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Service Standards
Sydney Desalination Plant

Document Information

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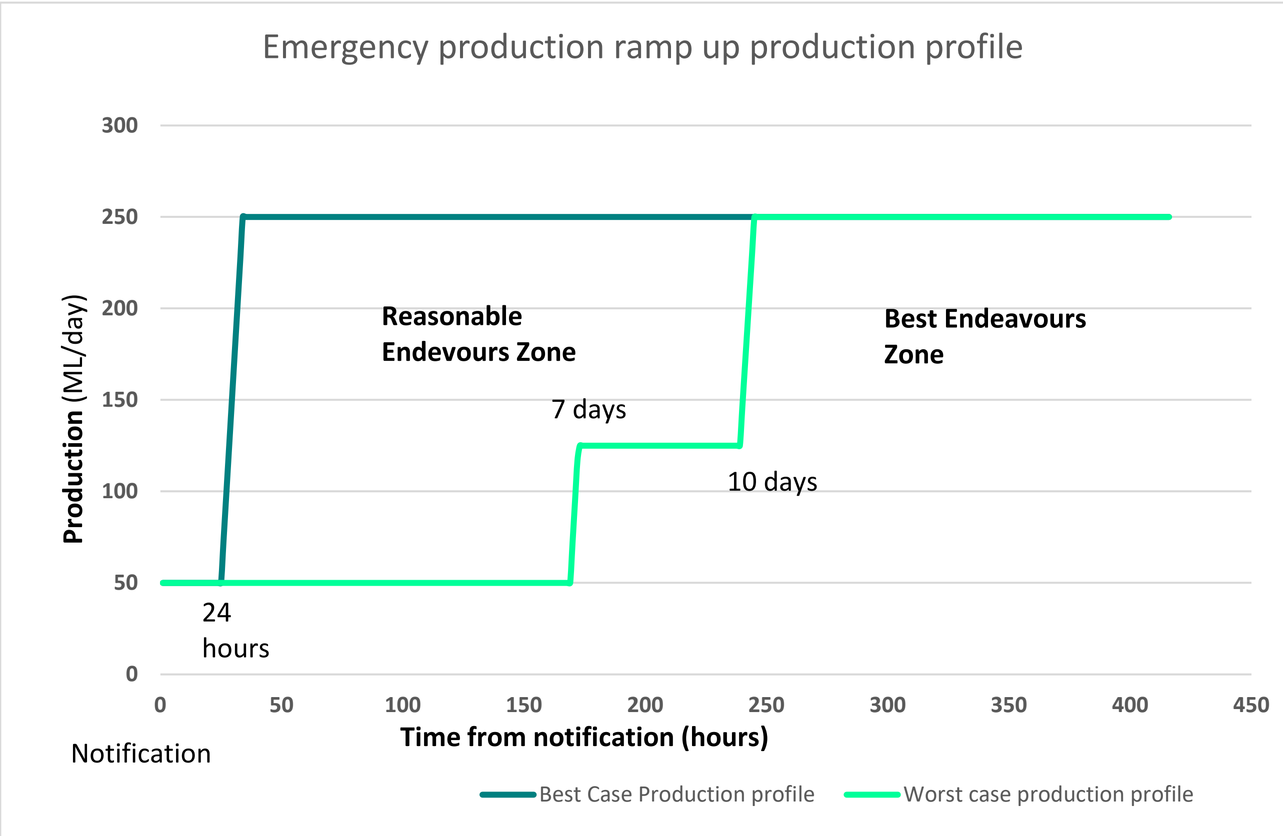
1. Executive Summary

Sydney Desalination Plant Pty Limited (SDP) are currently preparing a pricing submission to the Independent Pricing & Regulatory Tribunal (IPART) for Prices from 1 July 2023. The pricing submission is being made in the context of the new Greater Sydney Water Strategy (GSWS) and SDP's revised Network Operator's Licence. This report details the operating challenges, risks, and technical limitations of the desalination infrastructure in meeting the new production requirements. It recommends a revised equitable set of Service Standards, transition conditions and verifies the proposed minimum production rate of 23GL/year ensures the Sydney Desalination Plant (Plant) is operated in a way that is prudent, efficient and under guidelines of "Good Industry Practice" as per the obligation in the SDP Network Operator's Licence and referenced by numerous Practice Guidelines published by Water Services Association of Australia and the Australian Drinking Water Guidelines.

Desalination plants are designed as continuous base load water production facilities. For SDP, the new operating environment has been set, to have the facility operate with variable production rates, with an ability to respond to emergency events. The Plant was originally designed for production rates of zero, 46 and 91.25GL/year at 94% availability with extended periods to transition to each production mode. It was not designed operate at minimum production rate of 23GL/year for extended periods with short ramp up time to full production. The Operator has diligently trialled various operating scenarios to provide a solution to achieve the NSW Government's new requirements while maintaining Good Industry Practice. However, in operating in High Availability/Low Production, it does increase and introduce additional operational and asset risks.

The key recommendation from this report is to articulate the time that SDP will reasonably require, to respond to an emergency request from Sydney Water, to ramp the Plant up from its minimum baseline production (50MLD) to full production (250MLD), whilst maintaining all its obligations, including the production of compliant drinking water at the Sydney Water Delivery point at Erskineville. In addition, the time impact of environmental factors (inclement weather, seawater quality etc) that may hamper and or delay the transition from High Availability (50ML/day) to Full Production (250ML/day) have also been considered. The following table graphically represent the key recommendation.

Figure 1-1 Ramp-up from High Availability to Full Production Mode



This ramp up time is supported by two other Australian desalination plants operational context. One at the Gold Coast which is half the capacity and does not take any commercial risk (it falls under a cost-plus arrangement); and the other Adelaide Desalination plant which was built some years later with more purpose-built flexibility to support variable production rates with only a 'reasonable endeavours' obligation. The four other desalination plants in Australia are base-load plants and do not have such requirements to transition relatively instantaneous for an emergency response. Benchmarking the Australian desalination demonstrates that the new operating environment for the Plant, particularly the function to respond to emergencies, presents some of the most onerous production requirements and conditions in the industry.

High Availability at the lowest possible production rate.

The report confirms that it is prudent and efficient to operate the Plant at a minimum annual production rate of 23GL/year. This ensures the Plant is regularly operated at full production at a minimum of four times per year for an extended period. The benefits to Sydney Water, customers, SDP and the Operator are:

- Timely and efficient ramp up times (i.e. the ability to ramp up the Plant in an emergency as quickly as possible)
- Minimise blockages and degradation of Plant assets that are notably the remineralisation and reverse osmosis systems.
- Ensure the operational resilience ability of the Operator to maintain skills and continuously learn how best to ramp up and ramp down the assets quickly and efficiently.
- Provide full production testing periods directly after major Plant overhauls and membrane replacements to test and verify critical equipment and systems.
- Learn new solutions and implement improvements to the asset to minimise future costs at low production rates.

The overall benefit to Sydney Water and customers is high availability at the lowest annual production rate and the ability to ramp up relatively instantaneously. This ensures the Plant is operated safely, minimises the additional risks on the operations and assets while operating at the extreme limitation of the Plant. This recommendation balances the risk and cost and provides Sydney's Water supply system with highest level of flexibility, reliability, and operational resilience.

2. Objective

This report proposes the Service Standards to meet the new role for the Plant under the Greater Sydney Water Strategy 2022 (GSWS) and SDP's Network Operator's Licence. It takes into consideration the technical capacity, impacts and risks associated with the Plant, drinking water pumpstation and delivery pipeline. This report is written to align with the new GSWS, SDP's Network Operator's Licence and "Good Industry Practice", to provide Sydney with long term water security. The desired result is to maintain and protect the asset, and to ensure reliable and consistent delivery of the desalinated water to the Sydney Water interface delivery point at Erskineville. In addition, the report comments on the proposed 23GL/year baseline production equating to about 25% of full annual production when operating at lowest possible production rate. The Low Production rate is defined as the lowest possible production of drinking water from the Plant delivered to Sydney Water's delivery point at Erskineville called "shaft 11c".

3. Background

3.1. Context of this report

SDP are currently preparing a pricing submission to the Independent Pricing & Regulatory Tribunal (IPART) for its prices from 1 July 2023. The pricing submission is being made in the context of the GSWS and SDP's revised Network Operator's Licence which has seen a significant transition in the role of the Plant from a long term 'on or off' base load plant to one that provides greater flexibility and resilience for Sydney. The key functions of the revised Network Operator's Licence are as follows:

1. SDP needs to respond to Annual Production Requests from SWC issued in line with a Decision Framework
2. SDP must use best endeavours to respond to other production request such as emergencies that are in line with the Decision Framework

The Decision Framework provides Sydney Water with guidance on what they should request.

