OPERATIONAL READINESS FOR CLIMATE-DRIVEN WATER CHALLENGES

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ABSTRACT

Since 2020, Upper Nepean catchment has experienced poor raw water quality events annually due to climate change, derating Nepean Water Filtration Plant (WFP) capacity by up to 60%. Sydney Water have adopted a proactive approach to maintain reliable and continuous supply of safe drinking water and mitigate risks until the completion of a new treatment upgrade project. Strengthening plant resilience through dedicated process engineer-operator hubs supporting day-to-day optimisation and issue resolution, building operator technical expertise in jar testing, and filtration and online performance analysis allowed the team to successfully navigate these events with full understanding of the WFP condition and ongoing issues. Operational readiness was strengthened through 24/7 rostering, coordination with WaterNSW for dam operations based on raw water quality forecasts, and the use of a pre-event checklist. The Sydney Water Instantaneous Filtration Technology (SWIFT) model, developed using historical plant data, along with supplementary jar testing and process modelling support, enabled real-time decision making on chemical dosing adjustment with up to 18 changes in a 72-hour period during rapid raw water quality changes. Data recording during the event, structured post-event debriefs with all involved personnel and implementing lessons learnt significantly benefited the plant's preparedness and response capability for future raw water quality events.

1.0 INTRODUCTION

Nepean Water Filtration Plant (WFP), built in 1976, uses coagulation and two-stage filtration to treat raw water from Nepean Dam. It is the sole supply of drinking water to 30,000 customers in the Thirlmere, Picton, Buxton, Green Hills, and Oakdale water supply zones in NSW. The Nepean system is isolated with no interconnections with other water delivery systems. Since 2020, Upper Nepean catchment experienced multiple heavy rainfall events which significantly deteriorated the raw water quality. In order to maintain safe drinking water meeting operational guidelines during these events, Nepean WFP production capacity was downrated from 32 ML/day design capacity to 13 ML/day (Australian Government, 2011). The WFP is currently undergoing augmentation to include two-stage pre-treatment clarification and additional dual-media filtration, increasing the total plant production capacity to 33 ML/day to address raw water quality challenges and growth over the next 20 years. Until the upgrade is operational, Sydney Water has taken a proactive approach to strengthen plant resilience and operational readiness in preparation for future wet weather events on a day-to-day basis as well as with technical, operational and management support during the event.

2.0 DISCUSSION

Operational readiness and plant resilience was strengthened through collaborative efforts between operators, process engineers, operational engineers, management, Regional Delivery Partners (RDP) and WaterNSW. These methods include: 1) dedicated process engineer-operator hubs who support day-to-day operation and optimisation; 2) building operator technical expertise; 3) use of

the Sydney Water Instantaneous Filtration Technology (SWIFT) model; 4) pre-event preparation; 5) technical and operational collaboration during the event; and 6) post-event procedures.

2.1 Climate-driven Water Challenges

Since 2020, Upper Nepean catchment experienced several wet weather events which led to high peaks in turbidity, true colour, Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC). Nepean WFP's production capacity is reduced from its design capacity of 32 ML/day to 13 ML/day when raw water turbidity and true colour exceed 20 NTU and 30 CU_{400nm}, respectively. These events occurred 10 times from 2020 to 2025, with 3 events in 2022 alone, and the parameters remained elevated for extended periods (Figure 1 and Figure 2).

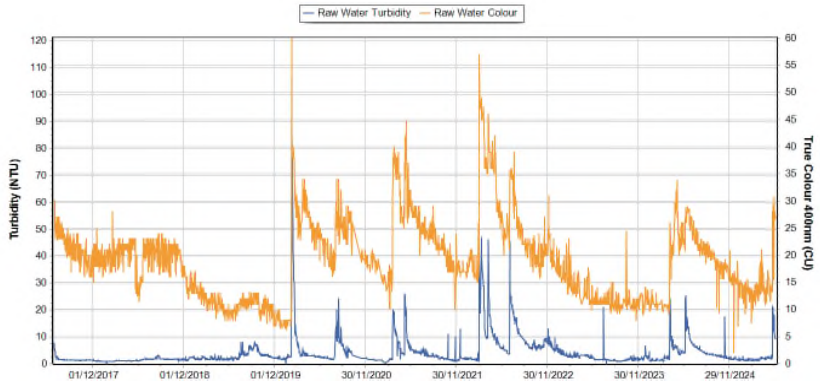

Figure 1: Raw water turbidity and true colour (measured at 400 nm wavelength), July 2017 - June 2025

Maximum raw water turbidity and true colour experienced at the WFP was as high as 132.7 NTU and 60 CU_{400nm}, respectively, with online turbidity analyser readings higher than daily laboratory samples due to the difference in sampling frequency and the WFP being offline during peaks in turbidity. An additional challenge to operations was the great variability in turbidity and true colour within one day due to the rapid change in raw water quality from the dam. During the April 2024 event, the plant saw raw water turbidity and true colour drop from 75 NTU and 40 CU_{400nm} to 22.5 NTU and 19 CU_{400nm}, within a 24-hr period. Poor raw water quality significantly impacts filter performance and requires more frequent backwashing which leads to a decrease in water production.

