Upper South Creek Advanced Water Recycling Centre – Response to Request for Information 42286993 – waterway health

11 July 2022

Attachment A – Response to EPA comments on design matters
Attachment B - Detailed responses to comments on hydrodynamic and water quality modelling

Table 1 NSW Environment Protection Authority

This table provides a summary response to issues raised by the EPA on waterway health. Attachments A and B include a more detailed analysis of these matters.

Recent productive discussions with EPA and DPE have helped Sydney Water better understand the key areas of concern in the latest EPA comments dated May 2022. Sydney Water has prepared the response below considering how to inform all parties to support sound decision-making in approving Stage 1 of the project.

As discussed, the response outlines why wet weather releases from the treatment plant are unavoidable and addresses the questions raised by EPA including where infrastructure improvements have been considered and why Sydney Water has decided for or against those mitigations at this early stage in the new Advanced Water Recycling Centre's (AWRC) development.

Importantly, the response shows the potential for primary treated releases to South Creek assessed in the Environmental Impact Statement (EIS) are highly unlikely in the early years of plant operation given inflows to the plant will be very low at this stage compared to the size of treatment capacity, especially the inlet works and primary treatment units. This allows time to monitor actual impacts, to better understand the nature of incoming flows as the catchment develops and to use this information in designing future AWRC stages.

Sydney Water is committed to ongoing dialogue with the EPA to achieve positive environmental outcomes for the AWRC facility. Sydney Water is committed to protecting the environment in Western Sydney as urbanisation and population growth occurs and is pleased this project will provide options in the future for how the infrastructure can be developed.

Issue	Response
How will inflows to the AWRC and primary treated releases change over time?	The AWRC will be designed to treat dry weather wastewater flows to a standard that exceeds other plants in Sydney. It will capture six times Average Dry Weather Flow (ADWF), treating up to three times ADWF to tertiary quality and up to 1.3 times ADWF to advanced quality. This approach allows Sydney Water to balance wet weather management with protection of the biological treatment processes for dry weather flows and the operational limitations of reverse osmosis treatment units. The AWRC will provide a benefit for the Nepean River by releasing advanced quality water, and a new source of recycled water to offset our drinking water supplies. During wet weather, it also includes release of tertiary treated water to Nepean River and advanced treated water to South Creek. In extreme wet weather events, the releases to South

Issue	Response
	Creek will also include primary treated water blended with the advanced treated water. This is unavoidable but can be well managed as envisaged in the project's reference design and as the AWRC develops over time. The EIS assessed a worst-case scenario for Stage 1 of the project, assuming 50 ML/day of ADWF to the AWRC. Current predictions suggest these flows will not be reached until about 2037 or 2038. When the new plant commences operations in 2026, inflows will be about 2 ML/day and increase over time in line with population growth. Figure 1 below shows Sydney Water's current forecast flows to the AWRC, which may change depending on how the wastewater catchment develops. Corresponding wet weather releases will also be low in the early years of operation and increase over time. Sydney Water has completed further analysis to estimate annual volumes of primary treated water released to South Creek in the first five years of operation: • From 2026-2028 our modelling suggests primary treated releases are highly unlikely. • Primary treated releases are modelled to be about 3 ML/year in 2029 and 11 ML/year in 2030. This compares with the 206 ML/year estimated when the AWRC is operating at 50 ML/day. This shows in the early years, there is capacity in the AWRC for wet weather flows as growth occurs and it will be about a decade after it starts operating before the full extent of the impacts predicted in the EIS will be realised. Sydney Water considers this time period presents a good opportunity to monitor waterway impacts of Stage 1 (as outlined in measures WW22-WW34 in Appendix B of the Submissions Report) and better understand development in the wastewater catchment. This will provide a sound basis to inform design of future AWRC stages. Sydney Water is keen to retain optionality for the design of future stages to adapt to this information and incorporate any future technologies that may be available. Stage 2 of the project will require an Environmental Impact Statement and Sydney Water considers this would be an appropriate document to consider and assess

Issue	Response
	these factors.
What benefits to nutrient loads in South Creek would be achieved if primary treated flow releases could be avoided?	Table 3-2 in Attachment A shows that by investing in reverse osmosis treatment and transferring most flows to Nepean River, the AWRC releases have already been reduced to less than 2% of TN loads and less than 1% of TP loads entering South Creek. This does not imply that wet weather releases are inconsequential to the health of South Creek, but places in perspective that predicted loads from the AWRC are minor when considering the annual nutrient loads to South Creek from all sources. AWRC nutrient load contributions to South Creek are based on the AWRC operating at 50 ML/day. As outlined previously, these loads will be much lower during the early years of AWRC operation. The following sections in this table consider opportunities to further reduce nutrient loads to South Creek. However, in Sydney Water's view the substantial technical, environmental and cost constraints outweigh the marginal additional benefit that would be achieved, particularly in light of lower nutrient loads in the early years of AWRC operation.
Can wet weather flows to South Creek be avoided by managing stormwater inflows? If Sydney Water is able to provide clearly defined and measurable agreements or works (including stormwater harvesting and infiltration management) that will further reduce the modelled volume of primary discharges to South Creek, these should be outlined and an estimated reduction in the volume of primary treated discharge included.	**We are committed to the health of South Creek in the region; not just at the AWRC site.** Sydney Water was recently named trunk drainage manager for the Aerotropolis. This means separate to the AWRC, Sydney Water will be implementing measures to improve stormwater flows and quality to South Creek, and reuse stormwater. We understand there is room for improvement in the health of South Creek, and that it is further at risk from the considerable development expected in the area over the coming years. While stormwater management will provide meaningful improvements to South Creek, it is unlikely to substantially reduce wastewater network infiltration or flows to the AWRC. The stormwater management project is in early days and there is not enough detail to quantify any benefits. **Wastewater is captured in the network before flowing to the AWRC for treatment** Sydney Water minimises infiltration by installing low infiltration connection networks (pipes and pumping stations) that reduce infiltration to 2%, which is vastly improved compared to older networks. This

Issue	Response
	success has been demonstrated in other networks built by Sydney Water in recent years. For example, our Silverdale network experiences inflow and infiltration (I/I) rates of less than 1.64%. It is not possible to design a system with no infiltration, no matter how well it is designed and constructed. Sources of infiltration include damaged or low-lying maintenance holes, emergency relief structures, infiltration via cracks and infrastructure on private properties. It is not possible to manage stormwater inflows to avoid wet weather being discharged to South Creek, but we work hard to minimise this. **At treatment plants, wet weather flow management must be balanced with overall performance of the treatment processes** Sydney Water takes a conservative approach to estimating network infiltration to ensure there is enough treatment plant capacity for all flows. For example, although modelling shows the wet weather peaking factor in the USC network at 5.2 times ADWF (based on 2% infiltration), the treatment plant is designed to catch 6 times ADWF. This means that Sydney Water is providing greater storage in the inlet works and primary treatment units for wet weather over and above what the modelling shows is needed. We consider this as an extra buffer. Flows to treatment plants are catchment-specific and influenced by factors such as population, area, distance travelled, topography and infrastructure age. Given these uncertainties, particularly for what is currently a largely greenfield Upper South Creek catchment, Sydney Water has taken a conservative approach to treatment plant design. Although difficult to quantify, Sydney Water will monitor incoming flows over time to identify and manage high infiltration in the wastewater network, as it does for its other catchments.
Can wet weather flows to South Creek be minimised by building wet weather storage? The EPA considers there are sufficient grounds for the development of this additional storage capacity. The ability to store and prevent the discharge of 165 ML/day of effluent on just one ‘peak day’ would appear to remove about 80% of the total yearly discharge of only primary	Given that infiltration is unavoidable, Sydney Water has considered the feasibility of storage of wet weather flows at the AWRC site or in the network. The discussion of 165 ML/day in the Submissions Report was based on an example estimate of the requirements to store flows over consecutive days and cater for the peak day flow, with some pre-accumulation in the storage. This volume is required

Issue	Response
treated effluent into South Creek. Based on the modelled size of various components of the proposed AWRC, the potential for storage to developed at an offsite location (where land and planning constraints may not be as significant), and the demonstrated footprint of other major storage tanks of EPA-regulated sites, the development of 165 ML storage is considered reasonable and feasible given the modelled and potential water quality impacts from these primary treated discharges. Clarification should also be provided around the accuracy of the RtS statement above. The EIS indicates that up to 144 ML of flows can be discharged per day before primary treatment is required during severe wet weather. Sydney Water should provide confirmation that the 165 ML/day figure refers to additional flows that could potentially enter the plant during the day above the existing 144 ML/day maximum non-primary treatment capacity, rather than the overall plant peak daily flow. If the RtS statement above is referring to the overall plant peak daily flow, the infrastructure required to store a peak day's flows would be substantially less than the 165 ML/day stated.	if, for example, there are consecutive days of rain and an accumulated volume of 15 ML/d in the storage. To simplify for the purposes of this discussion, we have assumed a volume of 150 ML/day (equal to 3 times ADWF or the volume of primary treated effluent not passed through to the tertiary processes) is required to prevent any primary treated effluent discharge to South Creek. The storage would likely need to be slightly larger to provide complete containment for a peak day event. As noted above, one day of storage would not cover peak rain events where flows last longer than one day. This means that primary treated flow to South Creek can never be completely avoided with storage. As outlined below, there are substantial constraints in providing wet weather storage that Sydney Water considers outweigh the benefit provided in removing infrequent primary treated flows. **Storage at AWRC site** • Odour – although Sydney Water has wet weather storage at some other sites (including Glenfield, Fairfield and Liverpool), these experience odour complaints. Odour is particularly a problem in summer and for prolonged wet weather events where flows may be stored for days. Odour treatment works effectively when there is a consistent load. Intermittent treatment of a storage tank can compromise day-to-day odour treatment. • Footprint – with a depth of five metres, a storage tank would be the size of about 30 Olympic swimming pools, which takes up a sizable area of otherwise developable land. • Constructability – flotation of buried structures is a concern on the AWRC site given high groundwater levels. This risk can be managed for existing structures (such as the bioreactors) because they are full most of the time. However, it is of particular concern for a structure like a wet weather storage tank that would be empty most of the time. Design and construction to manage this risk would be complex and expensive. • Operations and maintenance – draining and cleaning tanks is required between wet weather

Issue	Response
	events to prevent odorous material building up over time and the tank becoming a permanent source of odour. We have not been able to identify any proprietary systems that can work on this scale. If the tank is covered (to minimise odour and the risk of attracting wildlife that could contribute to risk of wildlife strike associated with Western Sydney Airport) then it becomes a confined space, which is a safety risk for people to enter. It is also likely that groundwater would need to be continuously extracted from under the tanks to avoid structural damage from flotation. A residual risk of structural damage and the need for subsequent repairs would remain if the groundwater pumping system failed. • Sustainability – a storage tank would use about as much concrete as the rest of the AWRC combined which would substantially increase the project's embodied carbon. Additional considerations such as excavation, spoil management, ongoing groundwater extraction and managing additional stormwater runoff would also be a factor. • Cost – building a storage of this scale would have a capital cost upwards of $250 million, which substantially increases project delivery cost. **Storage in network** Storage in the network has similar issues to at the AWRC site. Storage would be required at the key pumping stations across the network to capture the equivalent of 150 ML of flows. As an example, one of the largest pumping stations, SP1211 in Austral would require about 50-70 ML of storage, which is about the size of a soccer field. This pumping station is planned to be located adjacent to a national park, residential development, and community facilities such as sports field and playgrounds. It would require a much larger land parcel than currently proposed (10,000m^2 compared with 1,300m^2), and result in a loss of amenity, visual impact and odour issues.
If wet weather flows to South Creek cannot be avoided, can higher treatment levels be applied to these flows?	For context, most flows to South Creek will receive advanced treatment, with primary treated water blended in as wet weather events become more extreme. This section focuses on considerations for

Issue	Response
While there may be limitations to treating all discharges into South Creek at an advanced treated (reverse osmosis) standard, minimal consideration has been given to increasing the capacity of other treatment stages. Based on 2056 population projections, Sydney Water expects that the AWRC will ultimately require expansion to treat wastewater flows up to 100 ML/day and has set aside additional areas of the AWRC site for future capital works to meet this future capacity. Sydney Water should further consider fast-tracking any incremental capital works to increase the capacity of the secondary and tertiary treatment components of the AWRC in the future so that these works are incorporated into Stage 1 of the project. Improved secondary or tertiary treatment of the currently proposed primary discharges into South Creek may have a significant environmental benefit.	additional treatment of the primary treated stream. **Treatment process summary** The secondary and tertiary streams of the AWRC treatment process involve a membrane bioreactor (MBR). The MBR consists of biological treatment to remove organic material, nitrogen, and phosphorus. A series of set conditions with aeration and anoxic zones, and chemical dosing are used to achieve this. Treated effluent is separated from the biomass using membranes to produce a high-quality effluent. Nitrogen removal processes consist of two stages in which ammonia is oxidised to nitrate and then the nitrate is removed as nitrogen gas using chemical oxygen demand (COD) as a substrate. Phosphorus is removed through a combination of biological processes and the addition of chemicals. Biological treatment processes work best under stable conditions and therefore wet weather events can cause disruption to the process (and jeopardise effectiveness of dry weather treatment) through higher flows and dilute concentrations. Sydney Water is already planning to treat some wet weather flows through the MBR process (up to 3 x ADWF) and has reduced the risk of disruption by making some changes around the feed and bypass of the primary sedimentation tank in the reference design to create more consistent conditions. This provides a balance of treating some smaller wet weather events but not introducing large, dilute flows above 3 times ADWF that would present greater risk to normal dry weather operations. **Effectiveness of nutrient removal in MBR** The current plant design balances TP reduction in the secondary and tertiary stages and in the RO process. To achieve higher phosphorus removal in the secondary and tertiary stages would require a high amount of chemical dosing (either alum or ferrous/ferric chloride). This would have implications on the effectiveness of other processes in the secondary and tertiary stages, particularly lowering pH which would disrupt nitrification in the MBR. Nitrogen removal can only be achieved in the biological treatment process. **Operability and functionality** Oversizing infrastructure for infrequent events is a

Issue	Response
	risk, causing operational issues such as settling of solids due to not achieving the normal cleaning velocities in pipes and channels. Increased size also leads to increased maintenance due to additional equipment or increased operator input for clearing settled solids. In this case, the maintenance effort would likely be doubled at an annual cost of close to $2 million from additional labour, chemical consumption, chemical deliveries and power usage. In summary, design of the plant focuses on achieving very high quality outcomes most of the time. There is a high risk that approaches to further treat the infrequent primary quality flows during wet weather will lead to a deterioration of the very high quality outcomes in normal conditions.
Can UV treatment rather than chlorination be used to disinfect wet weather flows? Primary treated effluent discharged to South Creek will receive pathogen treatment via chlorination. In these circumstances, there will be a high chlorine chemical demand and usage, and uncertainty as to whether an adequate level of chlorination can be consistently provided to kill pathogens, and uncertainty as to the effects of variable chlorination levels on aquatic life and water quality. There are acknowledged toxicity issues with chlorine for primary discharges. If primary treated wet weather discharges are to occur, it is strongly recommended that Sydney Water investigate and implement ultra-violet (UV) disinfection methods at the AWRC rather than use chlorine dosing/chlorination.	Sydney Water's preferred method of disinfection of primary treated effluent is chlorination. Disinfection is required during severe wet weather events when incoming flows exceed 3 times ADWF. Primary effluent is disinfected with chlorine via the chlorine contact tank (CCT) and subsequently dechlorinated through the addition of sodium bisulphite before release to South Creek. The addition of sodium bisulphite prevents excess chlorine entering the creek. Both chemicals are dosed based on flow entering the tank and chlorine residual feedback to ensure that the correct dose is added and that disinfection is maintained. UV disinfection in wet weather is not without its challenges. UV units require constant submersion to be effective and higher suspended solids can cause issues with the effectiveness of the UV in wet weather. Also, UV equipment has more maintenance demand than chlorination infrastructure. After a wet weather event, UV equipment must be cleaned to maintain reliability and operating life. A benefit of chlorination is it can use backup power during outages, ensuring disinfection quality is maintained. Back-up power in the form of UPS for a UV systems is inefficient due to the higher power demand and intermittent usage.
Nepean River - release design The EPA recommends that Sydney Water consider alternatives to the current proposed configuration of the discharges to the Nepean	Sydney Water has further investigated diffuser structures in Nepean River as a potential opportunity to improve dilution of treated water releases. This has confirmed that a diffuser structure presents significant construction, operation and maintenance

Issue	Response
River. In the RtS report, Sydney Water have considered an alternative discharge configuration (three port diffuser) that provides adequate dilution of Nepean River discharges. While there are identified construction and operational issues associated with this alternative, if these issues can be overcome or mitigated it will significantly reduce the risk to the protection of the environmental values in the Nepean River under severe wet weather conditions and, most likely, also under other rainfall conditions. In the RtS Report, Sydney Water has also committed to investigating opportunities during detailed design to see if there are any feasible opportunities to improve dilution of wet weather releases. While the EPA is supportive of this commitment, further assessment of alternative discharge locations and configurations at this stage of the planning process is considered a more concrete mechanism to identify a more beneficial environmental outcome.	risks as summarised below. This risks the effective operation of the main release point for the project, and therefore operation of the AWRC. Additional toxicity modelling at this location (see Attachment B) has also shown that the EIS presented a worst-case scenario. This further supports Sydney Water's position that taking the risks below are not warranted given the low toxicity risk from the releases. As previously committed, Sydney Water will look more closely into opportunities to improve dilution from release structures during detailed design. **Construction risks** • Construction would need to use a barge for the construction of submerged assets. This may not be feasible for this location due to constrained access from upstream, and no possibility of access from downstream given the Nepean River is not navigable by boat at this location. • Trenching/dredging activities within Nepean River to install submerged assets will cause significant environmental issues. These environmental impacts would be in addition to what has already been assessed in the EIS. • Construction within the riverbed is more likely to be affected by wet weather events (such as recent floods experienced over 2021-22), which can result in delayed construction and prolonged environmental and community impacts. **Operation and maintenance risks** • Water depths are shallow in this location (~2.6m) and variable depending on river flows (up to 5 m). Diffusers need to be installed at least one metre above the riverbed to avoid becoming clogged with sediment. This means there are times in which the assets could extend above the water level. As a result, the risk of not achieving adequate mixing is high. • There is a risk of impact forces from logs and other debris damaging the structures, and damage from river scour, particularly during flooding. • If submerged structures are damaged, replacement could require a similar scale of installation to the initial construction. This would require additional extensive construction work