To align the SDP Service Standards with "Good Industry Practice", it is critical to understand the limitations and key operating risks of the desalination system (marine intake outfall tunnels, desalination plant, drinking water pump station and delivery pipeline). This report aims to highlight these limitations and key risks to protect the facility and not to introduce new and excessive operating and compliance risks. In highlighting these elements, it is intended to generate a fair and reasonable set of Service Standards to satisfy the main stakeholders (Sydney Water, customers, SDP and the Operator). The methodology employed here is as follows:

- Review the proposed services from the Plant under the new GSWS and SDP Network Operator's Licence
- Assess the appropriateness of the proposed default or 'high availability' state that the Plant would remain in until called on to ramp up production (i.e. 23 GL/a)
- Assess the key risks for the Plant to provide the proposed services, given the Plant's design and technical capabilities
- Quantify the impact that key risks could have on the time for the Plant to ramp up to full production from the 'High Availability' state
- Recommend reasonable, and equitable set of service standards and transition conditions for the Plant when operated in line with 'Good Industry Practice'

3.2. Facility Background

It should be noted that the Plant was originally contracted by the NSW Government under two separate contracting models. The first contract model was a design build operate and maintain (DBOM) for the seawater intake and brine outlet tunnels, desalination plant and drinking water storage. The second was an Alliance to construct the drinking water pump station and delivery pipeline to Sydney Water's Shaft 11 at Erskineville.

The desalination asset's primary purpose was designed as drought response to shore up water supplies in response to the millennium drought. The Plant was originally conceived and designed to produce 45GL/year with a 94% availability, this was later upgraded to 91.25 GL/year at the same nominal availability. The drinking water pump station and delivery pipeline were designed to transfer the water at two rates 125 and 250ML/day, the final design included transfer rates between 90 ML/d and 375 ML/d in a duty/duty arrangement at a nominal availability of 85%.

The original design was in the context of a base load desalination plant with a high-quality seawater source, based on similar plants built in the Middle East. The need for quick ramp up and response was not included in the basis of design and therefore was not a focus in the design of the Plant - the Plant was not designed as a daily stop-start facility.

The Plant is a seawater reverse osmosis membrane desalination facility with the following key features.

- Seawater is drawn from the ocean under gravity, via four intakes that are approximately 300 metres offshore
- As the seawater enters the plant, two rotating drum screens then filter out material to 3 millimetres in diameter, such as kelp from the seawater
- The screened seawater is then pumped into the 24 dual media filtration tanks, which utilise a layered sand and coal product, to further clean the seawater in preparation for the salt removal
- Filtered seawater is pushed through the reverse osmosis membranes under high pressure (50-60bar), with approx. 36,000 reverse osmosis membranes in use
- There is a 2 pass reverse osmosis system, with 13 first pass trains and 7 second pass trains
- The Plant utilises a Dual Work Exchange Energy Recovery (DWEER) system at the end of each first pass train, which reduces the plant's energy needs by up to 60%
- Following the reverse osmosis process, the purified water (permeate) is then remineralised with carbon dioxide, lime, chlorine and fluoride to comply with the Australian Drinking Water Guidelines (ADWG)
- The drinking water enters the 40ML drinking water tank before being pumped 18km via the SDP pipeline, which is 1.8m diameter, until the final handover point to Sydney Water, located at Shaft 11C in Erskineville
- The Plant is separated into two distinct modules, each comprising the process steps above, and each with a nominal capacity of 125ML/day

Sydney Water required additional flexibility under the desalination O&M Contract to incorporate times when they required reduced volumes of water e.g. when Sydney's water storages are full. This came at additional operating cost to account for additional energy and process (or non-revenue) water to meet all possible operating configurations and environmental conditions. In general, desalination plants are best operated with continuous production profiles with allocation for times of major, minor, breakdown maintenance periods, so the addition of production flexibility also introduced 'rules' around the degree to which that flexibility could be utilised.

This led to the following concepts:

- each module being considered as 'operational' or 'in shutdown' independently,
- lump sum costs for the shutdown and/or restart of each module,
- grace periods to achieve restart of any module that was in shutdown, and
- the length of the restart grace period being dependent on the duration of the shutdown e.g. if a module was in shutdown for 11 -90 days it would require 5 days to be restarted, whereas if it were in shutdown for 2-5 years it would require 8 months to be restarted.

3.3. Report Author's Background

The author Richard Mueller is a civil engineer with a master's degree in business management. He has over 28 years' experience in the Australian and International Water industry. He has designed and constructed over 30 water treatment plants. In addition, he has operated some of Australia's most complex water treatment facilities. He has been an Operations Director in the Design and Construction phase for the Gold Coast and Sydney desalination plants and heavily involved in designs for the Adelaide and Victorian Desalination Plants during the proposals phase. Richard is a member of the Australian Water Association and the International Desalination Association. He is currently the National Manger for Asset Management and Operations at Ontoit.

4. Proposed Service Envelope

4.1. Proposed Service Envelope

It is understood that the proposed service standards envelope as it currently stands is detailed in Table 3-1. This report will review the context of this table with the detailed understanding of the Plant design capability and Operators current capability and capacity.

Table 4-1 below summarises the current proposed Service Standards.

Flow Request	Notice Period	Volume of Water requested	Duration of Water supply
High Availability	n.a.	Sufficient supply (minimum of 23GL/year) to ensure the Plant remains available to meet reasonable flow requests. Plant running at ‘Low Production’.	Ongoing – baseline production of at least 23GL/year
Emergency response	Agreed volume and response time (likely to be 24-48 hours)	To be specified and agreed in request (cap of 250 ML/day or ‘available capacity’)	Indefinite – but assumed duration of emergency will be ‘short-term’.
Annual Production Request	1 May each year for the following financial year Can be changed every six months or other times through agreement	23GL to 91.25GL/year	One year
Monthly sequencing requests	Monthly	Proposed monthly sequencing of the Annual Production Request	For a month
Fixed production day sequencing requests	Through monthly requests	Proposed specific daily sequencing of the Annual Production Request	For a day

Table 4-1 Current Proposed Service Standards

5. Key risks and limitations in meeting the Service Standard

5.1. Introduction

Section 5 details some of the critical elements that potentially impact the proposed GSWS Service of High Availability and the transition from High Availability to Emergency Response. The High Availability service standard provides Sydney Water and customers with the lowest possible overall cost solution to ensure the Plant is readily available for emergency situations on request. However, there are trade-offs in operating the Plant inefficiently when compared to operating at full capacity. It is operating the Plant at the absolute limits of its' capabilities. When the Plant is operating at this extremity of High Availability i.e. at 50ML/day or 20% of normal capacity; there are a significant number of mechanical and electrical equipment items not in use. Equipment that is not use for extended periods of time has a higher potential for start-up failure. Continuously operating equipment tend to have less breakdown failures. The Operator mitigates this risk by employing an asset rotation strategy whereby each train and duty standby equipment is given similar hours run-time.

The rotation strategy routinely exercises the majority of the equipment; however, with 80% of the equipment not in continuous operation it is inevitable that some equipment items will stick, seat, dry up, harden, corrode, not connect or not trigger; and as result equipment faults, alarms or 'trips" will typically be experienced particularly on start up. Furthermore, static chemicals, fluids and powders can change viscosity, adhere to pipe walls, or harden, resulting in restrictions and/or blockages. The Operator can flush and circulate chemical where possible, however not all chemical systems have this option. A very simple analogy is a boat that is not operated for a year is generally difficult to start versus a boat that is operated everyday basis. Eventually the boat should start with recharging of the batteries, priming of the fuel line and other miscellaneous tasks, provided more serious damage has not occurred such as seawater ingress corroding some of the electrical contacts. But it may take more than just turning the key.

The Plant was designed to predominately (and efficiently) operate in three modes: full rate, half rate or zero production, with zero, one or two modules in preservation i.e. mothball. It was not designed to operate long-term in at 20% production rate. Over the last two years operating the Plant in a low flow arrangement, the Operator has experienced many events and challenges that have caused the Plant to run at reduced capacity or delay the operation of some equipment or processes. The following discussion details some of the areas that have an impact on production and ramp-up from High Availability.

5.2. Original basis of the design

The SDP planning approval states *"the Government has adopted a policy that the proposed desalination plant and associated infrastructure will only proceed to implementation as a contingency in the event of extreme drought conditions"*.