2.2 Dedicated WFP Hub Operator-Process Engineers

Nepean WFP experiences multiple process and operational issues stemming from ageing assets, temporary operational changes to facilitate the treatment upgrade project, dated design or controls, and BAU operations. An issue that appears manageable during good raw water quality may exacerbate and become a major issue during a wet weather event. Sydney Water has designated process engineers to support each WFP hub for resolving ongoing issues and implementing improvements on a day-to-day basis with the operations team. A Process Issues and Improvements Register is used to identify, prioritise and track implemented actions for WFP process issues and improvements that are raised by operators and supporting teams. Monthly meetings are held to re-prioritise and escalate current and emerging issues with the operations and process teams, while targeted sessions are led by the delegated process engineer to present results of the investigation, proposed solutions and recommended actions. Progress on resolving issues and implementing optimisation at Nepean WFP strengthens the plant resilience in a proactive manner prior to wet weather events. Regular discussions between the operator and process engineer on ongoing issues increase the collective understanding on the current WFP capabilities and reduce response times during events. The rapport built between the operators and process engineers during BAU operations allows for open communication during wet weather events when personnel may be

working under high pressure/fatigue conditions.

2.3 Building Operator Technical Expertise

Leveraging the skills and knowledge from past extreme rain events since 2020 is extremely valuable for the operations to make well-informed decisions under high stress situations that require fast response times. Since 2023 recruitment was completed of three operators and two process engineers to bolster resourcing in the Hub. To rapidly establish the technical capability of the team in-house technical trainings are provided including:

1) Unit Process Guideline - fundamentals of coagulation, flocculation and filtration and
2) Plant-specific process training – jar testing (chemical optimisation), validation jar tests (confirming current dose performance) and filter assessments (optimise backwash parameters and assess filter health)

Plant-specific "quick reference" guides were developed to simplify complicated and generic Work Instructions for critical optimisation tools like jar testing (Figure 2). Operators and process engineers are now trained to utilise these during wet weather events. Technical training and regular implementation of the learnt skills are extremely beneficial during these events as it will allow operators to quickly and independently identify an abnormality, develop their understanding of the issue, anticipate the impact to the WFP, and use knowledge-based reasoning to develop a plan and execute it in a timely manner.

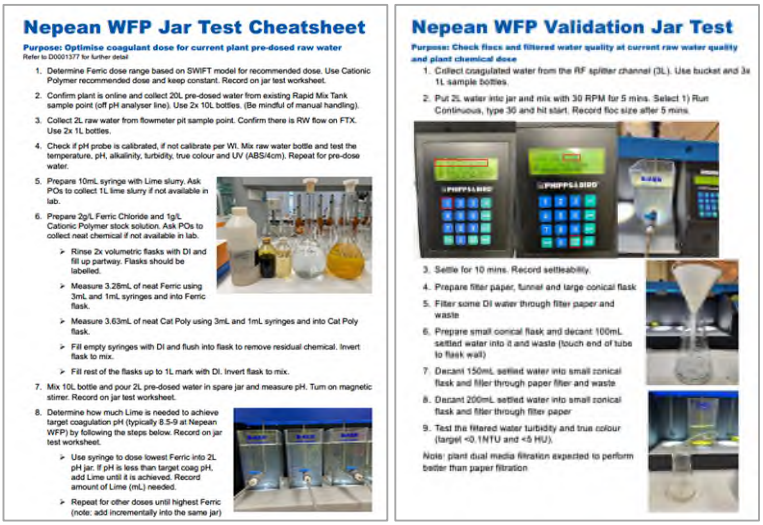

Figure 2: Nepean WFP Jar Test and Validation Jar Test Cheat Sheets

2.4 Sydney Water Instantaneous Filtration Technology (SWIFT) Model

The Sydney Water Instantaneous Filtration Technology (SWIFT) model is an in-house WFP modelling and optimisation tool, combining over 10 years of plant Supervisory Control and Data Acquisition (SCADA) and laboratory water quality data into a single application. Through careful analysis and consultation with operators, engineers and management, a variety of tools have been developed within the SWIFT application to support real-time decision-making. One of these is the coagulant dose rate estimator, allowing engineers to recommend a suitable coagulant dosing range to operators for rapidly changing raw water quality and quickly predict plant performance for anticipated raw water quality and chemical dosing conditions. This tool has drastically reduced the manual labour and time required for comprehensive jar testing and has allowed for 'validation' jar tests to take their place, which can be completed within 30 minutes. This involves sampling coagulated raw water downstream of all chemical dosing and at the start of the flocculation process. This water can then be flocculated, filtered and analysed quickly, without the need for