Issue	Response
	within the riverbed and potential for associated environmental impact. Impacts associated with any bypasses or alternative release locations could also be substantial. • A large, submerged structure close to or above the water surface presents a safety issue for people or vessels using the river in this location. • Given susceptibility to damage, frequent inspections and maintenance checks would be required. This would be challenging due to the relatively remote area, restricted boat access to the proposed release location, and need for specialist trained divers.
Nepean River – downstream release location The EPA recommends that Sydney Water consider alternatives to the current proposed location of the discharges to the Nepean River. While the potential erosion issues with discharge points further upstream are acknowledged, the EPA considers that further assessment should be given to a discharge location downstream of Wallacia weir. Specifically, this assessment should: • Outline further the construction issues associated with a downstream location • Further clarify any recreational areas downstream that may be impacted (if any) and assess the impacts to these areas relative to the current discharge location • Model the toxicity impacts of this downstream discharge location compared to current discharge point (including justification that limited levels of dilution would occur relative to the current discharge.	**Issues with downstream location** Sydney Water has further considered locating the treated water release structure downstream of Wallacia Weir in response to concerns raised by EPA. The following risks/constraints mean Sydney Water does not consider this a practical option: • The banks of Nepean River are considerably higher and steeper downstream of Wallacia Weir. This rocky steep terrain would pose significant challenges and risks for construction safety. This would require a longer construction period and a considerable increase in capital cost. • An access road would be needed for construction and operation of a release location downstream of Wallacia Weir. Due to the topography this would need substantial work to reduce the grade with extensive vegetation clearing and rock excavation. • The existing Warragamba pipelines are also downstream of Wallacia Weir and are critical for Sydney's water supply. Considerable rock excavation would be required for a release location downstream of Wallacia Weir and would pose significant vibrational risk to these pipelines. • There would be greater environmental impact associated with constructing the release structure downstream of Wallacia Weir. This is due to the increased construction footprint in a steeper more vegetated environment. • The depth of Nepean River downstream of Wallacia Weir is expected to be shallower

Issue	Response
	compared to the location upstream of Wallacia Weir. This means a diffuser option may not be feasible and presents a much greater risk of not achieving required mixing. The risk of damage to structures in shallower water is also very high. • Locations downstream of Nortons Basin are not considered feasible as they would require substantial vegetation clearing and construction activities in the Greater Blue Mountains World Heritage Area, including roads and ongoing access through this area for maintenance. Attachment A includes several figures demonstrating these points. **Recreational impacts** Recreational areas downstream of the release point were shown on Figure 8-17 in the EIS and described in detail in Table 8-24. Recreational areas downstream of the Nepean River release point include Nortons Basin and the Blue Mountains World Heritage Area. Locating the release point downstream of Wallacia Weir is unlikely to have any additional impact on recreational areas. **Toxicity modelling** As outlined above, Sydney Water considers a release location downstream of Wallacia Weir is not practical. As a result, we have not completed further toxicity modelling for this location.
Comments on hydrodynamic and water quality modelling The EPA raised several concerns about the hydrodynamic and water quality modelling, primarily related to: • model errors and limitations • suitability of the model and consideration of simpler alternatives such as box models • the assessment of cumulative impacts • concerns about toxicity impacts.	Attachment B (Table B1) provides detailed responses to these matters. Sydney Water considers that the modelling approach is best practice and fit for purpose. The model has been in development for over a decade and the improvements made as part of the EIS modelling represent a significant upgrade on previous versions. As with any model, there are limitations and Sydney Water has been transparent about these both in the Hydrodynamics and Water Quality Impact Assessment (Appendix F of the EIS) and the Calibration Report. The model performance and level of errors are typical for a model of this level of complexity and have been assessed as acceptable by the independent review. Alternative approaches, such as box models, would not have capitalised on the extensive and collaborative effort already

Issue	Response
	completed and would have not provided improved or more reliable results. Some of the concerns raised will be addressed as part of a larger program of improvement to the model, but are highly unlikely to change the predicted outcomes reported in the EIS. The model is sufficiently robust to allow various scenarios to be run in order to predict, with a high degree of certainty, the relative impact of the releases compared to a baseline and background scenarios. Cumulative impacts relative to other predicted changes in the catchment have been assessed as part of these scenarios. For a number of reasons, model runs have been limited to two years. Given that overall impacts from the AWRC releases are predicted to be positive, it is unlikely that longer model runs would reveal negative impacts over time. Sydney Water has also completed additional near field impact modelling for Nepean River releases to address EPA concerns. The results are included in Attachment B and demonstrate that the modelling in the EIS presented a worst case outcome and that releases in smaller wet weather events have a smaller potential for toxicity impacts. Overall, the potential for toxicity impacts is low in all scenarios, given the highly conservative guideline values adopted and the short infrequent nature of releases of tertiary treated water.

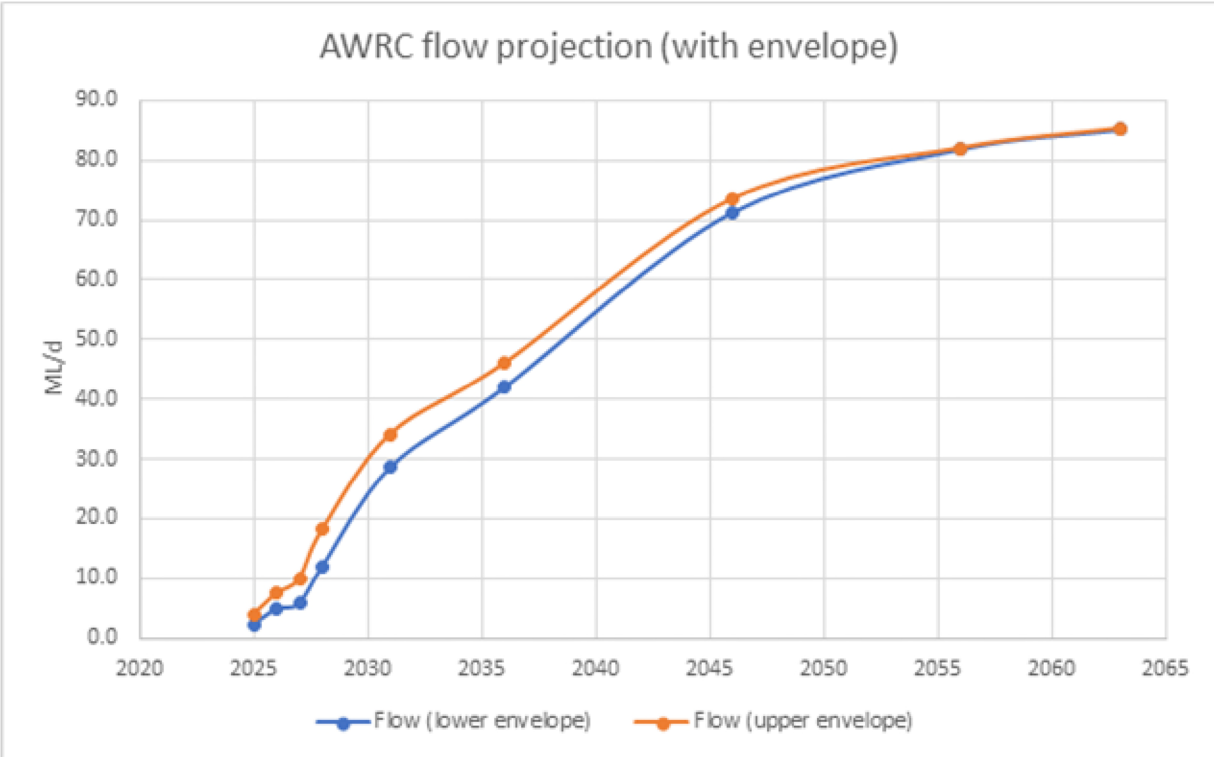

Figure 1 Current forecast of incoming flow to AWRC over time

Table 2 Department of Planning and Environment (DPE) – Environment and Heritage Group (EHG)

Issue	Response
Waterway health – conditions of approval Recommends a range of conditions relating to erosion and sedimentation, expert oversight of works, consultation, stormwater harvesting benefits.	Sydney Water considers these are matters for DPE's Water Assessments team and has no further information to add.
Waterway health – comments on hydrodynamic and water quality modelling DPE EHG raised a number of concerns about the hydrodynamic and water quality modelling, primarily related to: • model errors and limitations • suitability of the model and consideration of simpler alternatives such as box models • the assessment of cumulative impacts	Attachment B (Table B4) provides detailed responses to these concerns. A general response to these concerns is provided in Table 1 above.

Issue	Response
Waterway health – project design (water quality and hydrology) Without defaulting to models, it is intuitive to state that the wet weather discharges will have an impact over time. Indeed, this reflects the current situation in many waterways, and a cause of poor ecological health and water quality. Efforts to minimise the discharges to South Creek, should be revisited especially given the opportunity to build from scratch. The integration with a reticulated stormwater harvesting system may be of benefit as highlighted in Sydney Water's response to the NSW EPA – for example, minimising stormwater ingress but not unlikely to reduce the volumes during wet periods as the harvesting system (including wetlands and storage ponds) are also likely to be at capacity.	Table 1 and Attachment A respond to opportunities to minimise releases to South Creek.
Waterway health – alignment of risk assessment and flow objectives assessment (Ecohydrology and geomorphology) Regarding the risk assessment of South Creek, RtS indicates there is no impact yet the previous Table 30 shows exceedances from the flow objectives. Further information is required here.	DPE EHG refers to Table 30 of the Ecohydrology and Geomorphology Impact Assessment (Appendix G of the EIS). The results presented in Table 30 predicted that the cease to flow metrics would be exceeded for baseline, background and impact scenarios. This exceedance was discussed in the Ecohydrology and Geomorphology Impact Assessment. This table was subsequently updated in the Submissions Report (Table 5-8, section 5.4.9) to consider updated DPE EES criteria and an error in the drainage area adopted in the original calculations. The updated results showed that cease to flow metrics would continue to be exceeded. The results also predicted the following: • baseline median daily flow volume exceeds the pre-development criteria • background and impact scenarios exceed the mean daily flow criteria. Table 5-8 indicates a large increase in mean daily flows between the baseline and background scenarios (potentially up to about 250%). There is little difference between the background and impact scenarios (up to two percent). This highlights that the main contribution is the predicted changes in land use and associated increase in stormwater flows. The AWRC releases make a

Issue	Response
	negligible contribution to overall flow volumes. The Ecohydrology and Geomorphology Impact Assessment predicted limited change in the overall geomorphic risk to South Creek as a result of the AWRC releases, with a medium risk determined for both the background and impact scenarios. The hydrologic analysis suggests that the additional impact of the AWRC releases on the geomorphic condition of South Creek compared to the background scenario is likely to be negligible.
Waterway health – definition of minor in relation to impacts on high ecological value mapping (Aquatic and riparian assessment) Additional information has been adequately provided in the RtS and Appendix E Aquatic Ecology Maps. Impacts are considered minor and mostly occurring during the construction phase. The definition for minor is still not explained.	Minor impacts are impacts classified as being recognisable as short term, or temporary, or of limited magnitude in nature and only predicted at a local scale. The definition was included in the EIS (section 8.2.3) and the Aquatic Ecology Impact Assessment (Appendix H of the EIS).

Attachment A Response to EPA comments on design matters

Upper South Creek Advanced Water Recycling Centre – Response to EPA comments on design matters

Sydney WATER

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1 Report scope

This report responds to the Upper South Creek Advanced Water Recycling Centre (AWRC) (SSI 8609189) EPA Advice on the Submissions Report, particularly focusing on the following design aspects:

- Overview of the approach to AWRC development and sustainability initiatives, including those to protect waterway health
- Protecting South Creek
  - Why wet weather discharges are unavoidable, considering infiltration and inflow into the network and storage of wet weather flows, and monitoring performance over time
  - Treatment options for wet weather flows.
- Protecting Nepean River
  - Design of release arrangement
  - Location of release.

The response to the EPA's comments on water quality and hydrodynamic modelling is addressed separately.

2 Approach to AWRC development

Sydney Water has taken a range of initiatives in the AWRC design to ensure it will be a flagship development that exceeds Sydney Water's current best practice for wastewater treatment, demonstrates a high commitment to sustainability and protects and enhances the environment. The key design initiatives to achieve this include:

- The reference design uses the latest tried and tested technologies in wastewater treatment to produce the highest effluent quality that will be suitable for a range of beneficial uses such as recycling and environmental flows. As detailed design progresses, Sydney Water's contractors may identify further opportunities for innovation, while still meeting performance objectives.
- To protect waterways, the project will treat all dry weather flows to an advanced quality using reverse osmosis, and pump treated water 16 km to Nepean River to protect South Creek. Treatment and transfer of treated water on this scale is a first for Sydney Water and comes at a substantial cost and with high energy requirements. Sydney Water therefore needs to balance the treatment approach to achieve waterway health outcomes with other environmental drivers such as meeting our ambitious carbon reduction objectives.
- To reduce its carbon emissions, Stage 1 of the project will offset its electricity use by 50%, with the aim to reach 100% over time. This will involve incorporating technologies such as photovoltaic solar and co-generation to produce energy or purchasing renewable energy certificates.
- Beneficial reuse of biosolids produced by the AWRC.
- The AWRC includes about 40 ha of land that will be established as a green space area to enhance biodiversity along waterways, include best practice water sensitive urban design to protect South Creek, provide visual screening and potentially be available for future community use.
- Although not part of the current project scope, the AWRC provides a foundation for a range of other future circular economy initiatives in the Aerotropolis such as providing a hub for co-digestion of biosolids and other food waste and organics that could increase biogas production and electricity generation rates.

3 Protecting South Creek

3.1 Why wet weather releases cannot be avoided

The following analysis highlights the importance Sydney Water places on managing wet weather flows and the efforts taken to prevent infiltration, the primary source of wet weather volume received at the AWRC.

The investigation also considers the benefits of additional treatment or wet weather storage, and the practicalities of implementing them.

3.1.1 Stormwater infiltration

The EPA has recommended that: *'If Sydney Water is able to provide clearly defined and measurable agreements or works (including stormwater harvesting and infiltration management) that will further reduce the modelled volume of primary discharges to South Creek, these should be outlined and an estimated reduction in the volume of primary treated discharge included.'*

Infiltration is unavoidable and is experienced on all collection systems no matter how well designed or constructed. Given that 50% of sewer assets are in private property, management of all sources of infiltration is challenging. Some notable sources of infiltration are:

- Damaged or low-lying maintenance holes
- Emergency Relief Structures
- Infiltration via cracks or leaks in wastewater mains
- Private properties
    - Inflow via incorrectly connected stormwater connections
    - Damaged or low-lying overflow relief gullies
    - Cracked, damaged or poorly sealed private wastewater pipes & fittings.
    - Swimming pool overflow connections (there is a requirement in NSW to connect swimming pools to sewer)
    - Uncapped pipes during construction

Sydney Water is continually looking for ways to reduce infiltration into its network both by design of low infiltration sewers and through an ongoing program of works to identify and rectify infiltration in its existing systems.

The program is focused on three primary areas and would include the Upper South Creek catchment over time:

- **Inflow management:** Mostly focused on maintenance holes and emergency relief structures where backflow in the sewer systems has been identified. In many instances these are being reconstructed with the latest best practice configurations.

- **Infiltration management:** This covers all leaky sewers, stormwater cross connections, damaged manholes, and typically targets high infiltration areas.
- **Property connections:** Identification works such as smoke testing at property connections are being carried out to identify point sources.

With Western Sydney being predominantly new infrastructure in a well-planned region, there are two areas of opportunity to manage wet weather infiltration in the Upper South Creek wastewater network and ultimately the health of South Creek:

- Low infiltration wastewater systems.
- Improved management of stormwater runoff.

Low infiltration wastewater systems

Low infiltration systems are business-as-usual in Sydney Water. In 2010, Sydney Water developed a low infiltration specification covering planning, design, construction, and quality assurance of new gravity wastewater systems to minimise wet weather inflow and infiltration. The implementation of these systems has been proven to provide improved and more predictable infiltration rates.

The following changes were made in the specification to achieve these low infiltration systems:

- Fully cast insitu or fully precast maintenance holes with no segments.
- Increased use of 225 mm maintenance shafts instead of 1200 mm maintenance shafts.
- Private connections at least two meters away from Sydney Water wastewater assets.
- Overflow relief gullies to be fitted with leak proof covers.
- Additional acceptance testing and effects liability testing.
- Pipe material - PVC or Polypropylene (PP) pipe with rubber ring joints.

The changes were included in the Sewerage Code of Australia (published by Water Services Association of Australia, WSAA) and Sydney Water's version of the Code (WSAA, 2018) and are now a requirement for all new sewers.

Where traditional networks can achieve 5% infiltration at best, the new standards have enabled Sydney Water to develop new wastewater systems that experience no more than 2% inflow and infiltration for a period of 30 years. Sydney Water has trialled low infiltration systems for Mulgoa, Silverdale, Wallacia and Upper Blue Mountains gravity system catchments under the Priority Sewage Program (PSP). These systems have maintained an inflow and infiltration rate of about 2%.

As noted in section 3.6 of the EIS, Sydney Water is designing the wastewater collection network for the Upper South Creek Servicing Area to this specification. Therefore, 2% infiltration has been used in Sydney Water's modelling to estimate wet weather flows to the AWRC.

Low infiltration systems are considered industry best practice and there are currently no known solutions in Australia or internationally to effectively implement and maintain 0% inflow and infiltration on wastewater networks.

AWRC system hydraulic design assumptions

Wastewater network hydraulics in dry and wet weather are shaped by the features of the particular catchment such as population, area, distance travelled by influent flows, topography, infrastructure and age. Hydraulic modelling of Upper South Creek wastewater network (including low infiltration assumptions) suggested that the maximum peak wet weather flow has a peak flow to the treatment plant of 5.2 times Average Dry Weather Flow (ADWF). In designing the AWRC, the more conservative standard peak flow of 6 times ADWF was applied to the hydraulic, preliminary and primary treatment design to allow for uncertainties in the network.

In addition, it will take about 10 years to reach the 50 ML/day flow, and in early years the flows will be lower. Section 3.4.4 provides further discussion about the initial size of infrastructure and population growth, and the opportunities that provides to responding to changes in the predict infiltration and network characteristics.

Improved management of stormwater runoff

Sydney Water has recently been named trunk drainage manager for the Aerotropolis. This means separate to the AWRC, Sydney Water will be implementing measures to improve stormwater flows and quality to South Creek, and reuse stormwater.