The basis of design "TS06: Basis For Design, Construction and Operations" of the Plant included the following

> "*The Plant will generally be designed to produce 125 ML/day of drinking water*." This was later increased to 250 ML/day capacity.
>
> "*For the avoidance of doubt, references in this document and elsewhere to production capacities in terms of ML/day, shall be understood to refer an average output of the quantity stated over every day in a calendar year (unless specifically stated otherwise); hence, the actual daily production of drinking water required to be produced will be greater than the nominal output so as to take account of periods of non or reduced production due to repairs, membrane exchange, or maintenance."* This provides context that the Plant was to provide an average production over a long period, was not to be relied on for specific volumes over a shorter period and should be able to cope with repairs and maintenance but not capital works or renewals.

The Plant was thus originally specified and designed to produce 91.25GL/year with a 94% availability as a drought response asset. The Plant was initially designed primarily to produce drinking water most efficiently 125ML/day and subsequently later increased to 250ML/day. The basis of design also states "*but shall also be capable of* *effective operation at reduced rates down to 50 ML/day"* The Drinking water pump station designed with 85% availability with a duty-duty pump arrangement without any standby with a minimum 90ML/day.

The original Plant design was based on similar plants built in the Middle East as a base-load desalination plant with high energy efficiency using a high-quality seawater source. While the reference to providing turn-down capabilities to lower output, quick ramp up and response was not included in the basis of design and therefore was not a focus in the design of the Plant. The basis of design was clear that volume should be measured over a year.

Over recent times, Sydney Water has required additional flexibility within the Plant operations, when Sydney's water storages reached various trigger points (as detailed in previous Metropolitan Water Plan, now replaced by the GSWS). This flexibility has come at additional operating complexity compared to a mothball state to meet all the new operating environment's production requests. The Plant was not designed as a daily, weekly, or monthly stop-start facility.

5.3. Extreme Weather Events

High rainfall events tend to have impacts on seawater quality, which have potential to downrate capacity/reliability of the pre-treatment. The Operator notes that they are most likely to get an emergency request during periods of bad weather. These events tend to be the root cause for issues in the Sydney Water network.

The Plant is not completely immune to impacts of poor weather and can experience other types of issues such as flooding preventing access to the site, electrical faults, poor inlet water quality due to rainfall runoff or rough seas and other issues that come with significant bad weather.

Whilst the Plant is much less weather dependent than other, conventional water sources, this does not mean it is immune to impacts from extreme weather events.

The assessed implications of extreme weather events are:

- If the Plant is asked to ramp up production during extreme weather, there may be delays due to rapidly changing inlet water quality that requires adjustment to dosing before water is suitable for feed to reverse osmosis, or may require reduction in capacity due to excessive backwashing of pre-treatment. This could delay or reduce capacity for 24-72 hours depending on the extent and duration of the challenge.
- Excessive rainfall could cause trips to sensitive electrical equipment due to moisture ingress. Such trips could cause some or all of the plant to 'trip' which would require trains to be restarted and essentially start the 'ramp-up' process from scratch.

5.4. Marine Intake and Brine Outfall tunnels

The Seawater intake tunnel supplies water into the Plant. The system has a shock chlorination system inside the tunnel to inhibit marine growth along the length of the tunnel. Shock Chlorination is required on an intermittent frequency at varying duration and concentrations to ensure it inhibits the varying species of marine growth. During shock chlorination, it may be necessary to cease production. Some Marine growth (namely barnacles) are resilient to shock chlorination; and from time-to-time extended periods of shock chlorination may be required. It is critical to minimise the marine growth in the intake tunnels to avoid additional hydraulic head loss (and thus additional energy consumption) in the tunnel – effectively the diameter of the tunnel reduces over time due to excessive marine growth. It is good industry practice to keep the intake structure clear of excessive marine growth.

It should be noted that the increase in overall seawater temperature will increase the risk of higher marine growth. Therefore, seasonal shock chlorination frequency and duration may need to increase from time to time. Prior to the Plant starting, the residual chlorine must be removed and dechlorinated. The time for this event to be resolve can take up 8 hours.

The brine discharge nozzle requires a minimum velocity to achieve the brine dispersion requirements under the current environmental licence seawater discharge conditions. The brine discharge velocity is achieved when the Plant is operating at full production rate. At High Availability the production rate is about 50ML/D, there is insufficient brine volume to satisfy the nozzle velocity in the environmental licence seawater discharge condition. The Plant design relied on deployment of marine divers to physically remove discharge nozzles and diffuser caps and replace with a ‘low production’ nozzles. Nozzle change-out takes considerable notification time to secure the contractors and align with suitable weather and allow significant time to cap the discharge nozzles. The alternative to meet the service standards is to supplement nozzle velocity with process (non-revenue) water from filtered water tank overflow and make-up water tank. The make-up flow was introduced into the Plant design to allow for short term flow variations. This bypass system avoids marine divers having to cap the brine discharge nozzles every-time the Plant flow rate is materially altered. Therefore operating in High Availability and Low Production mode, less than the full capacity requires additional pumping (energy) and additional treatment (chemical cost) to achieve the compliance discharge velocities. The additional energy and treatment cost is a trade-off for the Plant production flexibility and relatively significantly shorter ramp-up time.

The assessed implications of an issue with the marine intake and brine outfall tunnels are:

- If the Plant is asked to ramp up production when a shock chlorine vent is occurring, it may take up to eight hours for the resolve
- Increased cost allowance required to run in Low Production/High Availability Mode

5.5. Inlet Pumping station and course screens

The inlet pumping station duty-standby inlet screens arrangements permit the screens to be available at all times at all flow rates. Divers are used for preventative maintenance and conduct inspections approximately every two years which takes the system out of operations for over two days.

Seawater quality is one of the critical events that can impact on the performance of the pump station and course screens and/or impact downstream treatment processes. Typical seawater events that can impact Plant operations include:

- High rainfall event causing high turbidity that challenge the capacity of the pre-treatment system (out-of-envelope Plant design seawater quality) – see also Section 5.3.
- A swarm of jellyfish that derate the Plant capacity by blocking screens (based on previous events)
- False hydrocarbon seawater quality analyser alarm that shuts down operations to avoid RO membrane damage risks (usually occur in high rainfall events)

The assessed implications of an issue with the inlet pumping station and course screens are:

- In the event the Plant is in transition from High Availability to Emergency Response, the Plant may take considerable time to get back on-line or flush the intake tunnel to clear the poor-quality water

The duration is dependent of the situation and can range from hours to several days.

5.6. Pre-treatment Dual Media Filter

High seawater solids load events (high Total Dissolved Solids, high turbid events) may require the Plant to operate at reduced capacity until the water quality event clears. While these events have been relatively infrequent in the past, they are becoming more commonplace with high intensity rainfall events and have occurred three times in 2022 by August. The Plant was designed and constructed under the assumption of a high-quality seawater envelope. In most instances, the Plant can continue to operate at a reduced production rate to achieve the required pre-treatment water quality on a best-endeavours basis. However, poor seawater quality events will require adjustment of the pre-treatment dual media filters coagulation mixing time as well a decrease in the filtration rate. The impact may be 20-40% reduction in filtration rate resulting in a subsequent 20 to 40% reduction to production rate. High seawater solid load events may take several days to clear depending on seawater currents to return to the water quality envelope in the original Plant design and O&M Contract, and relief is given to production expectations in the case of quality outside the envelope.

Gold Coast Desalination versus Sydney Desalination Plant Pre-Treatment

The Gold Coast Desalination plant has a more robust pre-treatment filtration system to deal with poor seawater quality events with flocculation mixing tanks and a decreased filtration rate (velocity of water through the filter bed) is 7.5m/hr at full capacity. The Sydney Desalination Plant does not have flocculation mixing tanks and has a design filtration rate of 10.0m/hr. Flocculation tanks allow for more efficient mixing of pre-treatment chemical to product larger flocs to be captured by the dual media filters. Slower filtration rate provides more time for the flocs to be captured in the filter media and avoid break through i.e. the floc particle passing through the filter. The conclusion is Sydney Desalination Plant is more sensitive to changes in seawater quality. To manage this situation the Operator may slow down the seawater flowrate into the filter i.e. reducing filtration rate. This will ensure the Plant can continue to meet the reverse osmosis membrane feed water quality requirements, however the impact will be a lower drinking water production rate.

The assessed implications of a pre-treatment dual media filter system being impacted by changes in seawater quality are:

- A minor change to seawater quality may take 12 hours to adjust to achieve the required water quality
- In very poor seawater situations, it may take 48 days for the Operator to adjust the system and monitor changes to achieve the required pre-treatment water quality

5.7. Reverse Osmosis

Reverse Osmosis is the process of removing or separating salts from the seawater using a membrane to produce desalinated water termed permeate. It is energy intensive and runs at very high pressures (in the order of 65-70 bar). It is a complex process that is fully automated for safety and asset protection reasons. The system has a significant number of process interlocks and control loops, including multiple individual instruments, that all must be ‘healthy’ or within limits for successful start-up of the system (and to a lesser extent, ongoing operation). These apply to high pressure and sensitive electrical equipment running under high electrical loads (significantly higher pressures and loads than a conventional water treatment plant). This complexity introduces multiple sources of operational “trips” or unavoidable failures, and these can increase as assets age. It is normal to expect such trips and they are difficult to predict. Trips should be investigated and with some taking several days. It is unreasonable to expect all trips to be prevented and avoided, regardless of operational and maintenance practices.