chemical stock solution make-up, dose preparation, pH adjustment and water quality analysis on 6 jars for each trial, which would typically take several hours to complete. This also avoids belated testing where sampled water may have already passed through the plant's coagulation process by the time results are obtained and recommendations provided. During the raw water quality events in April 2024 and May 2025, up to 34 and 16 coagulant dose changes were made over a week, as per recommendations from the SWIFT model, with up 10 validation jar tests and floc quality observations completed to verify these recommendations and inform decision-making. Implementation of the SWIFT model for coagulant dose and plant performance modelling has drastically improved the process of real-time water quality event management at the frontline.

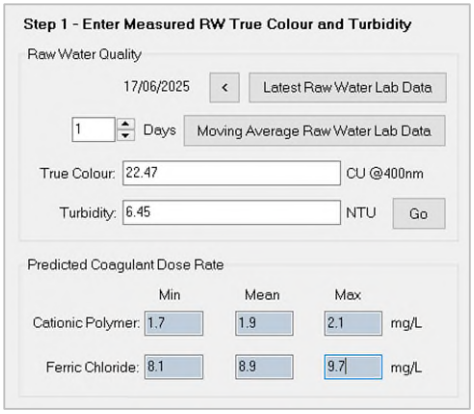

Figure 3: SWIFT Chemical Dose Calculator for Nepean WFP

2.5 Pre-event Preparation

When wet weather is predicted to impact the raw water quality in Nepean Dam, operators work collaboratively with operations engineers, process engineers, water catchment authority and delivery partners to prepare the WFP in advance. Sydney Water operations engineers interface collaboratively with WaterNSW (water catchment authority) to forecast raw water quality and monitor any changes that will inform operational decision-making on dam screen positions, outlet offtake depths and aeration as a contingency for intrusions and thermal stratification. During high-risk days during a wet weather event, operators work with Sydney Water's RDP maintenance team to ensure an electrician and mechanical fitter are rostered on at the WFP during morning and afternoon shifts to reduce downtime if any faults occur. The senior operator and WFP hub manager develop a 24/7 operations team roster with consideration for fatigue management. If resources are insufficient, additional operators from other WFPs may be called in to support the team. The roster designates a liaison operator or operations lead and liaison process engineer to streamline communication between onsite personnel and the wider team who are providing remote support. A live water quality datasheet and SCADA trends are prepared ahead of time, so that operators and managers have quick access to lessons learnt from previous events, log of operational adjustments carried out, raw water quality changes and key parameters monitored in real time such as coagulation pH, chemical dosing, filter head loss, filter turbidity, filter outlet valve position and filter level (Figure 4).

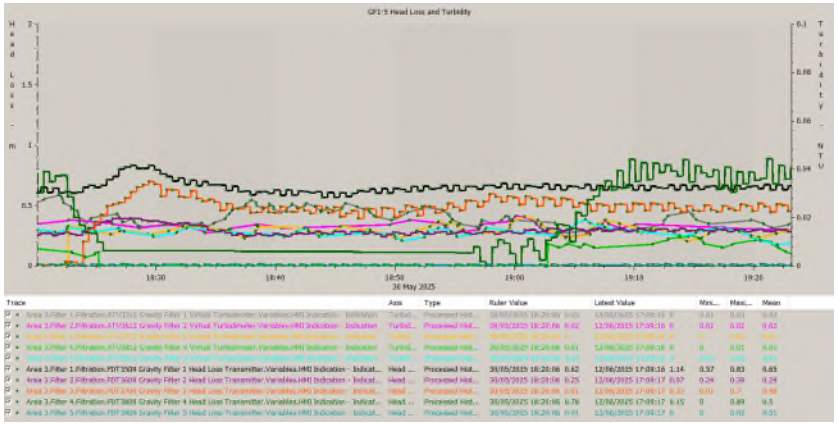

Figure 4: Nepean WFP SCADA Trend for Filter Head Loss and Turbidity

Nepean WFP operators have a pre-event checklist to ensure preparation activities are completed ahead of a potential wet weather event (Figure 5).

