L.
- Low pH of 6.5 will hinder the sequestration of manganese, but any pH higher than 7.5 will not further improve the Calgon T's sequestration of soluble manganese.

5.0 Acknowledgements

I would like to thank everyone who has helped me throughout the course of this project. I could not have accomplished this much without each and every one of them. Their unwavering support, invaluable expertise, technical insights, and their patience were instrumental in navigating all the challenges and achieving the milestones of this project. I hope that this work will provide useful information to Greater Western Water and the wider audience in the water industry. This project is still in the early stages and there will be more outcomes to expect after the site trial at Rosslynne, and further jar testings unravel the application and effectiveness of Calgon T / sodium hexametaphosphate.

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6.0 References

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