The Plant was designed as a bulk water supply, as are most desalination facilities. Frequent stopping and starting of the RO units is not good operating practice, particularly with direct on-line (DOL) high pressure pumping system. Frequent starting and stopping increases the risk of damage to the membrane (spiralling) and void their warranties. These issues may cause considerable time and cost disruptions to Plant operations. It is good operating practice to limit the number of stops and start of the membrane system where possible to protect the membrane units, however there should be a trade-off between asset rotation practices and the number of starts/stops.

Reverse Osmosis Trips

Common trips on the reverse osmosis (RO) trains can be related to high pressure or over pressure. These also extend to peripheral equipment which may lead to a pressure related risk, such as momentary loss of communication from an instrument or valve which the system interprets as a threat to safety or asset protection. The RO system consists of 13 first pass and 7 second pass membrane trains. Each RO train has six pumps and an energy recovery device (to achieve the 65-70 bar) and over 30 valves with the largest pump a 2.3MW direct on-line (DOL) motor which instantaneously apply pressure into the system (pressure shock). When the Plant is in High Availability only two first pass and one second pass trains are operating, leaving 11 first pass and 6 second pass trains shut down. In the transition from High Availability to Full Production individual trains can trip frequently due to pressure related protections integral to many control sequence loops. To minimise these trips when starting an RO module, the Operator regularly cycles routinely through operation of each RO train, which creates inefficiencies but is necessary to minimise trips on ramp-up. In addition, each RO train is regularly flushed with permeate water to protect the asset e.g. to avoid the potential of membranes from drying out or irreversibly fouling when not in operation.

Other RO systems incorporate variable speed drives (VSD's) on the high pressure pumping systems both protecting the membrane from damage and the RO train equipment. A VSD allows for slower pressure increase (gradient). The result is less high-pressure trips, reduced power consumptions and flexible production rates. In addition, the new generation energy recovery devices (ERD) provide more stable operations. The Plant does not have these features. To incorporate these features, it would involve a significant redesign, capital expense and considerable time to implement. In the event a future expansion, these types of features could be considered in the design to provide high level of production flexibility.

The RO membranes are sensitive to exposure to chlorine and exposure to air. Chlorinated seawater can enter the RO system following a shock chlorination of the intake tunnel. In the instance when this occurs, the chlorine will be detect through online water quality analysers and the Plant will be shut down to either flush or dechlorinate the seawater.

The previous operating mode of zero production required the Plant to be "mothballed". The benefit of the Plant operating at High Availability is to avoid the Plant being mothballed. When in zero production (mothball) the membranes are protected in a preserving solution. This solution must be drained from and flushed from the RO vessels prior to operating, and the preservative solution neutralised and disposed of. This takes approximately one week per train to bring a single train on-line and into production mode. The system has 13 reverse osmosis units, thus taking approximately 13 weeks just to prepare the RO units from zero production to a operational state.

When the Plant is operating in High Availability mode, the majority of the RO trains are not in operation. This potentially exposes the membrane to air, or to increase risk of fouling or damage. To counteract the risk of damage, the Operator will regularly flush the membranes with permeate water (Reverse Osmosis Water). The Plant is required to produce additional permeate water (at additional energy and treatment cost) to enable flushing and the Operator will have to transition the system from flushing the RO system to an operational state to enable Plant production.

The Safety of the Operator is paramount, when working in RO process areas, due to the pressures and high electrical loads. This creates limitations in working adjacent to operating equipment. If an issue arises, or there is a trip on start-up or during operations, it may not be possible to investigate or rectify the issue without serious risk of harm to personnel, or conversely, without shutting down adjacent equipment. To ensure safety of operating and maintenance staff, some RO units will need to be stopped and depressurised.

This will restrict the total number of first pass and second pass RO modules that are available for operations. Typically, three out of the 13 units may be out of operations leaving 10 units available at certain times during the “low production period” restricting the Plant production by approximately 12%. This would be allowed for in the long-term operating context, but could reduce short-term available volume.

The assessed implications of an RO system issue are:

- RO trips can generally be resolved with 24 hours however it is possible to have numerous issues as noted above with the system potentially taking up to six days (144 hours) to resolve.
- High pressure systems pose safety risks, and thus a fault in one train may lead to multiple trains being unavailable while the issue is rectified.

5.8. Remineralisation system (Lime and CO_2 dosing)

The lime dosing system is a complex array of equipment and is best operated at a continuous constant flow rate. Typically, a lime dosing system does not respond well to large fluctuation in dose rates associated with sudden flow rate changes. The system is required to produce a high-quality saturated “milk of lime” to ensure pH and turbidity compliance at the Drinking Water Storage. In essence, the milk of lime is dosed directly into the finished product water so it is very important that the dosed product is of the highest quality. The lime system is different to other chemical dosing systems as it is not just a matter of increasing a dosing pump speed to increase the dose. The system, instead, is a treatment process in itself. It takes powered lime, mixes it with permeate to create a slurry of varying concentration dependent on the production capacity of the plant, transfers the slurry to a saturator where it is mixed with further permeate, facilitates settling of any impurities in the solution within the saturator, and then separates out a pure ‘milk of lime’ or limewater for dosing into the final drinking water. The system relies on a steady state lime ‘sludge blanket’ in the saturator and it takes time to perfect this steady state.

In the case of the Plant, a production rate increasing from 20% to 80% is a significant transition from High Availability to Full Production. A Full Production ramp-up requires the lime saturator to produce the correct consistency of “milk of lime” from the lime saturator. This can take several days and sometimes up to a week or longer to perfect. The following points expand on the complexity and limitations of the current lime dosing design.

In High Availability mode, one lime storage silo may be emptied to avoid the lime in the silo and surrounding the lime feeder (incline screw) absorbing moisture from the atmosphere. This is most likely to occur when equipment is static and not operating. Hydrated lime when exposed to moisture in the atmosphere will harden. Once hardened, it requires significant time to clean out the screw feeder, as the hydrated lime hardens over time when exposed to long term moisture. In addition, lime arching/bridging in the lime silo may occur resulting in no lime being able to be feed to the feeder equipment. It is good operating practice to minimise the lime volume in storage to ensure a reasonable turn-over of the hydrated lime in the lime storage silo and feed equipment. This minimises the time lime is exposed to moisture in the atmosphere i.e., absorbing moisture and setting hard within the silo and the feeder equipment.

In the High Availability mode, only one lime saturator unit operates, and two units are shut down (there is not sufficient throughput to operate more than one saturator). These two units must be brought online from a complete shut-down situation. As discussed above, it takes time to develop the sludge blanket and have the system operating in a reliable steady state.

The start up the of the two lime saturators takes considerable time to produce good quality saturated lime. In the interim, it is required to bypass much of the permeate to the outfall as non-revenue water until the water quality is stable. To produce drinking water quality with a turbidity of less than 0.5NTU consistently, it can take several days before the lime is at full reliability to meet water quality. Overall, a fully operating lime system is less problematic than a stop-start operating lime system.

The assessed implications of a lime system issue are:

- Lime dosing issues can reasonably resolved in 24 hours but have been known to take up to seven days to work effectively from a complete restart.