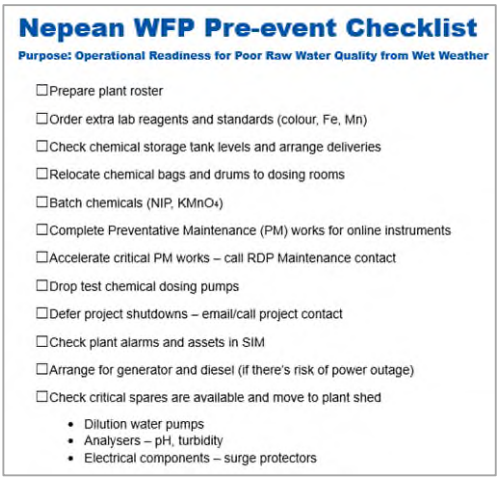

Figure 5: Nepean WFP Pre-event Checklist

2.6 Technical and Operational Collaboration during Event

Collaboration between the on-site operator and various internal and external teams are critical to successful management of WFP production during a water quality event. During daytime shifts, two operators are rostered on to allow one person to manage liaison with internal and external collaborating teams while the other person monitors plant operation and conducts field work. During night shifts when only one operator may be rostered, they are supported by the WFP hub operations lead, hub manager, or process engineer. The operations engineer provides updates on daily rainfall updates and works with WaterNSW to provide SCARMS profiles (dam water quality depth profile over time) delivering predictions of the raw water quality the WFP may expect (Figure 6). Operators coordinate with the operations engineer and WaterNSW water quality advisors on decisions pertaining to source water quality window selections, outlet offtake selection, aerator operation and required plant shutdowns to facilitate these changes.

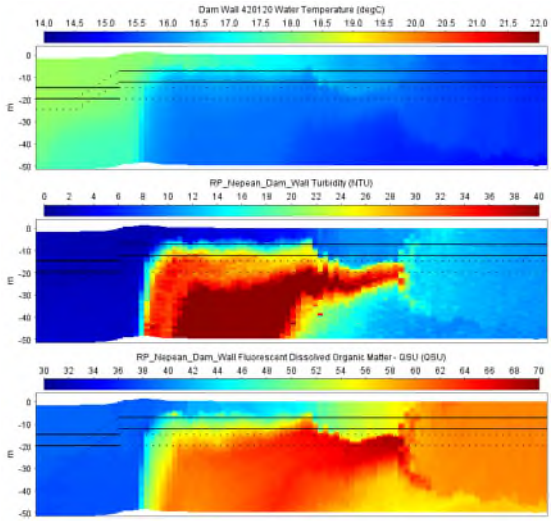

Figure 6: WaterNSW SCARMS Profile for Temperature, Turbidity, and Dissolved Organic Matter

A process engineer is available on-call outside of regular hours to provide technical support for the operators and has increased presence on-site to assist with process testing. During an event, operators increase the frequency of raw and treated water sampling and testing for turbidity and true colour, where they work with the process engineer to use the SWIFT model and conduct validation jar testing and floc quality monitoring to implement chemical dose changes. The process engineer assists with monitoring of filter performance parameters such as filtered water turbidity, ripening, head loss, and runtimes, and conduct filter assessments or backwash turbidity profile measurements as required. This information is used to recommend modifications to filtration and backwash parameter setpoints, which will be implemented by the operator following consultation. The team works together to populate the live water quality datasheet, recording key events such as raw water quality changes, chemical dose changes, filter breakthrough, and any filtration or backwash setpoint changes.

Operators monitor plant performance and flag any relevant or emerging issues with the process or RDP maintenance teams to maintain continuous supply of drinking water. Any urgent or critical issues are escalated to the Emergency Control Centre (ECC), if available for the event. Operators also attend ECC meetings as required to provide updates on the status of the plant and emerging issues. Operators work closely with System Operations Centre (SOC) operators to manage the system storage downstream. If critical maintenance works require a shutdown, operators coordinate shutdown durations and timing with SOC and RDP maintenance team to minimise impacts to production. If there are any water main leaks in the network, operators work with Networks technicians to ensure continuity of drinking water supply. Operators coordinate with water quality scientists if any chlorine tablet dosing is required in the drinking water reservoirs.

2.7 Post-event Procedures

After the water quality event has stabilised, a face-to-face debrief with the wider team is held on-site to review the sequence of events including water quality changes, key issues, and operational changes implemented, and to discuss what worked well, what could be improved, lessons learnt and recommended actions. Key actions and timeline for implementation are recorded in a register managed by the action owner. Any actions assigned to process engineers are transferred to the Process Issues and Improvements Register. A post-event checklist for operators and process engineers involves returning setpoints (including chemical dose rates, filter runtimes and filter backwash parameters) back to pre-event values as raw water quality gradually improves, in order to prevent overdosing and excess chemical or water consumption. Debrief and post-event procedures allow for operators and the wider team to understand plant performance and

constraints, which significantly improves readiness and response capability for future raw water quality events.

3.0 CONCLUSION

Nepean WFP has successfully managed numerous poor raw water quality events using a proactive approach to strengthen plant resilience and operational readiness to maintain continuous supply of safe drinking water. This is achieved through close collaboration of operators with internal and external teams on a day-to-day basis, increasing operator technical expertise, thorough pre-event preparation, technical and operational support during the event including use of the SWIFT model, and post-event debriefs.

4.0 ACKNOWLEDGEMENTS

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