While some of these measures may result in benefits in reducing infiltration to the wastewater network (for example, stormwater captured before it reaches the point of overland flow and infiltration into the network), this is unlikely to have a substantial impact on wastewater network infiltration and flows to the AWRC. This project is in early days and there is not enough detail to quantify any benefits.

Table 3-1 shows the impact of this new stormwater harvesting approach on nutrient loads to South Creek. The loads at 2036 are compared for the business-as-usual (BAU) scenario to the Parkland scenario. The Parklands assumptions were developed during the Aerotropolis Precinct Planning on the basis of improved stormwater management approaches. This level of management is assumed to be representative of the Western Parkland City stormwater strategy as outlined in the Western Sydney Aerotropolis (Initial Precincts) Stormwater and Water Cycle Management Study Interim Report.

The total nitrogen (TN) and total phosphorus (TP) loads are reduced by about 15% for both TN and TP in the Parkland scenario.

Table 3-1: South Creek annual loads - BAU vs Parklands Scenario 2036

	South Creek loads 2036 – BAU stormwater scenario (kg/yr)	South Creek loads 2036 – Parkland stormwater scenario (kg/yr)
TN	205,743	175,467
TP	25,173	21,766

1. Annual load values based on median values of a wet year. Note this is total load in South Creek, including load from AWRC.
2. See Section 4.6.3.2.1 of Upper South Creek AWRC EIS: Hydrodynamic and Water Quality Impact Assessment for more details of this modelling.

Summary of infiltration management

Infiltration management is a critical component of reducing primary treated discharges to South Creek, and as noted above, Sydney Water is committed to minimising infiltration.

The AWRC servicing catchment continues to vary as more commitments are made in the region, which means some contingency needs to be allowed in the infrastructure sizing. The infiltration impacts on the AWRC have been calculated based on network modelling of well proven low infiltration systems (5.2 x ADWF), but traditional conservative wet weather peaks have been allowed for in sizing of treatment infrastructure (6 x ADWF).

There is likely to be an increased proportion of wet weather inflow into the network at the early stages of the AWRC being operational (up to 10 times). This is due to the wet weather entering wastewater connections during construction stages, plus the length of trunk infrastructure relative to the early population. This will be short lived and is not expected to adversely affect the number of primary effluent discharges to South Creek.

However, given the demonstrated benefits of low infiltration systems, ultimately there is likely to be a lower wet weather peak than allowed for, and hence an overall reduction in the predicted volumes of primary treated effluent discharged to South Creek.

3.2 Potential benefits of storage and increased treatment capacity

As shown in Table 4-6 of Appendix F of the EIS, the projected yearly volume of primary treated effluent into South Creek in a wet year is 206 ML, based on six wet weather events per year. Reduction of these primary discharges may be possible using additional storage or treatment of the >3xADWF flows. However, the benefit of these changes to South Creek must be understood and weighed against the performance, operational, and environmental impact of these options.

Due to limited wet weather capacity of the reverse osmosis (RO) treatment component, it is likely that any stored wastewater would ultimately be treated by the membrane bioreactor (MBR – a combined secondary and tertiary process) before being discharged to South Creek. Therefore, for the purpose of considering benefits to South Creek, additional MBR treatment capacity to treat wet weather flows and storage of wet weather flows for treatment after the wet weather event, would have the same outcome.

3.2.1 Current level of treatment

As shown in Table 3-2, the AWRC wet weather discharge is a small
fraction of the total nutrient load in South Creek in the Parkland stormwater scenario. Loads have been reduced to this level through the high level of treatment (reverse osmosis) for most flows and transfer of most flows to Nepean River. This does not imply that wet weather discharge is inconsequential to the health of South Creek, but places into perspective that the predictions of wet weather discharges are minor when considering the annual load sources to South Creek.

Table 3-2: Percentage of South Creek TN and TP loads from AWRC at 50 ML/day

	South Creek loads 2036 (including AWRC) (kg/yr)	AWRC loads to South Creek 2036 (primary and RO) (kg/yr)	% of total load from AWRC (primary and RO)
TN	175,467	3,380	1.93
TP	21,766	211	0.97

1. South Creek loads from median values of wet weather year in Parklands scenario, including stormwater management

While reduction of AWRC loads may be possible through options such as storage and increased treatment capacity, these have significant performance, operational, and environmental impacts. Sydney Water considers these do not appropriately weigh against the <2% reduction of total South Creek load possible from these options.

3.2.2 Increased benefits of secondary treatment of wet weather flows

Options to further reduce these loads to South Creek include additional storage or additional treatment capacity to store or treat the 3 x ADWF of wet weather flows that is currently discharged to South Creek as primary treated flow. Storage of wet weather flows would involve storing primary treated flows >3 x ADWF during a wet weather event. Once the event has ended and plant flows have returned to dry weather flow, these stored primary treated flows would be returned to the treatment process, treated through secondary treatment, and discharged to South Creek as secondary effluent. In addition, the prolonged discharge of dilute wet weather flows into the secondary treatment process may have an adverse effect on the process performance. The outcomes of discharge to South Creek in this option is equivalent to those of storage of wet weather releases as outlined in section 3.3.2. However, the footprint, constructability, odour, maintenance, and environmental impacts differ between the options.

In addition, the actual nutrient removal if secondary treatment was to be implemented would be limited due to potential disruption to performance of the biological treatment process and limited ability to remove phosphorus (phosphorus removal is balanced between the secondary and advanced treatment processes). As TP loads in freshwater systems is generally considered to be the limiting factor to eutrophication, additional MBR treatment of wet weather flows is not likely to have a significant impact to the waterway health.

As discussed in section 6.1.1.5.3 of the Hydrodynamic and Water Quality Impact Assessment, the AWRC releases are expected to have a very low risk of impact on the water quality of creek, including the potential for algal blooms, particularly given additional nutrient loads will occur infrequently and away from sustained dry periods when conditions that favour eutrophication are more prominent.

3.3 Wet weather storage

The EPA has recommended further investigation into storage of the wet weather flows: '*If the figures provided in this statement are accurate, the EPA considers there are sufficient grounds for the* *development of this additional storage capacity. The ability to store and prevent the discharge of 165 ML/day of effluent on just one 'peak day' would appear to remove about 80% of the total yearly discharge of only primary treated effluent into South Creek. Based on the modelled size of various components of the proposed AWRC, the potential for storage to developed at an offsite location (where land and planning constraints may not be as significant), and the demonstrated footprint of other major storage tanks of EPA-regulated sites, the development of 165 ML storage is considered reasonable and feasible given the modelled and potential water quality impacts from these primary treated discharges.'*

Given that infiltration is unavoidable, one option to prevent or reduce primary treated effluent discharge to South Creek is storage of wet weather flows, either as:

- centralised storage at the AWRC site
- network storage.

For the discussion, we have assumed a nominal volume of 150 ML/day is required to prevent any primary treated effluent discharge to South Creek. This equals 3 x ADWF which is nominally the maximum wet weather flows above tertiary treatment. The storage would likely need to be slightly larger to provide complete containment for a peak day event.

It should also be noted that one day of storage would not cover peak rain events where flows last longer than one day, as seen in early 2022. This means that primary treated flow to South Creek cannot be completely avoided with storage.

3.3.1 Storage at AWRC site

Sydney Water has several sites that store wastewater in wet weather, but the practice is generally avoided due to known issues, mainly relating to operations and community impacts. This section considers the potential for providing a 150 ML storage at the AWRC site, particularly in relation to constructability, odour, operations, environment and sustainability, and cost.

Storage of wet weather flows will involve storing primary treated flows >3 x ADWF during a wet weather event. Once the event has ended and plant flows have returned to dry weather conditions, these stored primary treated flows will be returned to the treatment process, treated through secondary treatment, and discharged to South Creek as secondary effluent.

Footprint and constructability

Storage of 150 ML with a tank about five metres deep (which is the depth of the primary and chlorine contact tank), would require a footprint of about 350 m x 100 m. This is equivalent to the footprint of about 30 Olympic swimming pools. Installing this amount of storage would take up a significant area on the site, complicating and limiting space for other uses such as solar panels and future stages of the AWRC. Figure 3-1 shows the impact that storage of this size would have on the plant footprint. It would also not be practical to cover a tank of this size.

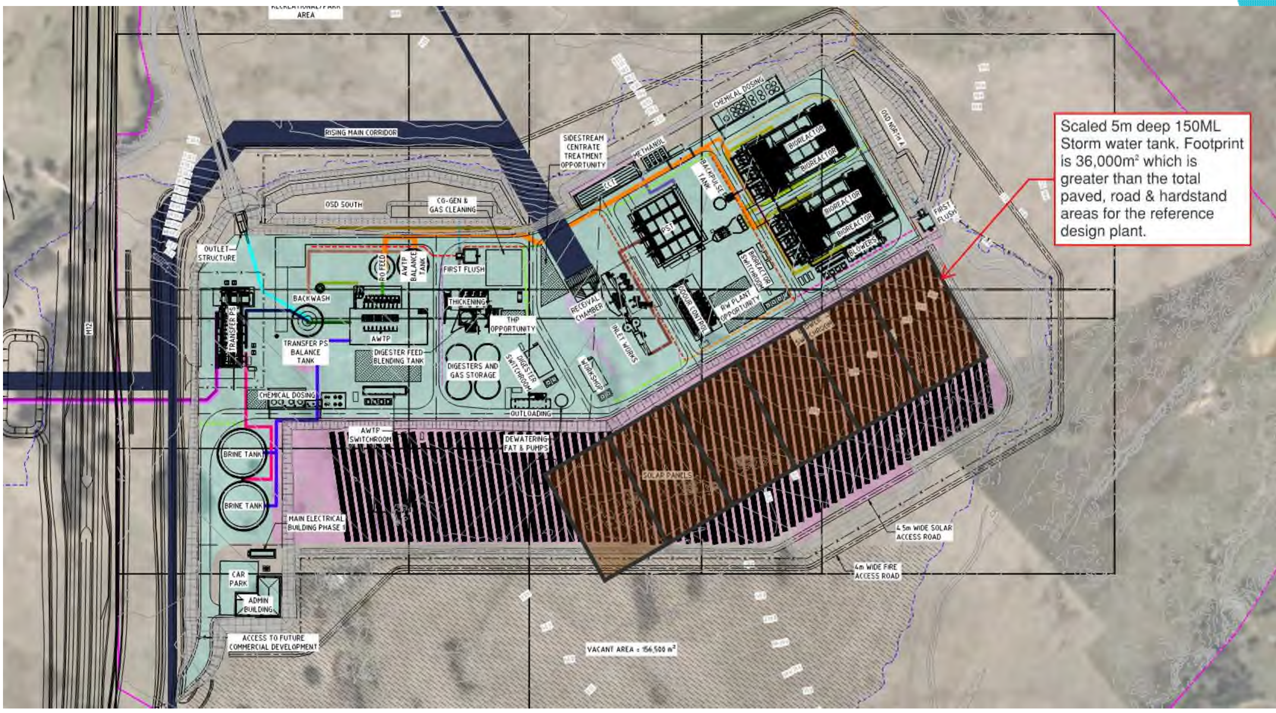

Figure 3-1 Size of 150 ML wet weather storage at AWRC site

The footprint of the storage is greater than the total hardstand and roads for the remainder of the AWRC site.

During the reference design it was noted the high ground water levels on the site present a buoyancy risk to many of the large, buried structures, especially the bioreactor. The risk was considered acceptable for the bioreactor given the structure would only be empty for short periods once every five years. A similar risk would not be acceptable for 150 ML storage tank that is normally empty. The alternative means of buoyancy control is frequent tension piles to prevent the structure lifting, further increasing the complexity of construction.

Odour

Storage of primary effluent will have odour impacts, particularly given the duration of a storm event is unknown. While some other treatment plants store diluted wastewater or primary effluent in wet weather events (including at Glenfield, Fairfield and Liverpool), these plants regularly experience odour complaints. This is especially an issue for prolonged wet weather events where flows may be stored for several days or longer until flows to the treatment plant subside due to the build-up of solids and the potential for sewage to turn septic. When this occurs there is significant potential for odour, especially during summer months. The presence of rural residential properties and the plans for a green space area put additional emphasis on the need to manage odour at the AWRC site.

Containment of odour and odour treatment is normal practice at wastewater treatment plants. Odour treatment facilities, much like wastewater treatment plants are largely a self-sustaining biological process. The odour is treated through a natural biological process, called a biological trickling filter. The type of ‘bugs’ selected specifically feed on the elements that need to be removed. With biological processes it important to maintain consistent load. Intermittent treatment of odours associated with the storage tank is like to compromise the day-to-day odour treatment.

Covering wet weather storage tanks to reduce odour emission will present operational and safety issues for access to the tank for maintenance and cleaning. A covered below ground structure with potential for odour would likely be assessed as a confined space.

Operations and maintenance

Maintenance is required between wet weather events to prevent odorous material building up over time and the tanks becoming a permanent source of odour. This is primarily draining and cleaning storage tanks.

As part of this investigation, we have not been able to resolve a way to clean and maintain tanks of this size. There are numerous proprietary systems, such as tipping buckets, and spray systems, however none of these solutions can be applied to a tank of this scale.

It is anticipated that groundwater would need to be managed by continuously extracting ground water from under the tanks to avoid structural damage of the tank. Groundwater flows would then be returned to the head of works for treatment. Both the pumping and treatment of the groundwater increases the carbon footprint of the plant, potentially to a level that exceeds the environmental benefits that might be derived from the storage. There is still an ongoing risk that failure of the ground water pumping system leads to failures of the tanks, creating a potential need for future concrete works and repairs.

Environment and sustainability

A structure of this size will have some negative impacts on the environment. A storage tank of 150 ML has about the same amount of concrete as the rest of the AWRC combined. This has impacts on the project’s embodied carbon, and impacts associated with removal and disposal of spoil.

Capital costs

Although the EPA has identified that cost is not a key factor in decision making, this is something that Sydney Water must consider in prudent and efficient expenditure of its capital program. The scale of the structure and associated volumes of excavation and structural concrete make this tank a considerable portion of the entire AWRC delivery cost and is estimated to be more than $250m.

3.3.2 Network storage

Network storage would need to be located at pump stations given these are typically be located at specific low points in catchment areas.

Storage of wet weather flows in the network would have similar issues to the centralised approach, such as odour and maintenance. Typically, the wastewater network and pump stations have some storage sized to allow for operational response in the event of failures during dry weather (nominally four hours). This is essential to avoid dry weather overflows in the network.

Due to their location in residential and urbanised areas, pump station storage facilities are discrete, below ground, covered and sealed for odour. Where there is additional risk of community impact, the pump station and storage will have odour treatment.

Where the storage volumes become impractical due to size, the pump station would typically have provisions such as a permanently installed backup generator and/or a dual wet well to minimise the risk of not having the operational storage.

To help understand the impacts of network storage for wet weather flows, we can consider one of the largest network pump stations proposed to feed the AWRC. This is SP1211 located in a proposed new development suburb of Austral.

A storage volume of about 50-70 ML would be required at SP1211 if the forward flows were to be limited to 3 x ADWF. Although this discussion considers only SP1211, similar storages would also be required at all other pumping stations to reach the 150 ML storage size of the centralised storage at the AWRC site.

The allocated block of land for SP1211 is about 1300m^2, however the storage would need to be over 10,000m^2, which is almost the size of a soccer field. The pump station is located adjacent to a planned community hub, surrounded by national park, residential developments, sports fields, and children's playground. Figure 3-2 shows SP1211's location on the precinct plan and its proximity to community facilities and residential areas. For the network storage to be effective at SP1211, it would require building a wastewater storage in either the sports ground or green open spaces.

Most infrastructure for SP1211 would be below ground, with visual screening and odour treatment to minimise the impact on the local community. Given the scale of a wet weather storage structure, there would certainly be loss of amenity, visual impact and odour issues for the life of the installation.

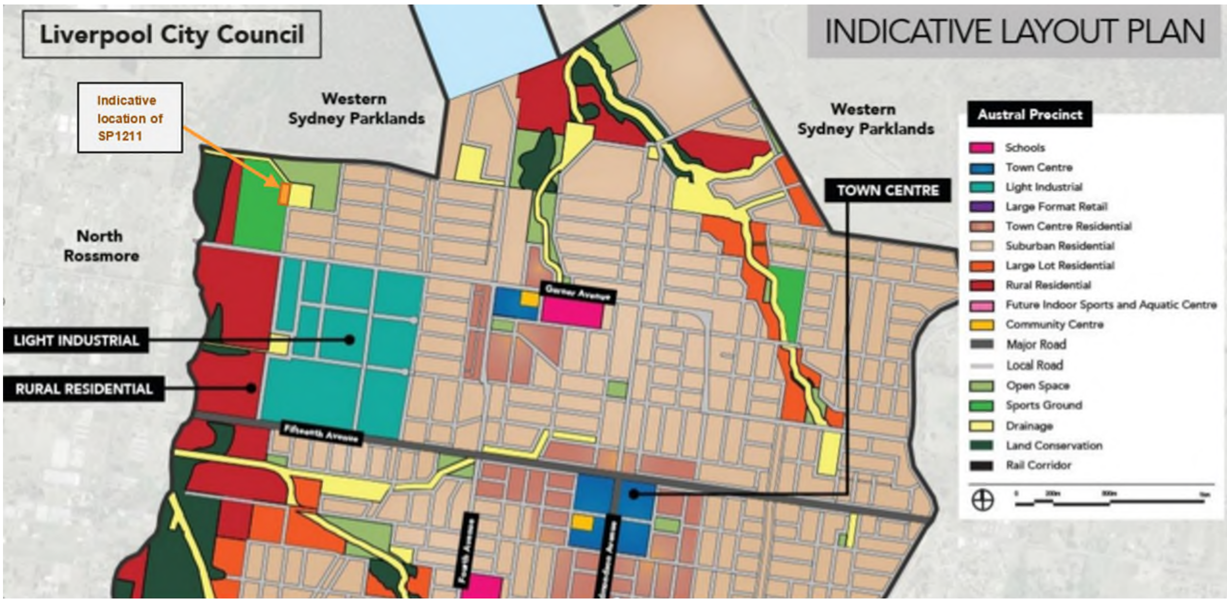

Figure 3-2: Austral Leppington precinct plan showing SP1211 location

3.3.3 Summary of storage opportunities

Sydney Water considers the scale of wet weather storage required does not allow practical application of this approach. Given Sydney Water's existing sites with wet weather storage regularly receive odour complaints, the community and operational impacts outweigh the benefits.

The intent of the tank would be to prevent six releases of primary treated effluent annually. Sydney Water considers other NSW Government investments in waterway health would provide more benefit for the cost.