- Starting a lime system or increasing its throughput requires a long period where permeate is diverted away from the treated water tank. During this period, the water is not generating revenue and thus there is additional treatment and energy cost which is not compensated through the volumetric water charge

5.9. Drinking Water Storage and Drinking Water Pipeline

There are a number of parameters to ensure drinking water compliance at Sydney Water's Erskineville Shaft 11 delivery point. Each parameter impacts on each other, and it is good operating practice to modify one parameter at a time to ensure the safety and stability in the system. While there is water quality measurement at the drinking water pump outlet, there is a resultant travel time of water within the pipeline before the effects of any dosing changes can be measured at the delivery point. The key parameters that have an impact are:

- Drinking water storage tank level set-point
- Chlorine residual set-point in the drinking water tank
- Water temperature
- Drinking water pump station flow rate
- Drinking water storage tank inlet flow from the Plant
- Detention time in the drinking water storage tank and delivery pipeline
- Chlorine and ammonia dose rates

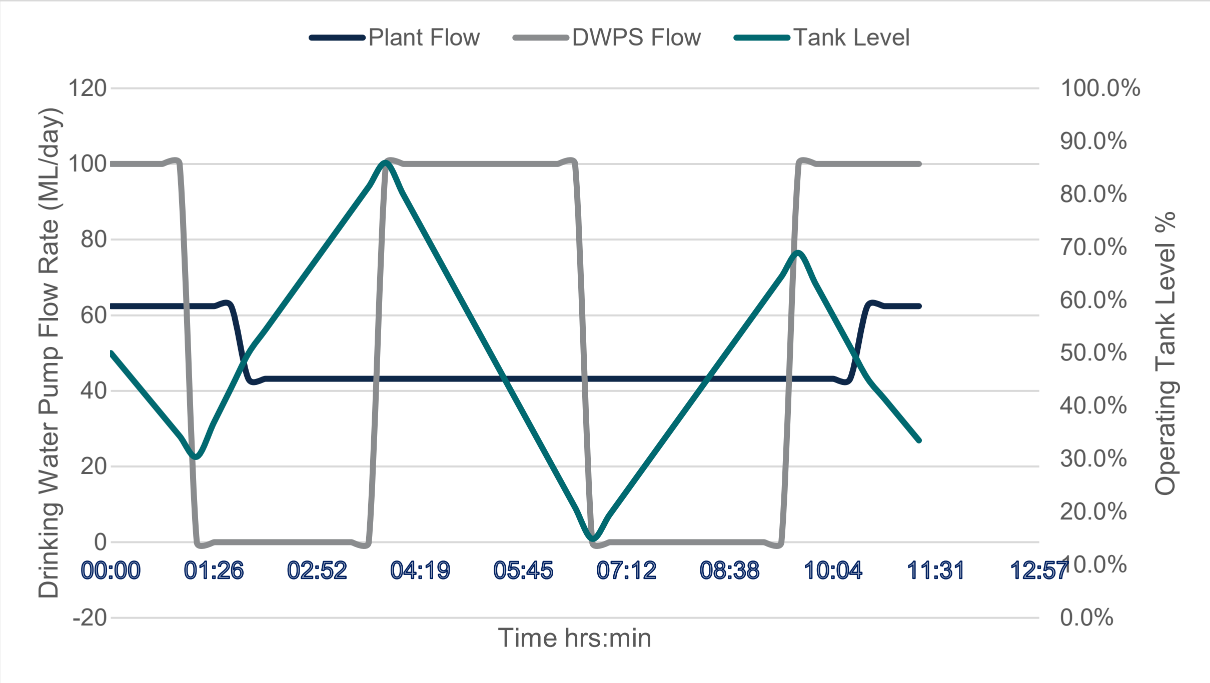
The assessed implications of transitioning the drinking water storage tank and drinking water pipeline to a to full production are:

- For the transition from High Availability to Full production, the operator will typically take four hours to make the necessary adjustments to manage this process and it could take up to eight hours to get the treatment process to into steady state compliant drinking water.

5.10. Drinking Water Pump Station

As noted in Section 2, the Plant and the drinking water pump station were designed and constructed under two separate contracts. While the Plant has some flexibility in drinking water production, the drinking water pump station has a limited operating delivery profile. The minimum flow is 90 ML/D. It is good operating practice to match the production profile of the Plant to the pump station operating flow to minimise the number of stops and starts of the drinking water pumps and resultant stop and start of chemical dosing dependent on the pump station running. Chart 5.9-1 details the typical frequency of stopping and starting of the drinking water pumps while at low production rate and varying tanks levels.

Chart 5.9-1 Drinking Water Pump station level, Plant flow and Drinking Water Pump station flow vs Time



At High Availability (23GL/year) it is not ideal to have drinking water pumps operating in a frequent stop start sequence. This has potential to cause faults and trips with the chlorine and ammonia chemical dosing systems (together termed Chloramination[1]). The chloramination system must be carefully monitored to ensure suitable disinfection and chlorine residual compliance at Erskineville. In the event of instability in the chloramination of the pipeline, a critical control point (CCP – an important check and balance to ensure the safety and quality of the final product water) would be triggered that would likely automatically shut the Plant down. The water in the pipeline may also need to be purged with water from Sydney Water's network. This is both very time consuming (hours to days) and can cause the wastage of the entire pipeline volume (about 46ML) due to the non-compliance.

Note also that, while unrelated to start and stop of the drinking water pump station, if the lime system is not stable and low quality limewater is dosed into the drinking water tank, it may also trigger a CCP transfer pump trip and lead to a required pipeline (and drinking water tank) purge.

It is good operating practice to operate the Plant production rate to match the minimum drinking water pump flow rate of 90ML/day to minimise the stopping and starting of the drinking water pumps and the associated stop start of the chloramination dosing system. This ensures water quality compliance and avoids excessive wear and tear on the drinking water pumps. However, operating in this minimum production mode would produce a minimum of 34GL/year The trade-off for this additional significant operational risk is the lowest annual production volume. Operating at 23 GL/year saves customers the cost of approximately 11GL per annum i.e. 23GL/year versus 34GL, but does introduce some process and asset risk.

Increasing production rates requires additional drinking water pumps, which like the RO high pressure pumps, can sometimes trigger a fault/trip and shut the drinking water pump station down. It takes over 40 minutes to reset the pumping station and this, in-turn, can induce a daisy chain of events on the Plant and shut down the whole desalination process, which will significantly delay production.

The assessed implications of a drinking water pump station outage are:

- Whole of Plant restart due to drinking water pump station failure can reasonably take four to 12 hours to reset the plant depending on the situation.

[1] Chloramination is **the process of adding chloramine to drinking water to disinfect it and kill germs**. It is sometimes used as an alternative to chlorination. Chloramines are a group of chemical compounds that contain chlorine and ammonia

5.11. Electrical, Instrumentation and Control Equipment

The Plant is a fully automated and was not designed to operate in manual with hands on operator intervention. In-order for the Plant to operate in automatic, several conditions (too exhaustive to list) must be met for both safety and process reasons. The Operator must ensure all of these conditions are fully met prior to starting the Plant. In the event one of these conditions fail the Plant will shut down. With every shut down event, the reason for the fault must be investigated and rectified to enable the Plant to start again. The following section details the key issues that could occur in normal operations that can impact on the availability of the Plant.

5.11.1. Variable Speed Drives

When the Plant is operating in High Availability mode, a number of equipment items (typically pumps) will not be in an operational state i.e. switched off. A high portion of these equipment items have variable speed drives (VSDs), which sit between the electrical supply and the motor to regulate the power that is fed to the motor and control the speed or the torque of the pump. It is not ideal to leave VSDs non-operational for extended periods of time due to the fact they lose what is known as capacitance due to their sensitive electrical nature. When the VSD unit re-starts from a period of non-operational performance, it may fault. Sometimes, it can be a simple reset of the VSD to clear its faults or it may require a service by a specialist contractor. In the worst case, a capacitor may need to be replaced. This exact situation occurred after the mothball period when the majority of the VSD capacitors had to be replaced as a periodic maintenance task. It is good operating practice to electrically exercise all VSDs on a quarterly basis (four times per year) to ensure they are readily available and minimise potential start up faults. The impact of VSD faults is significant as the equipment item is usually part of a control sequence and must be available for key pumps to operate.

The assessed implications of a VSD failure are:

- Depending on the size and location of the VSD it would typically take at least 12 hours and up to a maximum of three days to replace a capacitor

5.11.2. Lightning storms

In storm events, lightning can cause significant disruption to the Plant. While the Plant electrical and control system has lighting protection, these types of storm events can cause issues with sensitive electrical instruments and often result in equipment faults and trips, resulting in either resetting, reprogramming and/or even replacement of these instruments.

The assessed implications of a lightning storm/strike are:

- A typical instrument replacement would reasonably take eight hours
- Depending on the type and location of the instrument, the impact on the control of the Plant may take 12 hours before the relevant qualified team member is available to rectify replace an instrument.

5.11.3. High Voltage 132KV Switchyard

The Plant has redundancy available on the majority of its 132kV infrastructure, the exception to this being the 132kV incomer itself. There remains only one cable and circuit breaker that bring the incoming 132kV feed into the Plant, before it is then transformed down to 11kV and distributed through the Plant.

Faults on the incomer are uncommon but have occurred in the past and present a significant recovery risk should they occur.

A further complexity with the high voltage equipment is the interaction with Ausgrid, who operates the local electrical distribution network. As SDP is a significant energy user, any trips, repairs, tests and works conducted on the 132kV infrastructure typically involve Ausgrid via an exchange of operating protocols, however Ausgrid has the final say on timing of outages. Whilst the Operator makes all efforts to work with Ausgrid and maximise efficiencies between parties, ultimately, there remains significant potential risk to the operation of the Plant should Ausgrid be unable to provide the 132kV power supply.

