BALANCING THE COMPETING DRIVERS AND TRADEOFFS IN CIRCULAR ECONOMY – HOW MASTERPLANNING CAN UNLOCK A SITE'S FULL POTENTIAL

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KEYWORDS

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ABSTRACT

The Upper South Creek (USC) Advanced Water Recycling Centre (AWRC), Sydney, NSW represents a first of its kind facility. It will set a new benchmark for advanced treated water quality and serve as a foundational investment in driving circular economy ecosystems within the rapidly developing Western Sydney Aerotropolis.

To deliver on Sydney Water's vision for the AWRC whilst balancing competing circular economy drivers, a holistic approach to solution development was required. Whilst not commonly associated with detailed design, this paper explores how a masterplanning approach led to a transformational change in how we plan and deliver complex water infrastructure.

INTRODUCTION

The USC AWRC facility is designed to treat 35 ML/d ADWF initially, with expansion to 70 ML/d ADWF in Stage 2. The AWRC aims to achieve an energy self-sufficiency of 50% while meeting stringent effluent nutrient targets of <0.35mg/L total nitrogen (TN) and <0.009mg/L total phosphorus (TP). The AWRC is currently under construction and is expected to be operational in mid-late-2026.

Delivering on Sydney Water's vision for the AWRC, as an example of industry best practice in sustainable water management, whilst balancing competing circular economy drivers required an integrated approach to solution development. This approach needed to consider all aspects of facility's lifecycle impacts (Stage 1 and beyond) including cost efficiency, carbon footprint, energy self-sufficiency, environmental impacts, plant performance, urban cooling and place-making in the broader Western Sydney precinct.

Adopting a masterplanning approach was critical to achieving a holistic and fully integrated solution that achieved Sydney Water's performance requirements whilst also delivering on circular economy aspirations and planning for future capacity upgrades. Whilst masterplanning is not typically associated with detailed design, this approach was fundamental to enabling a truly integrated and adaptable long-term solution for the site.

METHODOLOGY/ PROCESS

Broadly, the solution development considered the Sydney Water's performance requirements, energy / net zero targets, and circular economy aspirations. Adopting a masterplanning approach allowed flexibility to balance competing circular economy drivers with longer term market drivers; the key pillars of the solution are described below.

Treatment plant design

Developing an integrated treatment solution that considered the following:

- Achieving the stringent Stage 1 effluent quality requirements of 0.35mg/L total nitrogen (TN) and 0.009mg/L total phosphorus (TP), while also designing in flexibility for multiple augmentation pathways in Stage 2. Pathways allow for the process to be configured for either carbon utilisation for nutrient removal, or carbon redirection for energy and resource recovery, depending on the highest value use of carbon.
- Optimising the energy self-sufficiency of the advanced treatment facility (including energy intensive reverse osmosis processes). This considered how to optimise the use of embedded carbon in the treatment process (via raw wastewater), while limiting the amount of imported carbon (via chemical use).

- Designed with adaptability in mind, allowing for future upgrades in plant flows and enhanced resource recovery and circular economy processes.

Urban design and place-making

The facility is located adjacent to Wianamatta South Creek, a significant waterway to the Dharug Traditional Custodians, and within the green spine of the developing Western Sydney Aerotropolis. Embracing a landscape led design approach was fundamental to ensuring the facility contributes and connects to broader regional amenity, and includes:

- Maximising water sensitive urban design in the operational site by minimising hard and gravel surface, using swales for stormwater management to maximise water retention in the land, and supporting biodiversity by providing a restored landscape along Wianamatta South Creek.
- Celebration of the heritage of the site through embedding 'Care for Country' as a core principle within the operational site design and 'Design with Country' engagement for the future greenspace development. This also considered acknowledgement of the site's European heritage; the Fleurs Radio Astronomy Station, through orientation of the treatment plant layout to align with the historical radio-telescope array.
- Consideration to how the facility will give back to the community through the greenspace plan, education spaces inside the admin building, and future community amenities and First Nations cultural space.

Future proofing of the site layout

With the operational area of the site constrained to above the existing flood levels, masterplanning of the site was critical to safeguarding its long-term development. Initiatives included:

- Process units for Stage 1 and future upgrades have been consolidated to reduce total number of assets while maintaining redundancy levels and ensuring operational flexibility to treat low initial plant flows.
- Void spaces have been reduced by promoting more efficient use of the site footprint and optimising the design of major structures. This approach also factored in design and construction planning for Stage 2 to ensure future assets can be constructed efficiently, with minimal disruption to ongoing operations.
- Future circular economy initiatives have been considered through allocation of dedicated space within the operational site footprint for a Circular Economy Zone with colocation of solids handling assets to support potential synergies.

Collaboration

A high degree of collaboration between John Holland, engineering design firms; GHD & Jacobs, urban design consultant Tract, operator, Trility, and Sydney Water was required from the outset to align on Sydney Water's objectives and vision for the project. This shared understanding led to a shared sense of ownership in solution development, and allowed for highly collaborative & integrated design making throughout the process.

DISCUSSION OF RESULTS/ OUTCOMES

The Stage 1 AWRC solution comprises includes the following main infrastructure:

- Preliminary treatment with two-stage screening and grit removal
- Biological nutrient removal bioreactor
- Membrane bioreactor for solids separation
- Advanced Water Treatment Plant (AWTP) with RO water purification
- Biosolids stabilisation via anaerobic digestion of WAS with energy recovery and staged/future delivery of cogeneration
- 4MW Permanent solar array.