3.4 Treatment of wet weather releases

The EPA has recommended Sydney Water further consider increasing the capacity of the secondary and tertiary treatment components of the AWRC: *'While there may be limitations to treating all discharges into South Creek at an advanced treated (reverse osmosis) standard, minimal consideration has been given to increasing the capacity of other treatment stages. Based on 2056 population projections, Sydney Water expects that the AWRC will ultimately require expansion to treat wastewater flows up to 100 ML/day and has set aside additional areas of the AWRC site for future capital works to meet this future capacity. Sydney Water should further consider fast-tracking any incremental capital works to increase the capacity of the secondary and tertiary treatment components of the AWRC in the future so that these works are incorporated into Stage 1 of the project. Improved secondary or tertiary treatment of the currently proposed primary discharges into South Creek may have a significant environmental benefit.'*

Additional treatment capacity of the secondary treatment streams would provide some reduction nutrient loads to South Creek, however the limited benefit needs to be considered against some of the risks it introduces. There are practical limitations of increasing this capacity for infrequent needs which introduce potential issues with dry weather treatment. This section provides analysis of some of the key considerations:

- Treatment performance.
- Operability and functionality.
- Environmental impact.

3.4.1 Wastewater treatment process overview

The proposed wastewater treatment process for the AWRC consists of:

- **Preliminary treatment including screening and grit removal**: Preliminary treatment will remove gross solids in the incoming sewage and screens and sized for all flows. Although not always the case, for the AWRC grit removal is also sized for all flows.
- **Primary treatment**: Primary sedimentation is required to remove suspended solids and associated particulate organics and some phosphorus. All flows will receive primary treatment as a minimum before discharge.
- **Secondary/tertiary treatment**: Consists of a membrane bioreactor (MBR). The MBR consists of biological treatment to remove organic material, nitrogen, and phosphorus. This uses a series of set conditions with aeration and anoxic zones, and chemical dosing. Effluent is separated from the biomass using membranes to produce a high-quality effluent.

  Nitrogen removal processes consist of two stages in which ammonia is oxidised to nitrate and then the nitrate is removed as nitrogen gas using COD as a substrate. Phosphorus is removed through a combination of biological processes and the addition of chemicals.

  Biological treatment processes work best under stable conditions so wet weather events can cause disruption to the process through higher flows and dilute concentrations. This has been reduced by inclusions in the reference design around the feed and bypass of the primary sedimentation tank to minimise this disruption by creating consistent conditions.

The protection of dry weather treatment also leads to the plant being designed for 3 x ADWF which provides a balance of treating some wet weather whilst not introducing large, dilute flows. As such, the design is to treat 3 x ADWF which is well in excess of PDWF (likely to be 1.5 – 1.7 x ADWF) and therefore small wet weather events will be treated.

- **Advanced treatment**: Downstream of the MBR to achieve the highest quality water membrane treatment. These processes need to be protected from poor quality water due to pore size.
- **Solids stream treatment**: Solids created by the primary and secondary processes will be treated in aerobic digesters stabilising the sludge for beneficial reuse and providing opportunity for energy generation and co-digestion.

Figure 3-3 shows a simplified process flow diagram for the AWRC.

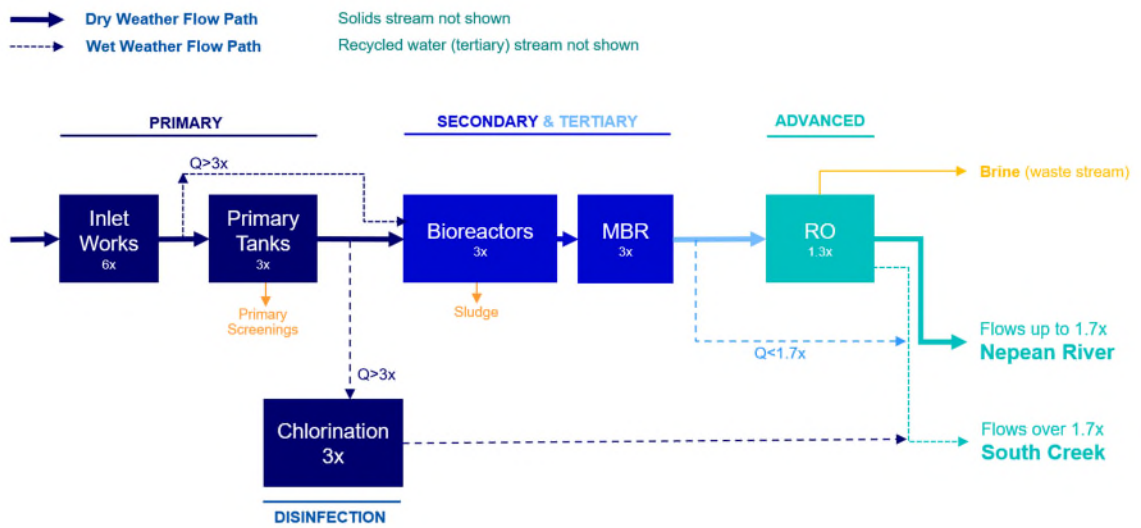

Figure 3-3: AWRC simplified process flow diagram

3.4.2 Treatment performance

If additional capacity was installed to treat the 3 x ADWF flows to secondary quality before wet weather discharge, there would be limitations in the nitrogen and phosphorus removal that could be achieved. As nitrogen is removed biologically sending additional wet weather flows may affect performance and reduce effectiveness overall. In addition, additional phosphorus removal would require a high amount of chemical dosing (such as alum or ferrous/ferric chloride). This would have implications on the biological process, particularly the lowering of pH disrupting nitrification in the bioreactor. As all dry weather discharges are treated by RO, which is capable of significant TP removal, the AWRC is still capable of removing TP from dry weather flows.

Ultimately, since the total AWRC loads to South Creek account for less than 2% of the total creek load as shown in Table 3-2, additional treatment capacity is unlikely to significantly change the waterway health outcomes for South Creek.

3.4.3 Operability and functionality

In addition to the performance issues that arise from the biological treatment process there are also issues with designing plant and processes with a large turndown (that is, oversizing them for infrequent events), especially where the peak flows occur intermittently. These issues may include:

- turndown of mechanical equipment such as pumps and blowers (that is, the operational range of a device is limited)
- velocities in pipelines leading to solids settlement
- in the case of membranes, having additional membranes will require additional aeration, cleaning and replacement (where MBR membranes have a lifetime of 5-7 years).

In additional to the process limitations with a large turn down, expanding the capacity of the MBR requires a proportional increase in operation and maintenance effort. Maintaining MBR requires membrane chemical cleaning, replacement of membranes and blower operation for agitation air. The increase in maintenance result in increased labour, chemical consumption, chemical deliveries and power usage. This level of effort, cost and vehicle movements are proportional to the number of membranes installed and not the flow they are producing. It should also be noted that the additional chemical delivery trucks will also have noise impacts on the surrounding residents.

Therefore, normally dormant capacity associated with the additional storm flow, would effectively double the level of maintenance and labour needed for the MBR.

The additional annual cost of operating the wet weather component is estimated at about $5,000,000, excluding power costs, for the six days of operation per year.

3.4.4 Treatment capacity and staging opportunities

The AWRC is sized to allow for population growth so in the early years there will be latent capacity available. However, for the reasons presented in section 3.4.2, staging will need to be developed to avoid over-sizing assets and causing performance issues. That is, as the capacity is approached more process units will be commissioned, but the full plant will not be commissioned in the first year.

The AWRC is therefore likely to be able to treat slightly greater flows than the design as each stage is brought on-line, reducing the impacts to South Creek. This will be further developed in detailed design. In addition, the water quality modelling was completed at the 50 ML/day design flows, so the impact on South Creek will be significantly less in early years.

Figure 3-4 shows the current forecast flows to the AWRC over time. In the first ten years, flows are well below 50 ML/day so wet weather discharge loads in these years will be lower than the 2036 loads shown in Table 3-1.

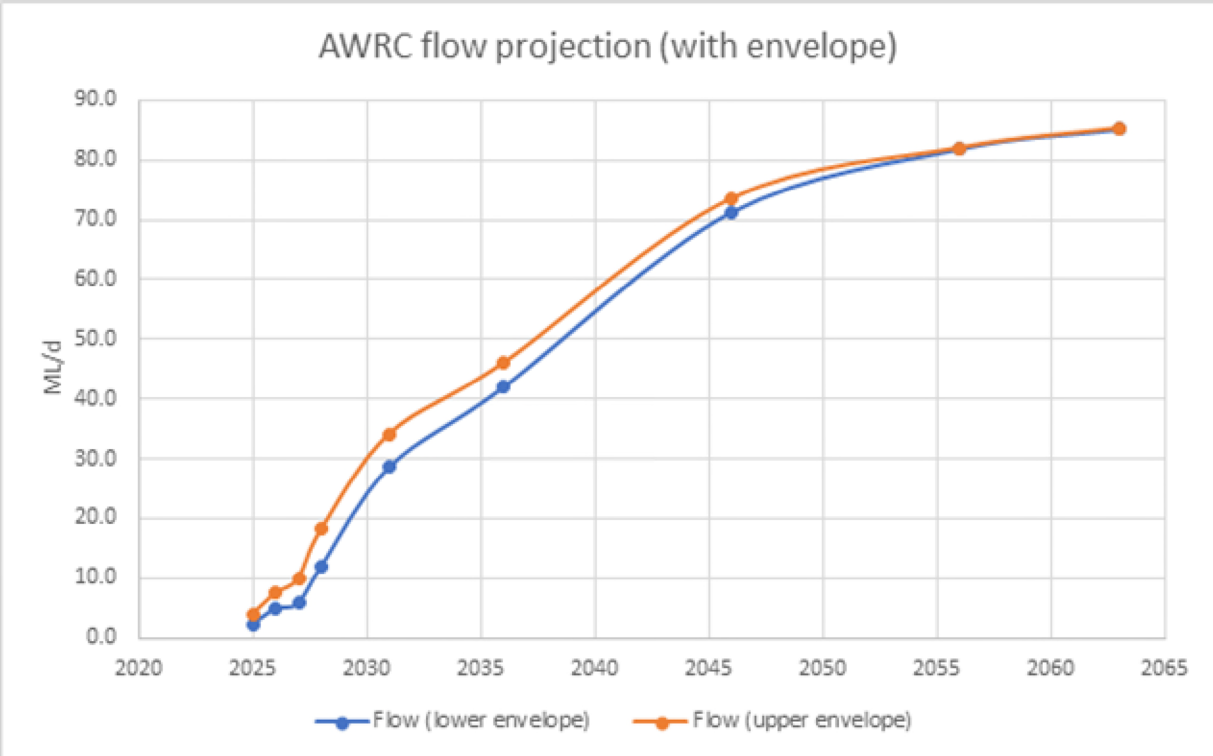

Figure 3-4: Current forecast of incoming flow to AWRC over time

This growth period allows Sydney Water to understand the trends in the region to best predict flows and loads as they slowly increase. This will happen as Sydney Water forecasts the next upgrade to meet the catchment demands. This presents an opportunity when planning the next stage of the treatment plant, with regards to timing and design to ensure that the plant always meets or exceeds expectations.

3.4.5 Disinfection of primary treated flows

The EPA has recommended that *'Sydney Water investigate and implement ultra-violet (UV) disinfection methods at the AWRC rather than use chlorine dosing/chlorination.'*

As outlined in Table 4-2 of the EIS, the preferred method of disinfection of primary treated wastewater is chlorination. Disinfection is required during severe wet weather events when incoming flows exceed 3 x ADWF. Primary effluent is disinfected with chlorine via the chlorine contact tank and subsequently dechlorinated through the addition of sodium bisulphite before release into South Creek.

The quantity of chlorine required depends on the amount of primary effluent passing through the chlorine contact tank (CCT) during wet weather. Chlorine analysers in the CCT will work with flow monitoring to providing continuous feedback to ensure the correct chlorine dose and sodium bisulphite de-chlorination dose. This ensures an adequate level of chlorination to effectively kill pathogens in the primary effluent. Excess chlorine is removed from the primary effluent by adding sodium bisulphite prior to release into South Creek, to minimise the effects of chlorination on aquatic life and water quality.

UV treatment has more maintainable infrastructure than chlorination. After a wet weather event, UV treatment infrastructure would need to be cleaned and maintained to extend its operating life. As the wet weather projections for the AWRC forecast six wet weather events in a year, the UV infrastructure will be mostly offline, and the response time and reliability may become an issue due to infrequent use. Reliability of chlorination is not typically an issue, as a single additional dosing pump can provide 100% standby capacity and can more readily respond to wet weather events.

A further benefit of chlorination is the ability to easily provide backup power to maintain disinfection during a power outage. MBR and RO treatments are at greater risk with power outage as there is no gravity flow path and they rely on high power pumps to pass through process units. The risk has been reduced at the AWRC by adopting dual power feeds, however under power failure only 50% of the plant is operable. Under those conditions, the MBR will only have 1.5 x ADWF capacity and discharge of primary treated effluent becomes a higher risk. Chlorination can easily be configured to maintain 100% capacity as all times due to low powered dosing pumps. The power backup can be achieved with uninterruptable power supply or similar, which is unlikely to be viable for a UV system.

3.4.6 Summary of treatment options

The current design of the AWRC is to provide treatment for 3 x ADWF through a membrane bioreactor. This provides a balance of protecting dry weather treatment performance and treating some wet weather flows.

While the AWRC will be staged to avoid operability and performance risks, there will be some capacity available as the staging occurs.

In addition, the incoming flows (and therefore releases to South Creek) are expected to increase slowly over time, which allows Sydney Water to better predict and plan subsequent stages prior to reaching the 50 ML/day scenario presented in the EIS.

The chlorination and dechlorination control loop and monitoring implemented as standard in Sydney Water minimise the risk to South Creek. Chlorination also provides a more reliable and operable disinfection system given its infrequent use.

4 Nepean River release location and design

The EPA has recommended further investigation into Nepean River discharge location: *'The EPA recommends that Sydney Water consider alternatives to the current proposed location and configuration of the discharges to the Nepean River. The following approaches should be examined in further depth by Sydney Water:*

- *Expanded assessment of toxicity impacts for the current discharge location*
- *Further assessment of alternative discharge locations'*

Section 4.1 considers the risks associated with the multi-port diffuser discharge configuration and section 4.2 considers alternate discharge locations of the treated water pipeline downstream of Wallacia Weir at Nepean River. The expanded assessment of toxicity impacts is covered in a separate document.

Figure 4-1 identifies some of the point of interest discussed in this section.

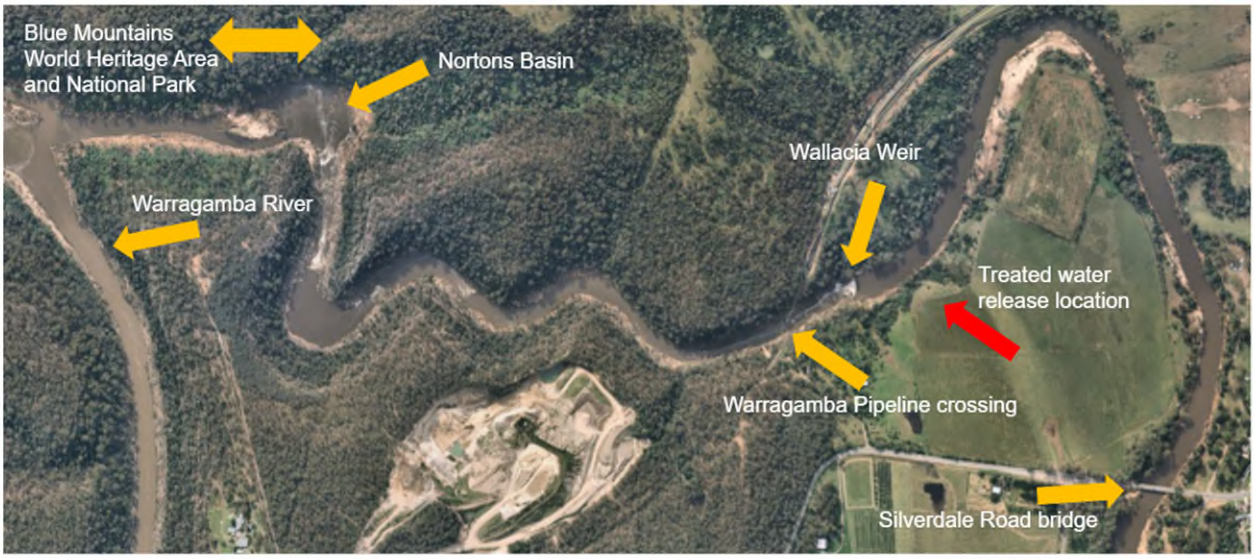

Figure 4-1: Nepean River release location and points of interest

4.1 Diffuser arrangement at Nepean River

Sydney Water has further assessed the opportunity of installing a multi-port diffuser at the proposed treated water pipeline release location upstream of Wallacia Weir. A multi-port diffuser would require permanent infrastructure within Nepean River, compared with the current proposed release structure set back from the water. The following sections outline the operational, maintenance and construction risks of an in-stream diffuser arrangement.

4.1.1 Operation

The depth of Nepean River at the current proposed release location presents considerable operational risk for installing a multi-port diffuser. The mean depth of the Nepean River upstream of Wallacia Weir is about 2.67 m for a flow of 229 ML/day, which can increase to up to five metres depth depending on flow conditions.

During periods of high flow conditions in Nepean River, deposited sand and debris can increase the localised height of the riverbed. To protect the diffuser from being covered up by sand and debris, a concrete encased riser (~1m) would typically be installed between the riverbed and the diffuser. Operational risks associated with a shallow diffuser depth include the following:

- Diffusers need to be installed at an optimal depth to ensure adequate mixing can be achieved in all flow conditions. As the water level is shallow at this location, the risk of not achieving adequate mixing particularly in low level river conditions is high.
- There is a risk of impact forces from logs and other debris damaging manifold and diffusers particularly during flooding. Any protective infrastructure close to the surface, such as the duckbill diffuser check valve, is susceptible to damage.
- Erosion damage from river scour isparticularly during high flow events and may expose both manifold and diffusers which may impact upon their operation.
- Safety issues for any public, recreational boats, or inspection vessels in the water in the vicinity of shallow diffusers and pipework.