The assessed implications of a high voltage outage are:

- The majority of high voltage events can generally be resolved in in two days.
- These events can vary depending on the type of event, however a major event can take up to 14 days to rectify as the Operator has experienced in the past.

5.11.4. Instrumentation and Profibus

All of the Plant signalling and messaging infrastructure relies on instrumentation that is connected to the programmable logic controllers (PLCs) via the Profibus network. The network can be sensitive to connection issues. This control instrumentation is critical to successfully operating the Plant. On a complex automated water production facility operating in a moderately aggressive seawater airborne environment, sensitive electrical, instrumentation and control equipment will be impacted and there from time-to-time corrosion will occur on the PLC connections.

In general, electrical, instrumentation and control equipment do suffer breakdown and faults from time to time and are sometimes only discovered on start-up of equipment when the PLC is activated. Issues can be time consuming to fault find and requires specialist electricians or high voltage technicians.

The assessed implications of a communication/instrumentation fault are:

- It is reasonable to expect instrumentation and control events to be resolve 24 hours
- Instrument and Profibus events can reasonably take up to three days (36 hours) to identify and rectify

5.12. Sydney Water Delivery point at Erskineville (Shaft 11)

Shaft 11 at Erskineville is the final compliance point before the water is delivered to Sydney Water. The following issues may impact on the Plant when transitioning from High Availability to Full Production:

- Sydney Water's ability to accept the water due to issues in the network when ramping up from High Availability to Full Production.
- When the second drinking water pump is introduced for higher production rate, the delivery pipeline may show a temporary spike in turbidity. This is due to the high velocity in the pipeline disturbing the settled sediment. It can take up to five days to have water quality samples within required limits as well as the potential to block the sample line needle valves (fine aperture valves for the sampling line). Non-compliant water can also be rejected by Sydney Water and this has a major impact with respect to Plant downtime (i.e. having to purge the pipeline)
- A non-compliant water quality event can be resolved by a purge. A purge is an event where the pipeline is replaced with drinking water from Sydney Water's network (i.e. reverse flow). Purging the pipeline, utilises the drinking water storage tank by-pass and sends the non-compliant water to the brine outfall. Typically, such an event will reasonably delay Plant operations by 12 hours.
- If non-compliant water is produced during the ramp up of production due to remineralisation system or changes in chlorine dosing it could take up to 36 hours to rectify. In this case the treated water tank may need to be manually drained in addition to the purge of the delivery pipeline. In this instance and the above case the EPA must be notified 72 hours prior to release of the drinking water.

5.13. Seawater Water Quality

Poor seawater quality issues typically coincide with heavy rainfall events which exceed the seawater total suspended solids (TSS) envelope of the Plant design. This occurred in February 2021 and March 2022. These events require considerable change in the operation of the pre-treatment system, notably chemical dose rates and potential filtration rates to achieve the required water quality for the Reverse Osmosis membrane system. It can take several days for the pre-treatment dual media filters to achieve the required water quality before the water is in compliance with the membrane warranty requirements (i.e. Silt Density Index (SDI) limit less than 3, 90% of the time with a maximum of SDI of 4). The pre-treatment system will waste filtered water via the filtered water overflow until the required RO water quality is met.

Jellyfish events can reduce the filtered water production due to heavy loading of the Dual Media Filters and the Plant may need to stop or reduce capacity when in full production. Jellyfish events have occurred previously at the Plant and can last for several days.

The assessed implications of a jellyfish event are as follows:

- A minimum impact of 0 hours to production, based on best case scenario that minor jellyfish intrusion is removed via the existing screening system without impact.
- A reasonable impact of 12 hours to production, based on a likely scenario whereby the jellyfish intrusion results in the inability to bring seawater into the Plant and direction of resources to clear the blockage over a typical shift.
- A maximum impact of 72 hours to production, based on a worst-case scenario where jellyfish completely overwhelm the intake system, resulting in multiple days of cleaning and/or specialist equipment (e.g. cranes/excavators) to remove.

5.14. Supply chain and access to the site

In recent times, supply chains have dramatically changed due to availability of various critical supplier inputs including but not limited to:

- Bulk treatment chemical
- Instruments and PLC cards
- Laboratory supplies
- Pump seals and consumables

5.14.1. Bulk Chemical Stock levels

Transition from High Availability to Full Production will require higher bulk chemical storage stock levels. While ramp-up in a short-term duration will be possible, long duration Emergency production durations may be impacted by the chemical supply chain. (i.e., a 70% to 80% increase in chemical inventory will be required to be called on within days of a Plant ramp up). A reasonable duration of months will be required to provide chemical suppliers sufficient time to secure raw material to meet new supply requirements.

During high rainfall events, access to the site has been limited due to localised flooding. This can result in restriction on chemical deliveries. Such events may typically coincide with Emergency response requests from Sydney Water to ramp-up and consideration should be given to the ramp up time from High Availability to Full Capacity. It is worth noting that it is not reasonable for the Plant to maintain full bulk chemical storage stocks to meet a potential emergency request. Various chemicals have short shelf lives and storing excess chemicals may lead to wastage.

The assessed implications of a chemical supply issue are:

- A reasonable impact of 12 hours to production, based on disruption to planned chemical deliveries
- A maximum impact of 5 days to production, based on a worst-case scenario where chemicals cannot be sourced quickly and the event to transition to higher levels of continuous production does not provide suitable lead time.

5.14.2. Critical Spares and plant consumables

It will be important for the Operator to regularly review and assess the critical spares inventory in light of the slow supply chain issues. What once was a stock standard spare on a stockist shelf in Australia may not be readily available, and hence may become a critical spare. This is particularly important when the Plant is required to be in Full Production mode. Delay to critical control instrumentation replacement could take up to 48 hours assuming express international air freight.

5.14.3. Electrical components and instrument consumables

Instrument probes/sensors for control instrumentation are essential to operate the Plant. Instruments that are not operating while 80% of the Plant is not in production can deteriorate or foul prematurely. On ramp-up the probes/sensors may require replacement and then recalibration. If higher than expected probe/sensor replacement and spares are not available on site; the Operator could first seek replacement from either the supplier and then from its' network of other operational water and wastewater plants across Australia. These types of parts are generally able to be express freighted overnight and can delay the ramp-up or limit to full production depending on the time for delivery.

5.15. Resource Management and Maintenance

Timing of an emergency notice could impact the ability of the Operator to respond appropriately. Notification during normal business hours can be responded to immediately. After-hours response may be impacted by the limited resources that are actively onsite. The Plant is fully staffed during the normal business days (nominally 7am to 3pm Monday to Friday), and then has a skeleton staff of two outside these hours. A higher level of skilled staff can be made available after hours however this is a trade-off of the additional cost and productivity. High level of nightshift staff is not prudent and efficient.

When transitioning from a High Availability to Full Production, a series of checks and setpoints must be reviewed to prepare the Plant for the new production mode. This is to minimise trips, faults, and ultimately time-consuming restarts. The checklist is comprehensive and onerous. While some parts of the Plant operations are automatic, for example the reverse osmosis trains, it still requires some skilled field work to prepare.

Attempting to ramp-up production outside normal business hours can be achieved when staff levels are low. However, this adds additional risk to the asset and operations staff. In the event of a high voltage electrical and/or high-pressure system fault trip, the issue can be investigated or rectified by the on-call maintenance technicians. In many cases, it may require specialised external contractors or complex isolations and permit to work processes which cannot be achieved out-of-hours.

In addition to planned maintenance tasks that require the Plant to be fully and partially offline for long periods (assets sent off site, works requiring time-consuming dismantling of assets or preparatory works such as scaffolding), there are regular (almost constant) requirements to isolate and work on assets which limit the ability of the Plant to operate to full capacity.

The two most recent emergency response ramp-up requests have been notified at a time when the Plant is least ready, on a weekend afternoon and late on a weeknight. These emergency response ramp-ups were a result of unprecedented rainfall, and resultant challenges in the Sydney Water network. It is important to note that the Operator is most likely to have the similar issues at this time and difficulty in securing expert contractors as they are responding to similar issues for other critical parts of the network.

Safety of Operator

For example, each reverse osmosis train requires ongoing routine maintenance, due to its high-pressure operational requirements, need to be expertly isolated under permit, and then restarted under an exclusion zone to prevent potential injury. The loss of one reverse osmosis train will reduce Plant capacity by approximately 10%. While these assets can be put back into service at short notice, it may still require up to 24 hours before it is available to start a ramp-up, let alone be available for consistent production. This task also requires valuable resources at a time when resources are inherently scarce as they are preparing other assets for quick restart

5.16. High Availability and Emergency Response

The High Availability service standard provides Sydney Water and customers with the lowest possible overall cost solution to ensure the Plant is readily available for emergency response. The benefits are:

- Lowest possible operating cost
- Routine, regular, high-quality, consistent supply keeps the Sydney Water network stable
- Ability to ramp up at best in 24 hours and at worst in 10 days to full production

However, there are some trade-offs and limitations in operating at High Availability as follows:

- Inefficiencies with respect to power, chemicals, maintenance and labour (losing economies of scale)
- Operating at the limits of the Plant's capabilities to meet both water quality and environmental compliance (the Plant is more sensitive to minor changes, making it more difficult for the Operator to change)
- Exposure of portions of the Plant to additional risk, wear and tear
- Exposure of non-operating and static equipment to trips, faults and blockages

In determining the ramp up period, consideration needs to be given to the variable of the numerous circumstances noted in Section 5 of this report that could impact on the Operator and Plant's ability to achieve full production. Table 7.1 Represents the total time delay assuming minimum, average and maximum impact of the event. Sequential events have been assessed as average and worst cases assuming some events can occur concurrently. Table 7.2 calculates an overall probability range of all events occurring.

Table 5.1 Summary of assessed potential impact events

Report Reference	Event	Type	Minimum time to resolve event (hours)	Average time to resolve event (hours)	Maximum time to resolve event (hours)	Average Case Sequential events (hours)	Worst case sequential events (hours)
5.1	High Rainfall event	Restricted Access to site	2	8	24	8	24
5.3	Intake Tunnel	Shock Chlorination	0	4	8		
5.4	Seawater Quality	Jellyfish or red tide event	0	24	72	72	72
5.13.1	Supply Chain	Bulk Chemicals	6	24	120		
5.13.2	Supply Chain	Instrumentation replacement	6	12	36		
5.5	Pre-treatment Dual Media Filter	Change in seawater quality	12	24	48	48	48
5.6	Reverse Osmosis	Over Pressure and/or ERD Faults one module	1	2	4		
	Reverse Osmosis	Over Pressure and/or ERD Faults all modules	1	24	144	144	144
5.7	Lime System	Dry side blockages	4	12	48		
		Lime saturator start-up	12	24	168	168	168
5.8	Drinking Water	Chemical dosing set points and control steady state	2	4	8	8	8
5.9	Drinking Water	Drinking Water Pumps station	2	4	12	12	12
5.10.1	Lightning Strike	Profibus PLC Card replacement	4	8	24		
5.10.2		VSD restart or replacement	6	12	36	36	36
5.10.3	Ausgrid	HV Switchyard	12	48	168	48	168
5.10.4	Controls	Instrumentation and profibus Control system issues	6	12	36		
5.11	Delivery Pipeline	Water quality issue and reverse flow the pipeline	6	12	36	35	36
		Total Hours	**54**	**258**	**992**	**579**	**716**

To estimate a maximum reasonable period for the Operator to ramp up the plant from 50ML/day to 250ML/day, the total delay time is summed using the total of sequential events. The calculation in Table 7.2 is the probability multiplied by the total sequential hours of all events. It is highly unlikely that all events will occur at once. It is responsible to assume at worst case, a 30% probability has been recommended as fair and reasonable periods for half and full rate production rates.

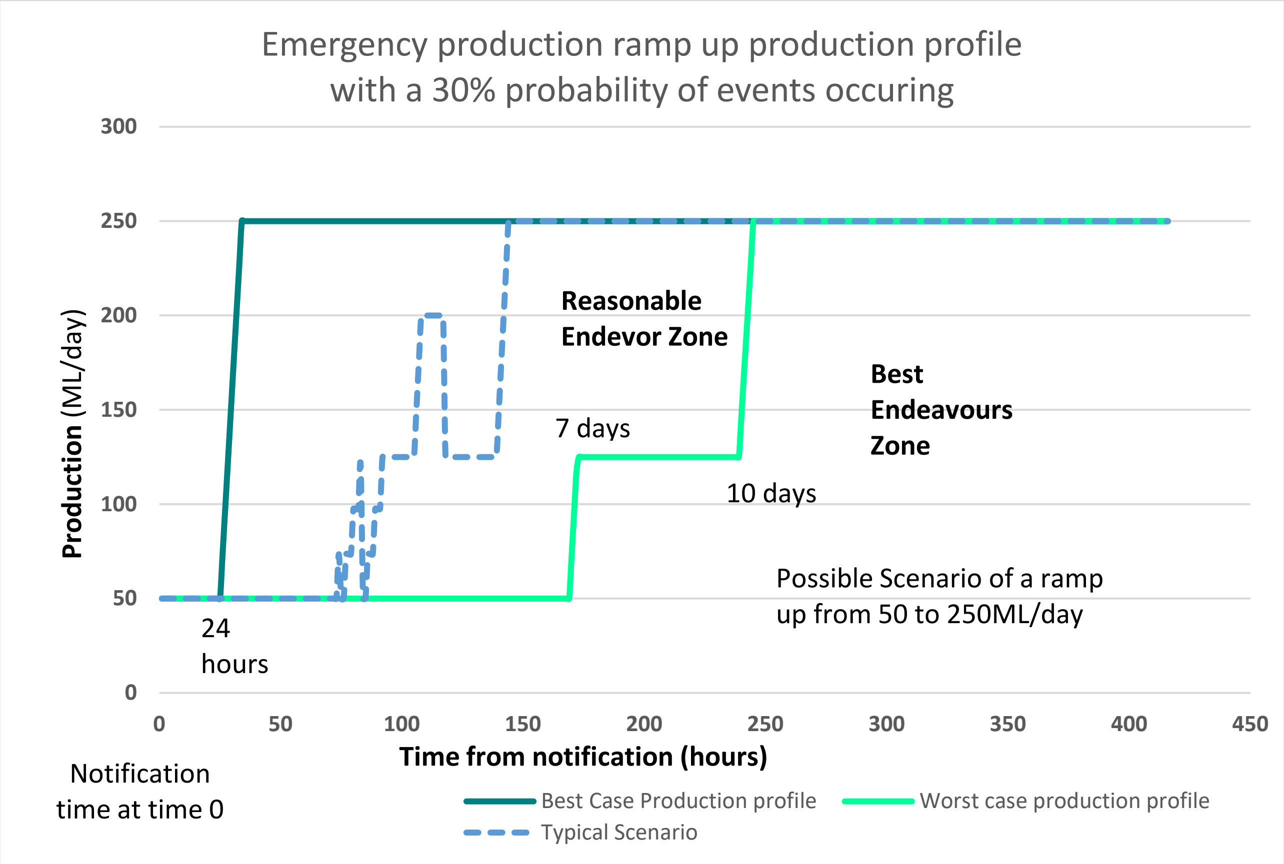
Table 5.2 Probability Assigned to worst case scenario

	Average case	Worst case
Probability	total hours x probability (hours)	total hours x probability (hours)
10%	56	80
20%	112	159
30%	168	239
40%	224	318
50%	280	398
60%	335	478
70%	391	557
80%	447	637
90%	503	716
100%	559	796

While it is theoretical possible to start production within 24 hours, taking the events above in to consideration and assuming a 30% probability of the above events occurring at any one time, it has been assessed and evaluated that 168 hours (7 days) would be reasonable for an operator to ramp up facility to produce fully compliant water from the first 125ML/day module and 239 hours (10 days) from the second module. This would be a reasonable worse case to reach stable continuous production based on an Operator being diligent and having suitable capable resources at hand.

Chart 5.1 represents a time zone whereby it is fair and reasonable for the Operator to ramp up from High Availability to Full Production requirements.

Chart 5-1 Ramp-up profile (High Availability to Emergency Response)



5.17. Planned flow request (specific event) and or Annual production.

A one- and two-month allowance to transition from High Availability to Planned flow request (specific event or annual production request respectively) is sufficient to achieve the desired production. The ramp up time from date of the water production request is likely to be up to 174 hours to achieve the required production level with stability of operation, noting all of the same issues in Section 4, with the exception that the Operator will be able to plan around essential maintenance interventions.

5.18. Planned flow request full rate.

A two month allowance to transition from High Availability to Planned flow request is sufficient to achieve the desired production level. The ramp-up time from date of start of water production request is likely to be 10 days to achieve the required production level, noting all of the same issues noted in the above section 4 with the exception that the Operator will be able to plan around essential maintenance interventions.

5.19. Mothball

The author notes that there is no provision for Mothball in the Service Standards. Mothball is not a recommended operating mode due to the time and effort it takes to restart the Plant, i.e. in the order of 9 to 10 months and considerable cost in the millions of dollars and the significant cost to restart the Plant.

6. High Availability mode - Baseline Production

A High Availability operating mode is unusual for large scale water treatment and desalination plants. Desalination plants are generally designed as bulk water production facilities and are best operated a constant continuous rate. They are not designed to ramp up and down on a frequent basis.