4.1.2 Maintenance

As discussed above, a multi-port diffuser structure would need to be located in the Nepean River. The maintenance risks associated with this infrastructure are mainly due to having a submerged asset and associated access issues. Maintenance risks associated with shallow submerged assets include:

- More frequent inspections and maintenance checks would be required due to the increased susceptibility of damage. This would be challenging due to the relatively remote area and restricted boat access to the proposed release location.
- Maintenance checks of a submerged diffuser nozzle will be a specialised activity that can only be performed by trained divers. Remote inspection could be carried out for some structures, but not for the diffusers and check valve.
- There is a risk of silt building up over time in the manifold and provisions would need to be made to allow routine access to inspect and clear out the manifold. This creates an additional maintenance cost and potential environmental impact associated with the activity of silt removal.
- If the submerged assets were damaged, replacement of the diffusers or check valves could require a similar scale of installation to the initial construction, which would require extensive construction work within the riverbed and potential for associated environmental impact. Impacts associated with any bypasses or alternative release locations could also be substantial.

4.1.3 Construction

There are significant constraints and challenges associated with constructing a multi-port diffuser in the Nepean River. These include:

- Due to the size and depth of Nepean River, construction would need to use a barge for the construction of submerged assets. This may not be feasible for this location due to constrained access from upstream, and no possibility of access from downstream given it is not navigable by boat.
- Trenching/dredging activities within Nepean River to install submerged assets will cause significant environmental issues which have been avoided in the current proposal. The construction of a multi-port diffuser would increase the environmental impacts compared with what has already been assessed in the EIS.
- Construction within the riverbed is more likely to be affected by wet weather events, which can result in delayed construction and prolonged environmental and community impacts.

4.2 Alternative location of release structure

During the options assessment phase of the project, as outlined in Chapter 3 of the EIS, several potential release locations were considered. Table 3-5 of the EIS outlines the general locations that were considered, and the reasons why the current location upstream of Wallacia Weir is preferred. Ultimately, the constructability and the risks associated with many of the locations outweighed any functional benefits of alternate locations.

Sydney Water has further considered locating the treated water release downstream of Wallacia Weir in response to concerns raised by EPA. The following risks/constraints have been identified for constructing, operating and maintaining a release structure downstream of Wallacia Weir.

- As shown in Figure 4-2 and Figure 4-3, the riverbanks
  of Nepean River are considerably higher and steeper downstream of Wallacia Weir. This rocky steep terrain would pose significant challenges and risks in relation to construction safety. This would require a longer construction period and a considerable increase in capital cost.
- An access road is needed for construction and operation of a release location downstream of Wallacia Weir. Due to the topography this would require substantial works to reduce the grade with potential significant vegetation clearing and rock excavation.
- The existing Warragamba pipelines are downstream of Wallacia Weir and are critical for Sydney's water supply. It is anticipated that considerable rock excavation would be required with a release location downstream of Wallacia Weir. Any rock excavation in the vicinity of the existing pipelines would pose significant risk from vibrational loading. For similar reasons, it would also not be recommended to cross beneath these pipelines to locate the release structure further downstream of Wallacia Weir.
- There is likely to be increased environmental impact associated with constructing the release structure downstream of Wallacia Weir. This is due to the increased construction footprint in a steeper more vegetated environment.

- The water depth in Nepean River downstream of Wallacia Weir is expected to be shallower compared to the current proposed location. Considering this shallow depth, a diffuser option may not be feasible for this location and presents a much greater risk of not achieving required mixing. The risk of any damages to diffusers/manifold in shallower water is also very high.
- Locations downstream of Nortons Basin are not considered feasible as they would require substantial vegetation clearing and construction activities in the Greater Blue Mountains World Heritage Area, including roads and ongoing access through this area for maintenance.

Figure 4-2 View upstream of Wallacia Weir showing the change in topography

Figure 4-3 View downstream of Wallacia Weir highlighting the grade of the riverbank on the left

4.3 Summary

The additional toxicity assessment for Nepean River (outlined in a separate document) demonstrates that the modelling in the EIS presented a worst case outcome and that releases in smaller wet weather events have a smaller potential for toxicity impacts. Overall, the potential for toxicity impacts is low in all scenarios, given the highly conservative guideline values adopted and the short infrequent nature of releases of tertiary treated water. Given this outcome and the substantial constraints of relocating or redesigning the Nepean River release structure, Sydney Water considers the current proposed release arrangement presents the optimal outcome balancing environmental impacts, constructability, operability and maintainability. However, as outlined in management measure WW20 in Appendix B of the Submissions Report, Sydney Water will consider during detailed design if there are any further opportunities to improve dilution of Nepean River releases.

Attachment B Detailed responses to comments on hydrodynamic and water quality modelling

Table B1 Response to issues raised by NSW Environment Protection Authority regarding hydrodynamic and water quality modelling

Issue	Response
South Creek wet weather releases The EPA made the following comments in relation to South Creek wet weather releases: • Extensive bank attachment from the pollution plume will occur downstream of the release point will occur from the majority of the discharges. • These discharges would, in many scenarios, fail to meet toxicity dilution requirements for ammonia and chlorine.	Sydney Water confirms that section 6.2.1.3.2 of the Hydrodynamic and Water Quality Impact Assessment predicts the potential for extensive bank attachment of plumes from the AWRC releases. Based on analysis of release water quality from similar Sydney Water treatment facilities, it was evaluated that under extreme wet weather events (>3x ADWF), there is the potential for the South Creek release stream to contain elevated levels of ammonia and total chlorine, with 95th percentile concentrations above relevant toxicity DGVs. However, it is noted that this potential will not exist for most releases to the creek. Most releases will only consist of advanced treated (reverse osmosis) water containing no potential for toxicity. Releases of advanced treated water only are predicted to vary between three and eight days per year. In comparison, releases to South Creek including a blend of advanced treated water and wet weather primary treated water are predicted to vary between zero and six days per year. This blend/mixture is the low frequency, short duration release identified as potentially resulting in bank attachment of the downstream plume. As noted in the EIS, the potential for toxicity and environmental harm is considered low for the following key reasons: • The events are infrequent and of short duration. Typically mixing zones are only considered in terms of continuous releases with a focus on extended dry weather. • The adoption of ANZG (2018) guideline values is also conservative as these guideline values are applicable to long term exposure situations. No applicable shorter-term toxicity-based guidance values are available under the ANZG (2018) and ANZECC/ARMCANZ (2000) guidelines. • The releases correlate with conditions of significant flow within the creek and corresponding low residence times.

Issue	Response
	Further to the above, it is noted that the analysis is based on conservative assumptions relating to maximum (95th percentile) concentrations within the release stream. While this may be appropriate for assessments of continuous releases over extended dry periods, application of this criteria to wet weather releases of limited frequency is debatable. The likelihood of 95th percentile concentrations within the release stream during infrequent wet weather releases is expected to be low due to significant dilutions that occur during such an event. Lower concentrations, such as 50th %ile concentrations, may therefore be more applicable in the assessment. Median values for both ammonia and chlorine are predicted to be well below toxicity DGVs as outlined in Appendix B of the Hydrodynamics and Water Quality Impact Assessment (Appendix F of the EIS).
Primary treated effluent would contain substantial nutrient concentrations (18 mg/L median concentration for total nitrogen) and pathogens (7,400 CFU/100 mL median concentration for enterococci).	While Sydney Water confirms that the median concentrations of total nitrogen and enterococci in the wet weather primary treated water have the potential to reach the levels quoted by the EPA, these concentrations would not be experienced in the creek. As noted above, releases to South Creek will consist only of advanced treated water for inflows between 1.7 – 3 x ADWF. When inflows are greater than 3 x ADWF, wet weather (primary) treated water will be mixed with advanced treated water. Further dilution occurs at end of pipe. As per the analysis presented in Table D1, it is estimated that the concentration of nutrients within the blended primary and advanced water release stream would range between 2 and 8 mg/L total nitrogen, and 0.1 and 0.6 mg/L total phosphorus, which is significantly lower than the nutrient content of untreated sewage. Similarly for enterococci, it is estimated that concentrations in these releases would range from ~500 to ~4,000 cfu/100 mL As noted in the responses above, these blended releases would occur infrequently, between zero and six days a year.
Analysis of other pollutants likely to present in primary treated effluent have not been	There is potential for wet weather (primary treated) releases to contain other constituents that were not

Issue	Response
undertaken. A wide range of other constituents (e.g., endocrine disruptors, heavy metals, other pathogens) found in primary treated effluent will also likely be discharged to the river system during these discharges.	included in the WQRM or near field modelling. The concentration of these potentially numerous constituents in wet weather treated water is highly variable and also challenging to measure due to the high temporal and spatial variation in catchment inputs that is possible during a high rainfall event. A recent monitoring program at Fairfield Water Recycling Plant involved sampling of secondary treated water and testing for 371 indicators (including endocrine disruptors, heavy metals, other pathogens). Of these 371 indicators, 144 were detected in the secondary treated water, of which 10 were above guideline values. 57 of the 144 pollutants detected do not have guideline values. While this program targeted secondary treated water, rather than primary, it illustrates the potential challenge of analysing numerous other pollutants, many of which do not have guideline values. In light of this, Sydney Water adopted the approach of focusing primarily on constituents for which it is regulated. This includes a large range of representative pollutants that allowed a robust assessment of potential impacts on waterway values, including aquatic ecology, recreation and aesthetics, primary industries and drinking water. Modelling of these other pollutants within receiving waters is also not without its challenges. Simulation of some of the constituents mentioned are the topics of active research within the modelling community, but currently, the uncertainty and variation would be so substantial, that in most cases the results would not be meaningful. Sydney Water considers this to be a reasonable and practical approach to assessing impacts. Monitoring of wet weather releases will be undertaken during operation.
No assessment has been undertaken on pathogen impacts for recreational areas within South Creek. The discharge of effluent containing large concentrations of pathogens would present human health risks that could substantially limit recreational water use in South Creek in the future.	The EIS included an assessment of impacts on downstream pathogen concentrations in South Creek. The modelling results were compared to guideline values for enterococci and background levels (without the AWRC releases). The modelling predicted both short term reductions and spikes in enterococci concentrations depending on the severity of the wet weather event. The impacts vary between dilution during less extreme events when only advanced treated

Issue	Response
	water is released, and higher loading during more extreme events, when primary treated wastewater is mixed into the release. More specifically, during the minor events (less than 3 x ADWF), reductions in enterococci concentrations were predicted. Conversely, short duration spikes were predicted during severe wet weather events (greater than 3 x ADWF), when the proportion of wet weather treated releases is higher. This range of impacts is presented in the Hydrodynamic and Water Quality Impact Assessment at a site located 250m downstream of the release point. Figure 8-10 in the EIS presented the location of recreational sites along South Creek. The nearest one to the AWRC release point is Samuel Marsden Reserve, located about 13 km downstream. Figure B1 shows the predicted concentrations of enterococci at a site adjacent to the Samuel Marsden Reserve. As the site is a significant distance downstream, the influence from the AWRC releases is greatly reduced relative to results for the site presented in the Hydrodynamic and Water Quality Impact Assessment. Predicted impacts from the releases are limited to less than 3 cfu/100mL In line with the discussion provided in the EIS, many of the releases are predicted to improve recreational water quality, due to the low or nil pathogen concentration in the released advanced treated water. During, and immediately subsequent to, severe wet weather events when spikes in concentration may occur, it is highly unlikely that recreation would be occurring. These events are infrequent and of short duration. As shown in the modelling results for Samuel Marsden Reserve, the influence from the AWRC is also expected to be insignificant at the existing recreation sites downstream. Based on the findings of this analysis, the AWRC releases are considered unlikely to impact or limit future recreational water use in South Creek.
The cumulative impact of the South Creek AWRC discharges during wet weather with other similar wet weather discharges from	Wet weather discharges from other Sydney Water operations has been included in the assessment. Sections 4.6.3.5.4 and 4.6.3.5.5 of the

Issue	Response
Sydney Water operations have not been well modelled or quantified in the assessment.	Hydrodynamic and Water Quality Impact Assessment (Appendix F of the EIS) outlined the following model inputs: • Flows and corresponding water quality from other relevant wastewater treatment plants (WWTPs) and water recycling plants (WRPs), including St Marys WRP, Quakers Hill WRP, Riverstone WWTP, South Windsor WWTP and McGraths Hill WWTP for the South Creek catchment. Flows were adjusted for population growth, reuse, network transfers and any changes to inflow and infiltration to the wastewater system. Concentrations of the key contaminants were also adjusted in line with any planned upgrades that have been agreed with the EPA. Variability in water quality parameters was also included in line with historical monitoring data or forecast performance of the WWTPs and WRPs. Treatment bypasses during wet weather events were also considered and included where applicable. • Wet weather overflows from the wastewater system were also incorporated into the model. Timeseries of overflow release rates were simulated using the MOUSE software platform for both the existing and future network. The above inputs ensure that the cumulative impact from these existing and future point sources are included in the modelling results. With regard to cumulative impact over longer time scales, no continuous long-term (for example, 20 year) scenarios were presented. While such scenarios would be challenging to undertake from a model run time perspective, there are other key reasons for these simulations not to be included. As previously discussed, these include: • Long-term continuous simulations offering alternate possible future trajectories has not been identified as a requirement of the EIS or undertaken for similar EIS elsewhere in NSW. • Uncertainty in land-development, climate and future discharge regimes of non-AWRC facilities mean that these simulations would be hypothetical and too uncertain to be meaningful. • Given the low frequency and the expected

Issue	Response
	nutrient content of the releases to South Creek, the potential for long-term accumulation of nutrients is considered low, both in terms of South Creek and within the tidal pool of the Hawkesbury River. This is endorsed by the modelling undertaken to date, as reported in the Hydrodynamic and Water Quality Impact Assessment (Appendix F of the EIS).
Nepean River release location – toxicity modelling In the RtS Report, Sydney Water stated that "additional near field modelling of other release conditions during dry or mild to moderate wet weather conditions [in relation to the Nepean discharge] …is not warranted as the risk of toxicity in the release streams has been identified as low given the higher treatment levels of effluent in these conditions (ie advanced or tertiary treated water)." Further justification is needed for this statement. During partial and moderate wet weather events (1.3 – 3 x ADWF), tertiary treated effluent will be discharged into the Nepean River. This effluent contains multiple pollutants that exceed ANZG DGVs. While this discharge will be mixed with advanced (reverse osmosis) treated effluent, this does not necessarily mean that these moderate wet weather discharges will meet mixing zone toxicity requirements (especially given that tertiary treated discharges during extreme wet weather are modelled to have significant issues with respect to toxicity). Without this assessment, it is unclear as to the frequency and impact of discharge events in which toxicity impacts will be observed at the Nepean River discharge. An assessment of near-field toxicity impacts should be undertaken for the Nepean River discharge for scenarios in which tertiary treated effluent is to be discharged (between 1.3 and 3 x ADWF) and discharge concentrations are above ANZG DGVs. Even without a more complete toxicity assessment of the Nepean River discharge under other scenarios, TN, TP and NOx in the tertiary effluent do not meet ANZG at the edge	Additional near field modelling has been undertaken to consider the additional release conditions. Additional parameters including total nitrogen, total phosphorus and inorganic species have also been considered in this additional work. These are not usually a requirement of near-field assessment, as they are not toxicants. As an initial step in this modelling, the timeseries of AWRC inflows was analysed to determine the dates that fell within the following categories: • 1.3 to 1.7 x ADWF (12, 28). • 1.7 to 3 x ADWF (3, 12). The numbers provided in brackets relate to the number of days predicted in the 2013/14 dry year and 2014/15 wet year respectively. From this analysis, eight release events were statistically selected per category to provide a representative range of daily release volumes from the AWRC. Once selected, the following data was extracted for these events to allow for development of the CORMIX scenario boundary conditions: • Water quality of the AWRC Nepean release stream (from analysis of the AWRC water balance model). • Background water quality within the Wallacia Weir pool (from analysis of the WQRM). • Flow rates in the Wallacia Weir pool upstream of the release point (from analysis of the WQRM). • Water elevation and depths at the proposed Wallacia Weir release point (from analysis of the WQRM). The eight scenarios per release category were then run to develop dilution profiles in a similar format to the previous analysis (that is, dilution factor against trajectory distance from the release point) as

Issue	Response
of the near field mixing zone (which is at least 50m) during extreme wet weather events. Based on this very basic assessment and the mixing zone results for the identified toxicants in the EIS, the discharge represents a risk to the protection of the environmental values in the Nepean River under extreme wet weather.	described in section 6.2.1.2 and Figure 6-152 of the Hydrodynamic and Water Quality Impact Assessment (Appendix F of the EIS). These dilution profiles are presented in Figures B2 and B3 (included after this table). For completeness, the results from the third release category (>3 x ADWF) are also included as Figure B4. Of note, the scenarios and dilution profiles represent: • 2036 time horizon with a AWRC capacity of 50 ML/d but with release volumes to the Nepean River of between 59 and 85 ML/d • differences in the distribution of rainfall that has the potential to initiate higher inflows at the AWRC but not necessarily also in the Nepean River • flows in the Nepean River upstream of the release point that account for the potential discrepancy in hydrodynamic calibration discussed in Section 6.1.2.6 of the Hydrodynamic and Water Quality Impact Assessment. The following findings are drawn from these results: • Dilution factors of between 2 and 5 are predicted within 50 m, for the releases between 1.3 and 1.7 x ADWF • Dilution factors of between 2.5 and 5.5 are predicted within 50 m, for the releases between 1.7 and 3 x ADWF Of interest and importance, unlike the modelling of the extreme wet weather releases (>3 x ADWF), the plumes are not predicted to attach to the river banks immediately downstream (refer Figures B5 and B6 below). Due to the generally lower flows and velocities within the weir pool, the plumes are instead predicted to generally flow away from the headwall apron and the adjacent river bank. The plumes are then deflected to different degrees dependent on the ambient flows within the weir pool. The risk of bank attachment may therefore be significantly lower than presented in the previous modelling. However, the predicted dilutions are still relatively low and below the dilution criteria

Issue	Response
	presented for aluminium, copper and zinc within the Hydrodynamic and Water Quality Impact Assessment. In addition to the points raised in section 6.2.2.3.3 of the impact assessment regarding the low risk of toxicity, the following points are also identified: • Under these lower release conditions, the potential for elevated concentrations of these metals will be reduced due to the higher proportion of advanced treated water in the blended release. Tables B2 and B3 (below) present analysis of the potential concentrations to be released under these more moderate release categories. The analysis shows that with the additional dilution from the advanced treated water: • there is very limited risk of toxicity for releases between 1.3 and 1.7 x ADWF. Only aluminium and zinc have the potential to be above the ANZG toxicity DGVs in the release stream and dilutions below a factor of two are required to achieve these DGVs • there is reduced risk of toxicity for releases between 1.7 and 3 x ADWF relative to the original analysis undertaken for releases above 3 x ADWF. The maximum dilution requirements for aluminium, copper and zinc reduce to between 5.9 and 7.6 compared to 7.3 and 10.3 for extreme wet weather releases • In line with previous comments on the South Creek near field modelling, it is noted that the analysis of toxicants is based on conservative assumptions relating to maximum (95th percentile) concentrations within the release stream. While this approach is in line with the relevant ANZECC/ANZG guidelines for assessment, the application of this criteria to wet weather releases of more limited frequency is again considered debatable. Finally, application of the near field modelling was considered in relation to other contaminants of concern including total nitrogen, ammonia, nitrate, total phosphorus and FRP. However, the application of the modelling to these parameters presents challenges due to the relative levels of background concentrations compared to the ANZG