The new GSWS and SDP's Network Operator's Licence requires the Plant to be operated in a high-level flexible environment that includes the following key elements:

- That the Plant provides a minimum baseload volume each year to achieve the desired performance as set out below
- That the Plant can respond to shocks in the network, as required by the agreements between SDP and Sydney Water
- That the volume of water produced by the Plant can be varied as needed (in line with the Decision Framework) to support the resilience of the system, including to slow down dam depletion during droughts and keep dam levels higher when needed, but also to be decreased when dam levels are high in order to minimise the risk of spills and maintain cost effectiveness.

To provide these requirements with the current configuration of the Plant, the Plant will need to be operated at its extreme limits. The Plant has been designed as a continuously operated base load Plant. It should be noted that this flexibility comes at some additional cost, both fixed and variable.

This section considers the minimum production volume needed for the Plant to remain available, to provide both the level of service required under the GSWS and SDP's Network Operator's Licence and providing the lowest cost to customers. When assessing the minimum operational downturn of the Plant to achieve these outcomes, there are several key constraints that limit the extent by which the Plant can be reduced (in terms of output) while always providing the operational availability required. These include:

- The minimum hydraulic limit of the RO process to produce permeate, which requires two first pass, and one second pass train to be operating, is no less than 50ML/day, and under stable operation is usually grater than this
- The volume of the delivery water Pipeline, which is approx. 46ML to enable regular turnover of this volume to prevent water quality issues

Whilst the Plant does feature a 40MLD drinking water storage tank, which can be used for storage of treated water, the need to displace the pipeline volume regularly also becomes a limiting factor. The delivery pipeline remains full, even when the drinking water pumps are not operating, and this presents a water quality risk, whereby the pipeline volume will age, and deteriorate, leading to a potential breach of licence and/or drinking water specifications.

> ***On this basis it is reasonable and efficient to assume the Plant should endeavour to transfer at least 50 ML each day (being slightly greater than the approximate pipeline volume), and produce at least this much daily also.***

In addition, stop start approach to water production is not good operating practice for the RO systems, stability of the remineralisation system (lime and carbon dioxide chemical dosing systems), stability of the pre-treatment system to maintain RO feedwater quality and for various other reasons, particularly as outlined in Section 5 of this report.

> ***On this basis it is reasonable and efficient to assume that the Plant should, where possible, be kept continuously producing desalinated water and in an operational state***.

To keep the Plant operating in a continuous manner and always available to ramp up quickly in response to a production request, which will also reduce the likelihood of trips/ faults on RO system start-up, the minimum configuration of the RO process will result in around 50ML of permeate being produced each day. However, in the two first pass and one second pass train configuration (being the minimum stable configuration) there is inherent variation in the daily production output as follows:

- Each first pass RO train minimum design production rate is about 22.5 ML per day in order to meet the minimum annual production of 91.25 GL at 94% availability, however this production assumes the outer boundary of the design operating envelope (i.e. salinity, temperature and membrane performance will materially effect permeate quality, the proportion of water required to be treated through a second pass, and therefore the final permeate production rate).

- However, when operating the Plant at good/best practice, with well managed membrane performance and average seawater salinity and temperature conditions, it is possible to produce at a higher rate.
- It would be inefficient to artificially cap production by turning off RO trains, so it is prudent to make an assumption that daily output could be assumed as ~10% higher giving a limit of 55 ML/day.

(Assumption 6.1) *55 ML/day is a reasonable basis of calculating an efficient annual baseline production.*

It should be noted that the lowest possible operating cost to meet the level of service requirements is when the Plant is operating at ~50-55 ML/day. However, running at this low rate continuously puts the Plant and the operations at considerable additional risk. Furthermore, only operating at a low flow rate without operating at full production from time to time puts the Plant at additional unnecessary risk of further trips/ faults and water quality issues. Recent operational experience has provided the Operator with plenty of learnings about many aspects of the Plant operations that include operating at low flow and full production rates to ensure it continuously meets environmental compliance and contractual compliance requirements. It understood that this new operating environment of High Availability will likely lead to multiple different operating and production levels over a typical year.

Further to the minimum downturn of the Plant to produce 50-55 ML/day and to best ensure the ability of the Plant and operations personnel to respond to an emergency request and test equipment after a major overhaul, it is good operating practice to operate at full production at least four times per year for a reasonable extended period (up to a full week). The key benefits in operating periodically at full production are:

- The Operators are well rehearsed in ramp-up from High Availability to Full Production and are better equipped to meet the emergency ramp requirements and understand the issues as noted in this report i.e. understand what can go wrong when in transition.
- Allows SDP and the Operator to better understand the key issues and develop and test improvements in the current Plant design to minimise risk and cost.
- Better understand Plant operating mode issues for future expansion to ensure these are feed into the design criteria for the expansion.
- Ensures that all Operators have been involved in at least one or two ramp ups per year. Shift rotations do not always allow for everyone to experience a ramp-up and go through the additional checks required to be conducted when ramping up from High Availability to Full production
- The Operators can understand the seasonal impacts and water chemistry when operating in Full production mode (i.e. as previously explained, there can be material differences in permeate quality and output quantity depending on the feed seawater conditions and it is important that these effects are understood over time, particularly as membranes age)
- Good turnover of chemicals at high production rate to avoid blockages and build-up at lower pumping rates and pipe velocities
- Gives the Drinking Water pumps an extended period to operate noting the daily stop start nature when operating at High Availability.

(Assumption 6.2) *Quarterly ramp-ups to full production, comprising 12 days at 250 ML/d in total is reasonable and efficient to allow the above considerations to be met. It would be expected that such ramp-ups durations and frequencies could be flexible such that longer or shorter periods of full production could be chosen (i.e. a 7 day and a 5 day ramp-up, a single 12 day ramp-up)*

Other considerations also need to be taken into account when operating a desalination Plant as per Good Industry Practice. These include the following maintenance considerations:

- Testing of equipment that has been overhauled/repaired to ensure is working correctly when the Original Equipment Manufacturer is on site
- Keep the transfer pipeline clear of any accumulated sediment. Consistent high flow to flush out any sediment that may accumulate at lower transfer rates/pipeline velocities. Ensure that when drinking water is needed by customers upon a ramp-up request, that the quality that leaves the Plant is reflected in the water at the delivery point.

- Keep the intake pipeline clear of any accumulated sediment. Draw through any sediment that may accumulate at lower transfer rates/pipeline velocities. Ensure that upon a ramp-up request, poor inlet quality due to stirred up sediment does not challenge the pre-treatment (although this could also be achieved without operating the RO).
- Allow the Operator to test Reverse Osmosis membrane following a replacement event and or proving of equipment after a major overhaul

(Assumption6.3) *An assumption of a monthly run up to full production over a day is reasonable and efficient to allow the above considerations to be met. Given a quarterly ramp-up is assumed above, and that a ramp-up over 24 hours would include periods of increasing and decreasing production, and assumption of 8 days at 190 ML/d has been assumed for the calculation*

Further considerations have been made as follows:

(Assumption 6.4) *It is expected that Sydney Water will request increases in production at various times over a year. In order to meet the production request over the period requested, the Plant will need to ramp-up prior to achieve stable operation. No allowance has been added for this – it is assumed that any ramp-up will then lead to a reduction in the volumes estimated under 8.2 and 8.3.*

(Assumption6.5) *The Operator will need to cease production from time to time for planned maintenance. Based on recent practice, 12 days of shutdown per year has been assumed for this purpose.*

Table 8.1: Baseline production estimate

Index	Assumption Basis	Days	Production (ML/day)	Total (GL/a)
6.1	Minimum production	333	55	18.3
6.2	Operational readiness and performance assessment	12	250	3.0
6.3	Prudent Maintenance	8	190	1.5
6.4	Production Requests	*	-	-
6.5	Maintenance shutdowns	12	0	0
	TOTAL Baseline Production	**365**		**22.8**

* Addressed by reductions in assumptions 8.2 and 8.3

The trade-off for good operating practice is the additional production of water. The benefit to Sydney Water and customers is lowest possible production volume with high flexibility and reliability. Based on the operational experience at the Plant, the limitations of the original design, and the requirements the Plant needs to satisfy, a minimum volume of 23GL is considered both prudent and efficient.

7. References

7.1. Documents supplied

1. Memo – Basis of 23 GL per annum
2. Ramp up Wednesday 2nd March 2022.
3. Final Draft Decision Framework for SDP Operating
4. O&M Deed Schedule 23 Basis of Design Construction (existing plant).
5. Water Delivery Alliance Basis of Design
6. Draft – SDP Network Operator Licence August 2022

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