Issue	Response
	DGVs and also the concentrations in the AWRC releases. More specifically, in the majority of the release scenarios above 1.3 x ADWF one of the following conditions applied: • The background ambient concentration was greater than the relevant DGV. That is, prior to introduction of the AWRC releases, the river water quality was predicted to be non-compliant with the ANZG guideline values during the selected wet weather conditions. • The background ambient concentration was higher than the concentrations in the AWRC releases. That is, the AWRC was providing a degree of dilution. From a purely analytical perspective, this raises challenges as application of the equation that is generally adopted to determine dilution requirements was found to be incompatible as it generated negative nonsensical results.
Limitations of WQRMs – Brett Miller's comments Note that models have an inherent level of uncertainty. Support recommendations of peer review by Brett Miller that the statistical analysis of the calibration and verification in Section 4 of the Calibration Report should also report: • The equations used for each of the four statistical measures. • The number (n) of "samples" vs "model" data points that were used in each period, parameter and waterway zone. • Definition of what quantitative measures comprised "poor", "acceptable" and "accurate". • Referencing of statistical and modelling papers as to why these values were adopted.	To give context to the assessment strategy adopted for the modelling, the issued TUFLOW FV calibration report cites the paper Hipsey et al. (2020) "A system of metrics for the assessment and improvement of aquatic ecosystem models". *Environmental Modelling & Software*, V*128.* The error statistics are commonly used and clearly described in our report and the equations are available in this open-access paper. Error is computed when the sample number for a variable is more than 10 for that year and that zone. It is not possible to retrospectively add the number to the plots and report, but it is noted to add the sample number n into the error summary for the next model calibration cycle. Also, please note that the transect plots in the TUFLOW FV calibration report (one example shown in Figure B7 below) indicate the sample number when comparing sites along the estuary. In the confidence evaluation, modellers considered the: • quality of observed data, which is influenced by field and laboratory data limitations, methodologies, processes and protocols • performance scores (R, BIAS, RMS, NRMS) relative to what is typically reported in the literature for water quality models (eg. Arhonditsis and Brett, 2004. "Evaluation of the current state

Issue	Response
	of mechanistic aquatic biogeochemical modeling”. *Marine Ecology Progress Series,* 271) • ability of the WQRM to capture the mean of an indicator and its spatial gradient and seasonality, based on the seasonal transect plots • partitioning of water quality constituents within different ecosystem pools (eg. NO3:TN ratio) • natural variability of the indicator at different spatio-temporal scales (i.e. sub-daily to seasonal). All of these qualitative and quantitative metrics of performance were collectively assessed and interpreted by the modelling team who then assigned the categories of poor, acceptable and accurate.
Limitations of WQRMs – general Models can sometimes consistently overestimate or underestimate the flow and concentration of nutrients or other important water quality variables. The provision of the new Calibration Report provides an opportunity to explore the recent calibration and validation of the South Creek and revised Hawkesbury Nepean models.	Sydney Water notes the EPA’s general comments regarding provision of the Calibration Report and specific comments are addressed below.
Limitations of WQRMs – calibration and validation periods The first point to note here is that both models have been calibrated to only one years’ data (July 2017-June 2018). Variability from year to year is to be expected, which means there will be uncertainty related to the calibrated parameters in these models. It is not always clear what these uncertainties are, but the calibration/validation report does help provide some insights into this variability. The South Creek and Hawkesbury Nepean model has been validated for two years data (July 2013-June 2014 and July 2014-June 2015 years). An additional validation year, (July 2012-June 2013), was also run for the HN WQRM. The point here is that validation occurred for two years in South Creek and three years for the broader Hawkesbury Nepean. Neither include the drought year of 2019 and so it remains unclear how well the model would predict the	As outlined previously, it is of key importance to note that each model was continually refined with respect to performance across all the calibration and validation years and not just the calibration period. Therefore, while initial assessments of the model’s performance were undertaken for the calibration period, equal emphasis was placed on both the calibration and validation exercises. Therefore, if concerns or distinct anomalies were observed in either calibration and/or validation exercises, the model settings were reviewed, remodelled and reanalysed across the entire calibration/validation period. Sydney Water agrees with the point raised that extreme wet weather releases to South Creek and the Nepean River are highly unlikely in drought periods. Sydney Water agrees that model performance should be tested by validating against different conditions. While our two validation ‘periods’ were continuous, the combined duration represents both a

Issue	Response
behaviour of the catchment flows and water quality at other times and the impact of the AWRC during extreme drought. Luckily during drought it is unlikely that wet weather discharges would occur, but the effect of discharges and benefits of the proposal during such times remains uncertain. An important step in reviewing the model is the assessment of how well the calibrated model predictions agreed with observed data during the two (or 3) validation periods.	wet and dry year, as shown in Figure 4-5 of the Hydrodynamic and Water Quality Impact Assessment. The calibration and validation years were selected based on a number of criteria including but not limited to availability of field data and climatic range of conditions (wet and dry) under which to test the models' performance. It was not viable to include the 2019 year within the calibration and validation process as model development commenced in quarter three of 2019. Inclusion of this year would have required access to field data under collection and also forcing information (such as meteorological data) needed to drive the model. Therefore, 2018 was the limit with respect to accessible datasets. It is further noted that the year 2013/14 was included as it was considered as a representative and more extreme lower rainfall year as shown in Figure 4-5 of the Hydrodynamic and Water Quality Impact Assessment.
Limitations of WQRMs – flow losses at South Creek gauging station and other locations The EPA refers to section 3.1.2 of the calibration report and notes the level of adjustment to South Creek flows at gauge 212048 are fairly significant (up to 10 ML/day in some cases). Since the calibration period was for one year (July 2017-June 2018), very limited information on 'flow losses' are available for other years, or how well the adjustment used here affects model output in other years. The calibration years (July 2013-June 2014 and July 2014-June 2015 years) suggest some deviation between modelled and predicted, particularly for the second time period. Again it would be nice to know the behaviour and effects of this flow loss adjustment in the 2019 drought year and at other gauging stations in South Creek (or other catchments). More comprehensive assessment of this issue in other years and at other sites should be undertaken.	The interest in these flow characteristics is understood and acknowledged. The presence of over 4,700 farm dams and other features within the South Creek catchment that can influence the creek flow regime made the Source model calibration process complex. Sufficient information was not available to characterise these losses, which is why the 'loss node' was used. As a result, investigations into improving both our understanding of the catchment, and representing it more effectively in the modelling have been identified as a work stream within the multi-agency Hawkesbury Nepean Science Working Group. These investigations focused on three central elements. Firstly, research was conducted into the potential role of groundwater, which was deemed not to be a driver of these losses. Secondly, more explicit representation of the largely unregulated farm dams in the model is underway to better characterise their role in the catchment hydrology. Finally, as part of implementing the revised Water Sharing Plan for the region, we anticipate more definitive information regarding irrigator behaviour. Currently the model relies on IQQM modeling of irrigator behaviour provided by Water NSW, which was extrapolated out to cover the period from

Issue	Response
	2012-2018 (Figure 2-8 of the Source Model Calibration Report). This was noted as an assumption and limitation in 2.3 of the Source Model Calibration Report. As a coupled model, the South Creek WQRM is predominantly driven by the results from the Source catchment model. As identified in the Hawkesbury Nepean and South Creek TUFLOW FV and AED2 Model Calibration Report, it was therefore fundamentally unviable to achieve better calibration against the gauge data than that provided for by the Source catchment model. Consequently, any anomalies or discrepancies arising in the Source catchment model results were also reflected in the WQRM model results. Despite this reliance, the following points of relevance are provided: • Flow adjustments within the Source model (and consequently within the WQRM) were applied to address potential effects from farm dams and other flow controlling structures within the contributing sub-catchments. • As per the previous response, the 2013/14 validation year was selected as it was classified as a representative and more extreme lower rainfall year (refer Figure 4-5 of the Hydrodynamic and Water Quality Impact Assessment). • Model validation at gauge 212048 was considered good but less representative for flows below 5 ML/d. • Model validation at gauge 212320 implied weaker performance, but this was also attributed to the ephemeral nature of the creek higher up in the catchment, and also the quality of observed gauge data. Irrespective of these findings and the research and model development initiatives underway, the findings from the EIS regarding the AWRC wet weather releases are not expected to be affected. In particular, it is noted that the WQRM's performance in simulating higher flow events (when the AWRC releases to South Creek occur) is considered fit for purpose. The response below details further assessment

Issue	Response
	that will improve understanding of flow losses and the basis of calibration for all gauges, across the spectrum of climate conditions.
Limitations of WQRMs – calibration at other locations Other calibration/validation issues were found for the Colo River (212290; underestimation of low flows), Eastern Creek (212296; overestimation of high flows, underestimation of low flows) and South Creek (212297; underestimation of medium to low flows). No validation was available for the Eastern Creek gauge (567069) since all data were used in the calibration phase. It is unclear what effects the underestimation/overestimation of flow in model outputs have on various conclusions. Such effects will be minimised when relative comparison of one scenario are made to another (since they will cancel each other out), but it is quite difficult to say what this could mean in terms of absolute predictions, except that over/underestimation of modelled flow can considerably increase the uncertainty of model predictions.	The flow discrepancies come from predicting the inputs from several ungauged catchments. This is as expected in a coupled catchment-river model, particularly of such scale as the Hawkesbury Nepean catchment. The lack of gauges to constrain flows in the catchment is an issue identified by multiple agencies. DPE has conducted a review of gauges and, following engagement with other stakeholders, including Sydney Water, created a prioritised list for potential additional gauges. It should also be noted that gauges themselves are calibrated to focus on high or low flows, with the result that their corresponding performance is weighted around that. With reference to the Colo River catchment, there is negligible change over the time horizons of interest, so any limitation related to lack of gauges will have no relative impact on the comparative assessment. Regardless, the paired calibration and validation charts show strong level of agreeance between modelled and observed flow during these periods (Figure 4-2 of the Source Model Calibration Report) With reference to Eastern Creek, calibration results at the site indicate the model is reproducing total flow volume with a similar flow duration to that of the observed flow (Section 4.1.3 Source Model Calibration Report). Additional gauging has been flagged as a priority in this catchment to support modelling and implementation of the Greater Metropolitan Water Sharing Plan. When this additional data becomes available, it will be used by Sydney Water to help achieve a better calibration. Given flows from these sites are representative, they could be used to make direct inferences about flow characteristics in future scenarios. The calibration at 212297 in South Creek has an acceptable calibration, however the validation shows an underestimation of observed flow. As discussed in 4.1.4 of the Source Model Calibration Report, this relates to the poor flow rating available for the site. In remains an appropriate use of the model for

Issue	Response
	results at this site to be used for scenario comparison, such as for application in the project's EIS.
Limitations of WQRMs – over and under estimation of water quality As identified for flows above, depending on the site chosen, the models can sometimes consistently overestimate or underestimate the concentration of nutrients or other important water quality variables. The calibration report adopts a different approach when presenting water quality data (boxplots) than it does for flow (flow exceedance curves). Greater consistency and insight could be achieved if the water quality data were presented as concentration exceedance curves (similar to the flow exceedance curve). This is relatively simple to implement if one had access to the observed and model predicted data. Again, a detailed analysis of water quality at various sites was unable to be achieved in the timeframe available but some issues (underestimation/overestimation of concentrations) were also noted in passing for TN at 212290 & 212291, enterococci at 212213, TP at 212290, TDS at 212290 & 212291, TP at 212213 & 2122131 (see below). In some cases, it appears that the revised model actually does worse (has a poorer agreement with observed data) than the original model. It would be good to explore the underlying reasons for this. Again, it is unclear what effects such underestimation/ overestimation of model concentrations mean in terms of prediction for individual sites.	Flow exceedance curves are a routinely used metric to describe the likelihood of certain values occurring but require a continuous relatively high frequency record of data (for example, from a daily hydrograph). Unfortunately, this is not possible during calibration, since when using patchy water quality data, the number of samples through time is not as high in terms of sample density, and in many cases might just be at monthly frequencies, intense wet weather campaign or discontinuous and sporadic. A box-whisker is therefore considered more appropriate for application to water quality parameters as it simply seeks to describe the range rather than ranking the data to compute the likelihood. For comparing scenarios modelled in the WQRM, the model time-series of concentrations could be plotted as exceedance plots as suggested, but this will not provide much of a different outcome than the already prepared box-whisker plots since the shift in the mean and tail is generally modest between the impact scenario and the reference background simulations. Whilst these calibration issues noted by the EPA lead to a degree of uncertainty of the effect of a proposed release at a particular location and time, the following key conclusions can still be drawn from the analysis: • The overall annual load of nutrients from the AWRC discharge is low (approximately 0.5% and 1% of what is entering South Creek and Nepean River respectively in terms of TN). • The relativity between scenarios and the baseline clearly shows the indicative magnitude of impact on all simulated water quality variables across a range of flow conditions. We refer to previous responses about the suitability of the model for this impact assessment, sensitivity and statistical assessment applied, as well as the distinction between instantaneous prediction accuracy and ability to represent reach-scale changes under different scenarios.

Issue	Response
Limitations of WQRMs – defining acceptable performance The statistical analysis for the calibration report focused on a range of indicators including salinity, temperature, nitrogen, phosphorus and total chlorophyll a. The statistical metrics applied included the following: (1) regression coefficient (R) (2) bias of average prediction to the average observation (BIAS) (3) root mean square (RMS) (4) normalised root mean square (NRMS) calculated as RMS normalised by the average observation values. Tables 4-2 and Table 4-6 identified areas/sites of poor calibration where results need to be treated with caution. Chlorophyll a appears to be one of the poorest, but there also some issues with phosphorus (TP or FRP) depending on the zone considered. It is unclear how 'acceptable performance' has been defined when the statistical bias metric can be greater than 100%.	Table B4 responses include more detail about use and interpretation of the model error metrics, including a discussion about chlorophyll a results. The EPA comment refers to TP metrics being considered 'acceptable' when the bias was >100%, however as seen in the referred to Tables 4-2 to 4-6 of the TUFLOW FV calibration report, such results were almost always flagged as 'caution'. There are two exceptions to this, and as outlined in previous comments, assessment of model performance is not made off any individual statistic in isolation, rather a comprehensive suite of statistical and trend analysis. For chlorophyll a, results are flagged for caution at much lower percentages of bias. For variables like FRP, that can be an order of magnitude lower than total phosphorus in the system, a seemingly high bias is not necessarily considered a major calibration flaw. As highlighted in earlier responses to other comments, the error is also a consequence of uncertainty in the inputs from the many ungauged catchments that enter into this system, and with this in mind and experience with similar modelling studies, these categories were deemed appropriate when looking holistically at the system, including the mean transect plots. The bias does not prevent the assessment of the relative differences between the impact scenario and the baseline and background scenarios. Sydney Water has been working with DPE to undertake monitoring programs beyond individual licence compliance monitoring to help address issues such as this. These catchment-scale snapshots include not only greater spatial representation throughout the catchment, but also include additional analytes to inform in-stream processes. Sydney Water, along with DPE and the EPA, have mapped out plans for ongoing improvement of the model with the view to continue to improve its accuracy and ability to simulate a variety of conditions.

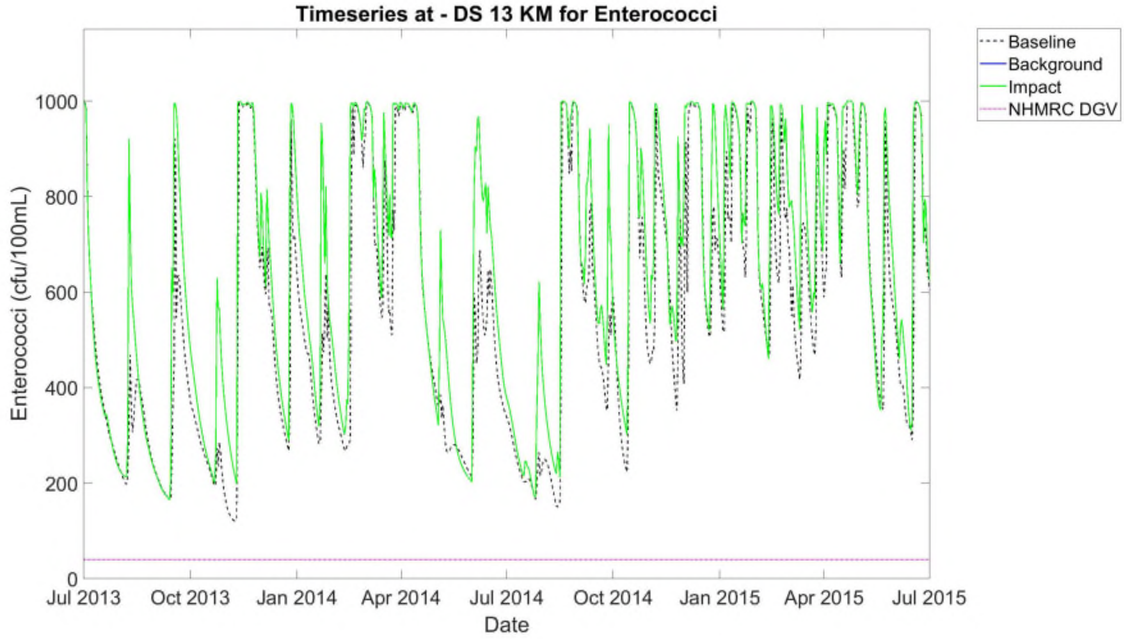

Figure B1 Timeseries of predicted enterococci concentrations adjacent to Samuel Marsden Reserve (2036 releases)

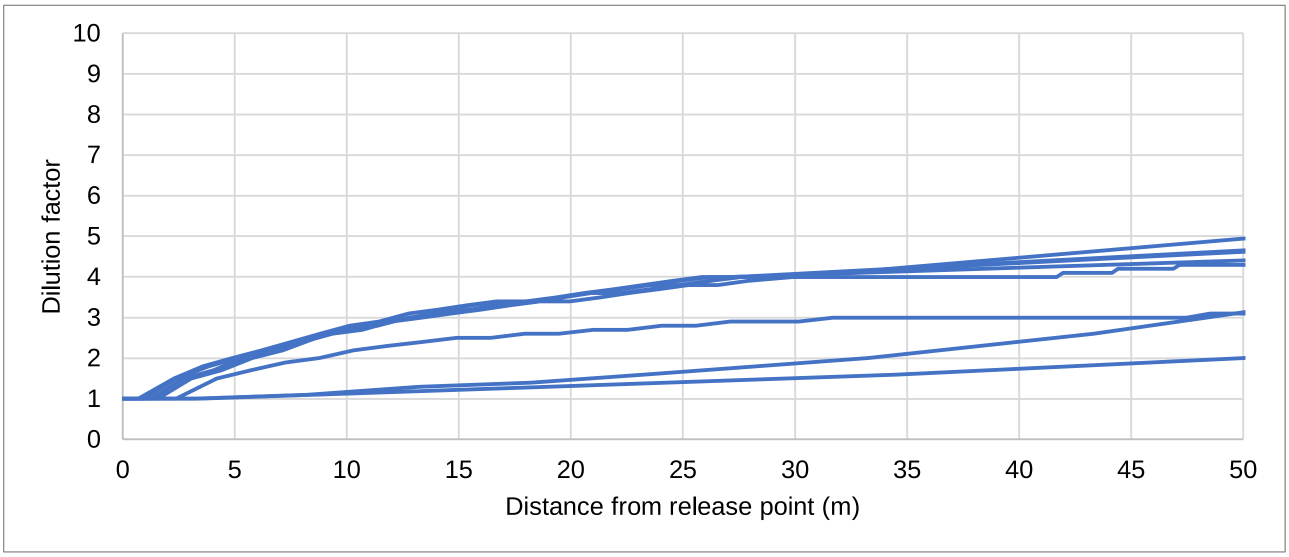

Figure B2 Predicted dilution profile for the Nepean River for releases between 1.3 and 1.7 x ADWF (2036 releases)

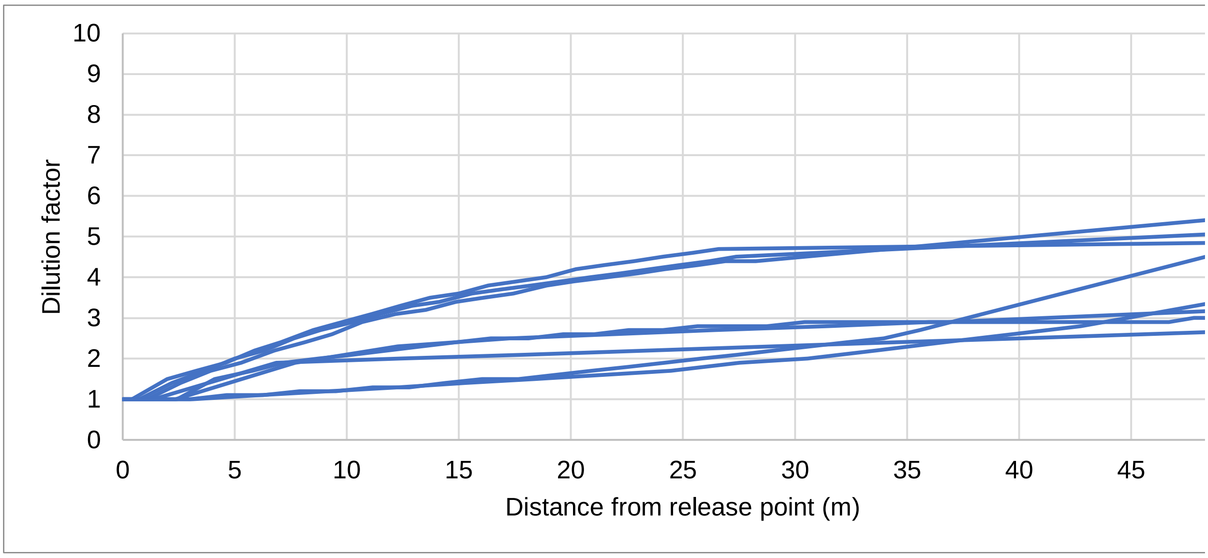

Figure B3 Predicted dilution profile for the Nepean River for releases between 1.7 and 3 x ADWF (2036 releases)

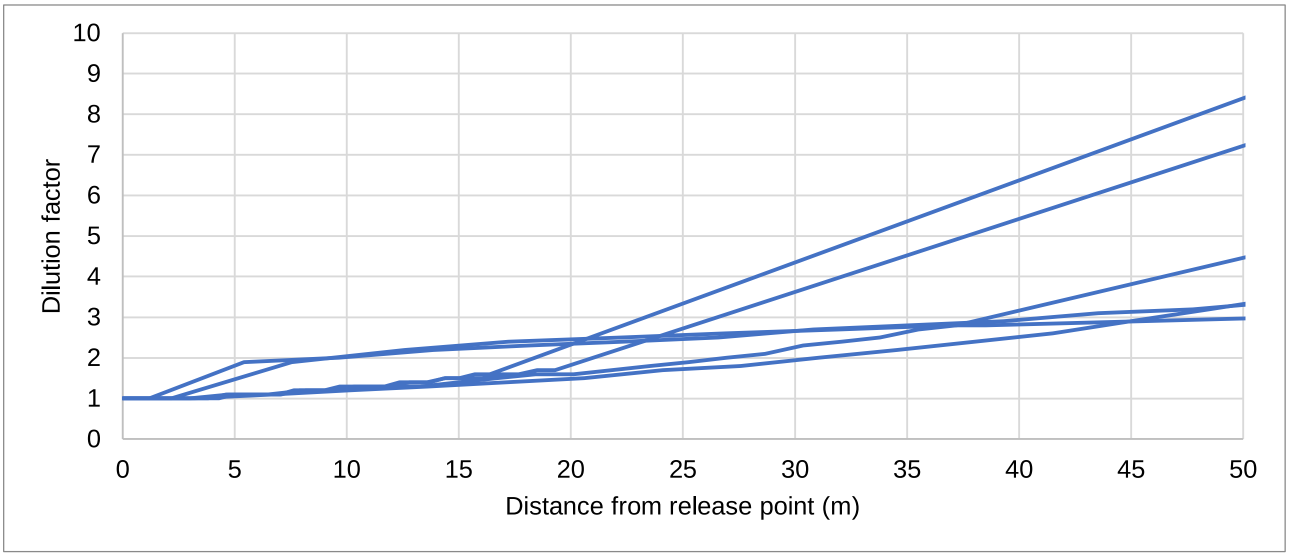

Figure B4 Predicted dilution profile for the Nepean River for releases over 3 x ADWF (2036 releases)

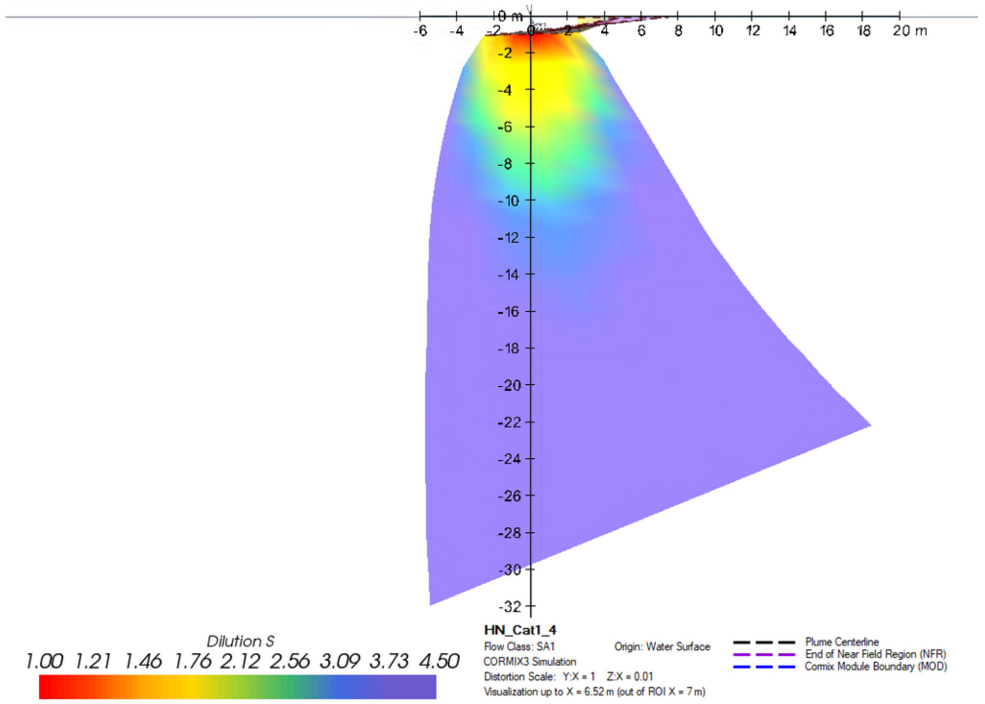

Figure B5 Example predicted plume dilution profile for the Nepean River for releases between 1.3 and 1.7 x ADWF (2036 releases)

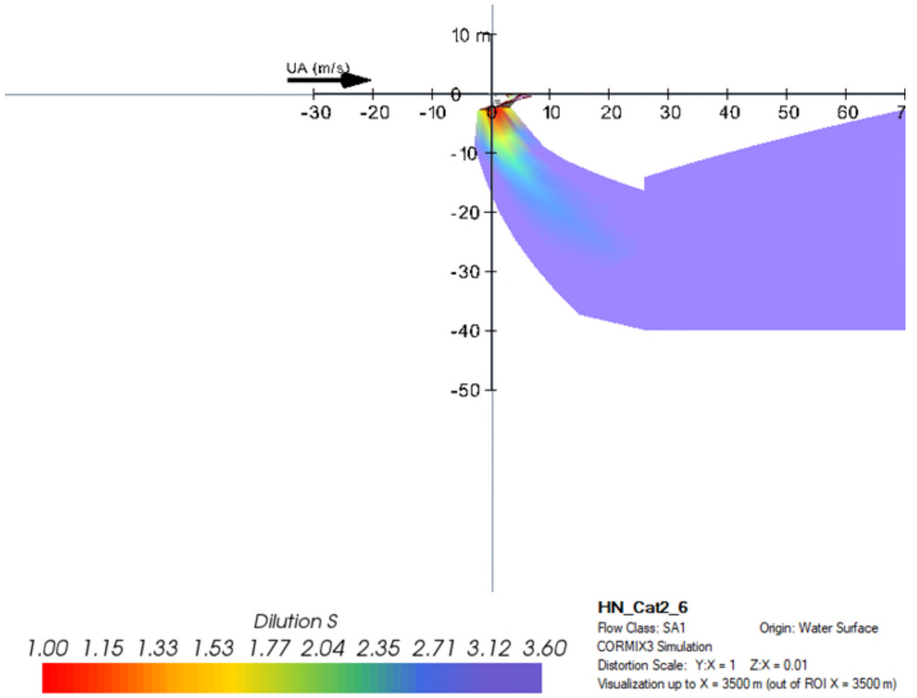

Figure B6 Example predicted plume dilution profile for the Nepean River for releases between 1.7 and 3 x ADWF (2036 releases)

Table B2 Dilution needed to achieve ANZG at edge of mixing zone for releases between 1.3 and 1.7 x ADWF (95th percentile)

	Aluminium		Copper		Zinc		Manganese	
	Conc (mg/L)	Dilution Required	Conc (mg/L)	Dilution Required	Conc (mg/L)	Dilution Required	Conc (mg/L)	Dilution Required
Minimum	0.003	<1	0.0000	<1	0.0004	<1	0.0006	<1
Median	0.037	<1	0.0005	<1	0.0053	<1	0.0139	<1
Maximum	0.079	1.5	0.0011	<1	0.0115	1.7	0.0304	<1
ANZG DGV	0.055		0.0014		0.008		0.100	

Table B3 Dilution needed to achieve ANZG at edge of mixing zone for releases between 1.7 and 3 x ADWF (95th percentile)

	Aluminium		Copper		Zinc		Manganese	
	Conc (mg/L)	Dilution Required	Conc (mg/L)	Dilution Required	Conc (mg/L)	Dilution Required	Conc (mg/L)	Dilution Required
Minimum	0.090	1.8	0.0013	<1	0.0131	2.0	0.0349	<1
Median	0.124	2.5	0.0018	2.0	0.0181	3.0	0.0482	<1
Maximum	0.275	5.9	0.0040	7.6	0.0403	7.5	0.1080	1.2
ANZG DGV	0.055		0.0014		0.008		0.100	

Table B4 Response to issues raised by Department of Planning and Environment (DPE) – Environment and Heritage Group (EHG) regarding hydrodynamic and water quality modelling

Issue	Response
Waterway health – general comments on suitability of water quality and hydrology model Commends the large monitoring and modelling program. DPE EHG made several comments about the suitability of the model. These have been consolidated and grouped into the following dot points: • **Calibration and complexity** – One key point for consideration is to assess whether there is a need for large complex water quality response models and whether there are opportunities to use the insights from the current	The role of the model is to predict the impact of the proposed AWRC releases on the river system, and whether these new releases will lead to improved or deteriorated water quality conditions near the release points and downstream. This includes any increased exceedance of water quality targets. Internationally and throughout all Australian states, it is a standard and acknowledged best practice approach to use a coupled hydrodynamic-water quality model to assess the effects of releases into a creek, river or estuary, since they: • resolve the mixing and dilution of the release plume • can look at subsequent fate processes (such as the degree to which the additional input loads are assimilated post-release).

Issue	Response
modelling to produce simpler models that are still fit for purpose and can be used for longer time series analysis. Large complex models are very difficult to calibrate and validate, have long run times, and require lots of field data that are unlikely collected at the extent required to assess whether the models are performing well and/or at the resolution of the model parameters (due to detection limit issues). These difficulties are reflected in the EIS, where the calibration period is 1 year, and validation is 1-2 years. Longer model runs to assess cumulative impacts were not completed, and post-processing via a 'zone analysis' was required to permit simpler comparison with field data. The latter zone analysis points to the feasibility of using a 'daisy chain' of relatively simper box models that can be run over longer time series. DPE EHG noted that it is good practice to run the model for longer time periods as part of the validation stage of model development. • **Simulation period** – DPE EHG noted that using a complex model should not be mistaken for best practice. The models need to be fit for purpose, and in this context, they are not as they cannot provide a time series prediction of the scenarios. It is noted that at this stage, the AED2 model cannot be run for long term series and hence cumulative impacts over time cannot be assessed/determined through this EIS. • **Calibration time-periods, trends and data variability** – Moreover, the plots in Appendix D (of the TUFLOW and AED2 calibration report) shows high variability in the field data used for model calibration and validation. It is very hard to infer trends over time from just two	The models also allow the new releases to be placed in context with other licensed point sources and inputs from surrounding catchments. **Calibration and complexity** Sydney Water agrees building models needs to consider matching calibration effort with the ability to constrain the model with useful field data. Sydney Water acknowledges EHG's view that the current model is complex and therefore difficult to calibrate and that a chain of simpler box models would allow longer simulation periods. Sydney Water and its specialist consultants disagree that a box model approach would make modelling for the impact assessment simpler or that it would lead to improved predictions of the effects of the proposed AWRC release regime. Indeed, there is a likelihood that results of such a model would be less reliable due to inability to resolve processes. For example: • The settings for key processes related to phytoplankton or sediment dynamics will similarly remain uncertain in a box model, and the calibration challenges raised by EHG will remain against the same field dataset. • The external loads added into the boxes (from WWTPs, WRPs or catchments) would retain the same error and uncertainty as in the present WQRM. Inputs of this nature are acknowledged as a significant contributor to the discrepancies in the model. • The fluxes between boxes would require a spatially resolved hydrodynamic model (similar or the same as the one developed) to quantify the material entering and leaving the 'boxes'. • Sydney Water has invested in the development of the WQRM modelling suite for a decade. A box model would need to be implemented from scratch, thus cancelling out any run-time advantages of running a higher resolution model such as that adopted by Sydney Water. It would further introduce risk and uncertainty in terms of its accurate implementation and robustness for scenario assessment. • Box models will not allow for the required degree of characterisation or spatial distribution of boundaries and other conditions, such as bathymetry, within the model domain, and would not have allowed

Issue	Response
years of field data, exacerbating the difficulty in calibration. • **Mitigation of releases** – EHG considers that it is unlikely that the models could be recalibrated and validated, and re-configured (i.e., simplified) within the timeframe of the proposed start to construction. It is recommended that if the project is approved, it should be conditioned to ensure Sydney Water explores all options for mitigation of discharges (e.g., UV treatment, as highlighted by the NSW EPA) and identifies any contingent infrastructure such as integration with the stormwater harvesting system (i.e., extra detention).	assessment of the mixing plume. **Simulation period** DPE EHG state that the models are not fit-for-purpose as they cannot provide a time-series prediction of scenarios, however, this is not accurate. The primary purpose of the models for this project has been the assessment of a new release to the river system and the model has been demonstrated, and independently reviewed, to be highly capable in this regard. The models can also predict time-series of scenarios. All scenarios were assessed for a two-year period in the modelling, to represent response in both wet and dry years. No continuous long-term (for example, 20 year) scenarios were presented as much uncertainty in land development, climate and future discharge regimes of non-AWRC facilities mean that these simulations would be hypothetical and too uncertain to be meaningful. In line with international and Australian recognised practices, our approach to undertake scenarios was to assess the relative contribution of the AWRC releases and to consider if this contribution would change under a range of possible future conditions. Sydney Water believes this provides the essential information necessary to fully assess the nature of the proposal under consideration. Long-term continuous simulations offering alternate possible future trajectories has not been identified as a requirement of the EIS or undertaken for similar EIS elsewhere in NSW. Further, Sydney Water notes that the suggested box model approach would also be limited by the same uncertainty in defining realistic long-term future trajectories. **Calibration time-periods, trends and data variability** An audit and comprehensive review of available data within the river and creek system was undertaken prior to model calibration/validation. The extensive suite of field data extended from 2005 to 2018. The data was inspected for trends prior to the selection of simulation years. A total of four simulation years were applied for calibration and validation in the Hawkesbury Nepean WQRM and a total of three years for the South Creek WQRM. The periods spanned both wet and dry conditions. Of note, the extent of this calibration and validation exercise, in terms of both data and temporal extent, exceeds industry standard for a model of this nature, for

Issue	Response
	which one year of calibration and one year of validation is typical. Also of note, no trends in the water quality data were notable over this period and this was not a focus of the impact assessment. Also of key importance was that each model was continually refined with respect to performance across all the calibration and validation years and not just the calibration period. Therefore, while initial assessments of the model’s performance were undertaken for the calibration period, equal emphasis was placed on both the calibration and validation exercises. Therefore, if concerns or distinct anomalies were observed in either calibration and/or validation exercises, the model settings were reviewed, remodelled and reanalysed across the entire calibration/validation period, until it was deemed performance could not be improved with the current model setup. Many of the issues raised by EHG speak to the need for cumulative assessment of all past, current and future planned inputs affecting the river in order to holistically assess land-use development, stormwater system design and licensed discharges. Sydney Water supports such an initiative and has developed a roadmap in conjunction with the cross-agency Hawkesbury Nepean Science Working Group to that effect. This level of detail is, however, considered over and above the present assessment of the AWRC impact. However, the present modelling has allowed the AWRC releases to be placed into the context of expected changes to catchment/tributary loads and WWTP loads and can serve as the foundational step for an expanded assessment. **Mitigation of releases** Sydney Water has designed the AWRC to minimise release impacts as far as feasible. Aside from the infrequent and short-lived periods of extreme weather bypasses, the releases are advanced treated water that will provide long-term benefits to the river's health and water quality. In addition, the proposed technology is a major advance relative to standard wastewater treatment which would otherwise be used to service the growing population. Alternative options for mitigation of releases (for example, UV treatment, as highlighted by the NSW EPA) is addressed in detail in Table 1 and Attachment A.
Waterway health – comments on WQRM	Predictions of water quality variables have different

Issue	Response
performance and errors DPE EHG made several comments about model performance and errors. These are addressed in the following rows. **Categorisation of WQRM performance** Analysis of model errors requires further explanation, especially regarding the categorisation of poor, acceptable and accurate model performance (Tables 4-2 to 4-5). For example, Table 4-4 of the TUFLOW FV and AED2 calibration report, indicates that for Zone_4_Box_2 the model is acceptable despite an R = 0.21 and model bias of 156.77%. It is suspected that the categorisation may have been based on the RMS and NRMS results, but these are hard to interpret as the equations for their calculation are not provided (which was a recommendation of Sydney Water's independent reviewer).	standard expectations of suitability than for traditional hydrological assessments. For example, variance in field sampling measurements of nutrients and chlorophyll-a is much larger than for measures like flow or temperature. Additionally, high variance for nutrient pools that are relatively low within the overall budget does not need to be captured by the model due to its relative insignificance in the fundamental cycling of nitrogen or phosphorus. This 'noise' in the observed data signal needs to be considered with caution when assessing a model, as in most cases, it is unrealistic to expect the model to reproduce the results from samples which represent a singular location and moment. For example, a model bias of 157% for a very low concentration can be considered an accurate prediction if the model also successfully predicted a similarly low value. Similarly, there are cases where we do not wish the model to capture the noise in the field data, but to simply capture the mean of a relatively static variable – in this case we would be happy with an R of zero if the bias was also acceptable. We also need to be aware that the model is presenting the mean of a reporting zone, and the data is a collection of grab samples. Additionally, much of the error in the model is created from the very high number of catchment inputs that enter the river and also have errors associated with the catchment modelling. For these reasons, the statistical error metrics are provided for completeness and transparency but should not be the only metric by which the models are judged as being fit for purpose. The categories adopted are therefore provided as an informed assessment of whether the model is capturing the variables to a degree which makes it suitable for the AWRC release scenario assessment or whether it is materially deficient. The categories of poor, acceptable and accurate are allocated based on expert review of: • seasonal timing and mean magnitude • the four error metrics R, BIAS, RMS (Root mean squared error) and NRMS (Normalised root mean square) • the partitioning of the pool relative to the total mass for that element (for example, NO_3 as a fraction of TN) • the degree of noise in the field data, and between agencies and different measurement methods (for

Issue	Response
	example, Chl-a is known to be an uncertain measure and different between in situ and lab based measures) • the degree of error coming from uncertainty in the boundary conditions • the expected norms in the water quality modelling community for that variable. For example, Chl-a of R between 0.4-0.6 is generally a high accuracy prediction in the scientific literature. The error statistics are commonly used and clearly described in our report and the equations are available in this open-access paper: Hipsey et al. (2020) "A system of metrics for the assessment and improvement of aquatic ecosystem models". *Environmental Modelling & Software*, V*128.*
Presentation and magnitude of WQRM model error • A good understanding of the magnitude of model error is needed to assess the impact of the AWRC operations on the receiving waterways and riparian corridors. • The model errors were not carried through to the presentation of results (i.e. longitudinal plots) that compare the changes to ambient water quality among scenarios. It is recommended the plots be amended to include the model errors. • Model errors and sensitivity analyses were also provided in Appendix D of the TUFLOW and AED2 calibration report. These show a comparison of the modelled outputs with the observed/field data. There are also plots against the error metrics, which tend to demonstrate that the model error is too large to determine whether there is an impact (positive or negative) of the AWRC on the receiving waterways and riparian corridors. • Given the range in errors shown in Tables 4-2 to 4-5 of the Calibration Report, it is very highly likely that the magnitudes of the errors are too high to permit a comparison of the scenarios.	Sydney Water agrees that model performance should be considered when interpreting scenarios but notes that: • error statistics need to be used with caution (see above reply) • error is not the same as prediction uncertainty when it comes to undertaking scenario comparisons. The comments suggest the need for an analysis of predictive uncertainty, such that the scenario results can be presented in terms of their confidence level at any point along the river. The task is not so straightforward as simply including a model error band. Computing uncertainty in water quality models remains an area of active research within the modelling community. Consequently, there are no routine workflows we could adopt for uncertainty analysis for this model. The TUFLOW FV calibration report instead included transect summaries (longitudinal plots) of all variables for all seasons that include the ranges of model outputs and field data together along the length of the river which provide the reader with a holistic overview of model error relative to the available data at different locations and at different times. From the viewpoint of Sydney Water's modelling specialists and the independent technical reviewers, the model is absolutely capable of predicting impact and comparing the relativity between scenarios. The argument that the model error needs to be smaller than the impact of the scenario is somewhat idealistic in that this would mean only a perfect model would be suitable to assess a scenario with a very small impact. It is generally accepted that all models have uncertainty and this is not

Issue	Response
	incompatible with the requirement to also make informed decisions from their outputs. Sydney Water respectfully disagrees that the errors reported during model calibration translate to a prediction uncertainty that is too high during the scenario analysis. There remains a high degree of confidence that the model captures the relative difference in water quality responses between the scenarios and relative to the baseline conditions. The error being interpreted in this comment relates to the model's ability to capture a concentration accurately at any given instant in time or any given cell (and includes error in the field data). This level of accuracy is not needed to meaningfully compare the mean changes at the river-scale brought about by the AWRC releases. It is important not to misinterpret this error and performance assessment in terms of predictive uncertainty. As an analogy, it is considered acceptable that climate models predict the mean future state of the climate (for example, as part of a seasonal forecast), but this does not mean they will resolve the exact hourly weather behaviour at a particular point accurately without error.
WQRM - Model bias To add to the above dot point (regarding magnitude of model error), the results of some of the sensitivity analysis show that model bias is much greater than the scenarios investigated. For example, Table 4-5 indicates that the model bias in Zone_4_Box_2 and Zone_3_Box_3 is -44.25 and -56.7%, respectively. The sensitivity results on page 91 concluded that the model has a: 'higher sensitivity for the scenarios with higher nutrient inputs (scenarios of High, Mod High and Mod High + sed) compared to that with lower nutrient inputs (scenarios of Low, Mod Low and Mod Low + sed), possibly due to the background nutrient concentration in the water and the sediment loads.' Rather than background concentrations, this result is likely due to the high model bias and means that even for assessments of relative trend change (%), it is very difficult to assess whether the models are reliable. On page 91, Sydney Water indicates that a 28% increase in	The issues of model sensitivity, error and uncertainty are complicated and Sydney Water appreciates the insightful questions raised. At the essence of the observation is whether the impact scenarios presented for the EIS are reliable for assessing changes to the water quality, noting the biased prediction in some zones for some variables. The example described highlights that, in simple terms, changes in waterway concentrations are very closely linked to changes in catchment inputs. That is, the upper river in particular is a blend of the relevant catchment sources. This is in stark contrast to the changes seen when assessing the AWRC discharge scenarios, which show that the waterway concentrations do not change much in response to either the 2036 or 2056 release volumes. This is of course understandable and makes sense given the load inputs from the AWRC are of the order of 1% of the total incoming nitrogen load. Please refer to Table 5-28 of the Submissions Report (March 2022) for further details. Regardless of the bias in some zones, this finding does not change and provides confidence that the AWRC discharge is a small contributor. In the case highlighted in

Issue	Response
nitrogen loading (High scenario) was predicted to lead to a 20-38% increase in water column TN concentrations in the wet year but based on the model bias, the change is TN concentration is likely to be underestimated. These issues can be inferred/observed from other examples described by Sydney Water for the sensitivity analysis.	the question, with or without a bias in the model, the AWRC impact scenario makes the nutrient levels reduce, which is as expected, given that advanced treated water nutrient concentrations are generally lower than the ambient conditions. Many of the questions raised ultimately come back to the point that the model uncertainty is tightly linked to our need to approximate the (ungauged) catchment inputs. If we look at the river as a whole, the issue raised is put in context. Although there is 50% bias in certain areas, the pattern across the length of the river aligns with the field data (see Figure B7 below), highlighting the need to assess our confidence in the model at the larger river scale and based on mean concentrations rather requiring the model to predict instantaneous conditions at all locations. For the purposes of using the model to assess land-use changes, stormwater management or other catchment related scenarios, Sydney Water agrees that improvements in reducing the total nitrogen and total phosphorus bias would increase confidence in nutrient budgeting. Sydney Water is investing in further work to improve the model accuracy, separate to this assessment. However, for the purposes of assessing the AWRC discharges the model findings clearly show that the magnitude of the AWRC discharge compared to other inputs is very unlikely to contribute to exacerbating water quality risks. This recommendation would not change significantly if the catchment input issues were refined and bias reduced.
Waterway health – use of coupled models A general issue that needs to be highlighted (again) relates to the coupled nature of the models. If one model is deficient, then this 'deficiency' is propagated to other models. Sydney Water's own contractors have conditioned the quality and reliability of their specific impact assessments according to the adequacy of the modelled outputs used.	With respect to coupling of catchment models with hydrodynamic and water quality models, the following comments are provided: • The alternative to using coupled models is to not characterise catchment processes which are inputting to waterways. This would result in larger assumptions and errors in the receiving waterways model. • The same issue of propagating error between catchment and waterway representation would also apply regardless of whether a complex or simplistic water quality response model is employed for the assessment. Sydney Water's acknowledgement of reliability being linked does not relate to these model outputs not being perceived as suitable or adequate, rather it is a transparent discussion on limitations of modelling in general.

Issue	Response
	• The catchment modelling used in both the model calibration and EIS assessments is considered to be of high quality and was undertaken in line with best practice, utilising the most recent and appropriate modelling software. With respect to coupling of the South Creek WQRM with the Hawkesbury Nepean WQRM, the following comments are provided: • The two WQRM models were developed separately and coupled to allow for suitable run times for each waterway during both calibration and scenario testing. • A location at the tidal limit of South Creek was applied as the interface of this coupling to ensure only uni-directional flow from South Creek to the Hawkesbury River. As such it is important to note that coupling of this nature did not increase or decrease model error or any form of model deficiency.
Waterway health – basis for scenarios (water quality and hydrology) The basis for the initial model conditions for the 2036 and 2050 scenarios should be explained in detail. It is acknowledged that there are no dry weather discharges in South Creek but during wet weather there will discharges of mostly untreated sewage. In this regard, the project should be conditioned on the basis that a cumulative impact assessment over time (for periods longer than 2 years) is provided. If issues regarding long model run times cannot be solved, it is recommended that the model errors be investigated and presented with the medians or averages of modelled outputs that impacts of wet weather discharges as well as scenarios.	The AWRC is predicted to reach up to 50ML/day in 2036 and up to 100ML/day in 2056. Sydney Water is seeking project approval for an average dry weather flow (ADWF) of up to 50ML/day and concept approval for an ADWF of up to 100ML/day. 2036 and 2056 were therefore chosen as the basis for the impact scenarios. The initial model conditions, inputs and assumptions were outlined in detail in Chapter 4 of the Hydrodynamic and Water Quality Impact Assessment (Appendix F of the EIS). The 2036 and 2056 scenarios incorporated predicted changes in landuse and releases from other existing wastewater treatment plants. Sydney Water confirms that releases to South Creek will only occur during wet weather when inflows exceed 1.7 x ADWF. The release strategy has been specifically developed so that releases to the creek will consist only of advanced treated water for inflows between 1.7 and 3 x ADWF. When inflows are greater than 3 x ADWF, advanced treated water will be prioritised for release to South Creek, allowing for blending with wet weather (primary) treated water. The assumption that these releases will contain mostly untreated sewage is incorrect. For example, Sydney Water predicts that 100% of the release volumes will be advanced treated water in a dry year and about 63% in a wet year. In terms of frequency, advanced treated releases are predicted to vary between three and eight days per year.

Issue	Response
	Wet weather releases (consisting of a mix of advanced treated water and primary treated water) to South Creek are predicted to vary between zero and six days per year. It is estimated that the concentration of nutrients within the blended primary and advanced water release stream would range between 2 and 8 mg/L of total nitrogen, and 0.1 and 0.6 mg/L of total phosphorus, which is significantly lower than the nutrient content of untreated sewage. Given the low frequency and the expected nutrient content of the releases (below, and above 3 x ADWF), the potential for long-term accumulation of nutrients is considered low, both in terms of South Creek and within the tidal pool of the Hawkesbury River. This is endorsed by the modelling of both rainfall years as reported in the hydrodynamic and water quality impact assessment (Appendix F of the EIS). Sydney Water has committed to monitoring water quality and aquatic ecology in South Creek, as outlined in Appendix B of the Submissions Report (management measures WW22 – 23 and WW30 – 32). Monitoring data collected will allow any changes to be identified over time. Sydney Water has addressed concerns regarding model run times and errors in the responses above.
Waterway health – explanation of impact categories Definitions for ‘slight’, ‘marginal’ or ‘minor’ have not been provided in the additional documentation.	The glossary in Appendix F of the EIS defined insignificant/minor as ‘In the context of this assessment, these impacts are classified as being recognisable as short term, or temporary, or of limited magnitude in nature and only predicted at a local scale.’ Similarly, in the context of the water quality and hydrodynamic assessment, slight and marginal impacts/changes are classified as being recognisable as short to medium term (up to seasonal), and of limited magnitude in nature and only predicted at a local or reach scale.
Waterway health – flow objectives ((water quality and hydrology) Notes that original comment not addressed. Flow volume releases are presented in Appendix F of the EIS but are not compared to EES’s flow related objectives, in manner consistent with the water quality objectives comparisons. It is recommended that this	Flow volumes presented in the Hydrodynamic and Water Quality Impact Assessment (Appendix F of the EIS) were directly adopted in the Ecohydrology and Geomorphology Impact Assessment (Appendix G). The comparison to EES’s flow related objectives was completed in the Ecohydrology and Geomorphology Impact Assessment only rather than duplicated in both reports. This was considered more appropriate as the

Issue	Response
comparison be included in the revised EIS**.**	Ecohydrology and Geomorphology Impact Assessment focused on flow related impacts. The results were also summarised in section 8.7.2 of the EIS. The assessment was subsequently updated in section 5.4.9 of the Submissions Report.
Waterway health – model error and flow objectives (Ecohydrology and geomorphology) Sydney Water has identified that an incorrect drainage area was used, and this has been rectified in the RtS. The results show an impact of the AWRC in South Creek, through exceedances of the flow objectives in almost all scenarios. Sydney Water also state that 'there is little difference between the background and impact scenarios which highlights that the main contribution is the predicted changes in land use and associated increase in stormwater flows. The AWRC releases make a negligible contribution to overall flow volumes.' As indicated above, the model error is too large to infer any differences (or lack of) among the scenarios. In other words, the 'little difference' may be simply due to the model error.	Concerns regarding model performance and errors have been addressed above. Sydney Water is confident that the model is sufficiently robust to allow various scenarios to be run in order to predict, with a high degree of certainty, the relative impact of the releases compared to a baseline and background scenarios.

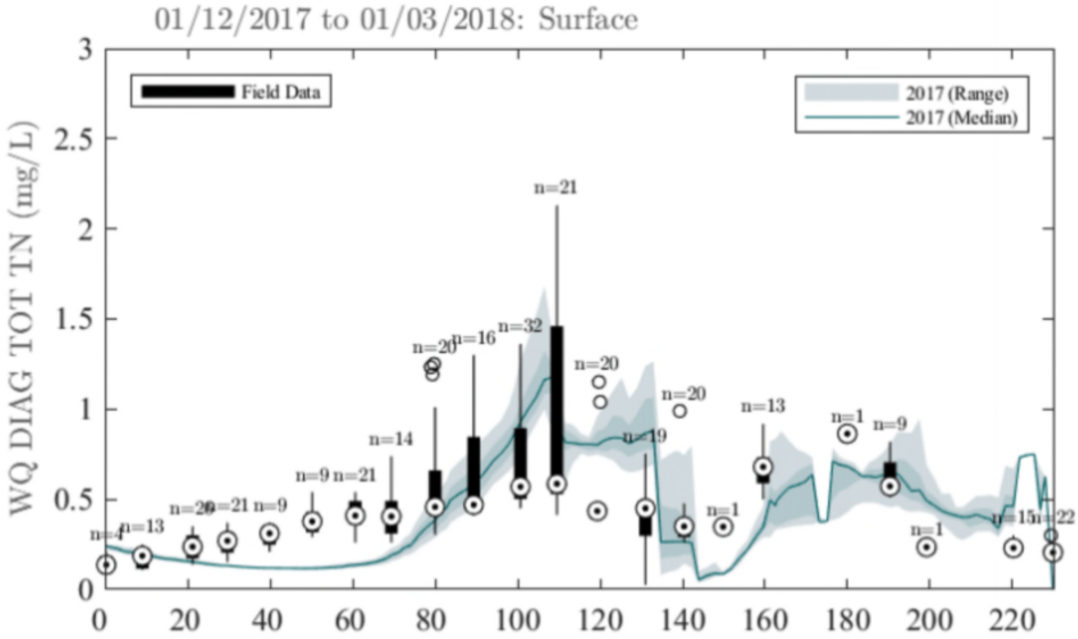

Figure B7 – Example calibration transect of Total Nitrogen - Summer 2017/18