A key feature and innovation of the Stage 1 solution came about through considering to how to best utilise the embodied carbon in the incoming wastewater in the treatment process. The reference design included primary sedimentation tanks to capture carbon in the primary sludge solids for treatment and energy recovery through biogas production. As a result, carbon supplementation (via chemical dosing) was required in the mainstream liquid process to achieve the stringent effluent nutrient quality targets.

Efficient use of embodied carbon in raw wastewater has the potential to impact the sustainability and TOTEX outcomes of a treatment solution[1]. An options assessment was undertaken to investigate the most efficient use of embodied carbon for the AWRC requirements. It was found that utilising the embodied carbon for nutrient removal in the wastewater process, instead of for energy recovery, was the highest value use for the carbon given the stringent effluent nutrient targets. As the embodied carbon is directed to the process to support nutrient removal, this also resulted in a significantly reduced quantity of supplementary carbon required (via chemical dosing).

This low chemical dosing solution resulted in a 37% reduction in operating costs as a result of the significantly reduced chemical requirements, in excess of $25 million dollars in capital cost saved through rationalised treatment structures and a number of sustainability benefits including carbon footprint and energy efficiency of the solution.

Upgrade pathway flexibility

The Stage 1 solution embeds an effective pathway to upgrade and expand the Stage 2 plant in future to optimise its energy recovery potential and enhance long-term circular economy opportunities. It includes flexibility for the Stage 2 design to pursue multiple upgrade pathways. The plant can either be upgraded to install primary sedimentation tanks (PSTs) to provide additional treatment capacity in the mainstream process and enhance energy recovery through the solids treatment system, or duplicate the bioreactor process and retain the low chemical dosing solution design philosophy.

Energy self-sufficiency

The energy self-sufficiency of the Stage 1 AWRC was a key parameter considered in evaluating the sustainability of the Stage 1 solution.

During the design phase, the Stage 1 solution was evaluated to achieve an energy self-sufficiency of 65 per cent when averaged over the Stage 1 design horizon, and 40 per in design year (2034). This assessment included all assets within the AWRC facility including the wastewater treatment plant, AWTP and solar farm. Adoption of a low chemical dosing solution in the wastewater treatment process was a key reason that enhanced energy self-sufficiency levels were realised for the Stage 1 solution. Figure 3 below demonstrates the energy self-sufficiency of the solution over the Stage 1 design horizon.

An assessment of energy enhancement options was also undertaken to understand opportunities to further increase the Stage 1 solution energy self-sufficiency. Implementation of cogeneration was found to be a preferred option on the basis of TOTEX however installation is recommended to be deferred until such time that there is sufficient surplus biogas available for energy production. Figure 4 shows additional enhanced energy self-sufficiency with cogeneration included, and was evaluated to achieve an energy self-sufficiency of 66 per cent when averaged over the Stage 1 design horizon.

Summary of masterplanning approach benefits

Adopting a masterplanning approach to the delivery of the USC AWRC allowed both short-term and long-term benefits whilst delivering against Sydney Water's Value for Money criteria. Key benefits were:

- Optimised Stage 1 TOTEX through the removal of PSTs whilst also planning for future stages. Removal of the PSTs provided the following Stage 1 benefits:
  - Significant reduction in chemical dosing and an estimated 37 per cent reduction in operating costs over Stage 1 design horizon when compared with a solution with PSTs.
  - Reduced size of the odour control system
  - Reduced risk of odour impact in the community via reduced fugitive emissions.
  - Over $25 million dollars in capital savings.

  A cascading benefit from this optimisation is the significant improvement in the quality of water discharged to Wianamatta South Creek under wet weather events greater than 3xADWF. The solution provides high quality MBR effluent up to 6xADWF and a significant reduction in annual nutrient loads discharged to the environment.
- Optimised earthworks through a net reduction of 150,000m3 of imported fill to site leading to an improved program, reduced cost, minimised local community impacts and improved sustainability and Care for Country outcomes.
- Provision of an optimised site layout that consolidates process units to provide more efficient use of land. Key areas optimised and additional key benefits are outlined below:
  - Installation of a single large inlet works sized to cater for Stage 2 flows, thereby providing the following benefits:
    - 50% reduction in the ultimate total number of mechanical units required. This provides a significant reduction in the preventative and reactive operational and maintenance activities.
    - Improved flow distribution with the consolidated structure in Stage 2 resulting in improved screening and grit removal performance.
    - Operational simplification with one consolidated location for screenings and grit bin movements.
  - Reduction in the number of digesters and associated ancillary equipment provided to meet Stage 1 growth. Provision of two digesters reduced from four in the reference design provides capital, operational & thus TOTEX benefits.

- Reduction in the number of bioreactors & associated ancillary equipment provided to meet Stage 1 growth. Provision of three bioreactors reduced from four in the reference design provides capital, operational and thus TOTEX benefits.
- Reduction in the number of RO trains & associated ancillary equipment provided to meet Stage 1 growth. Provision of five RO trains reduced from nine in the reference design provides operational and TOTEX benefits.

- Efficient use of land and rationalisation of infrastructure to install a permanent 4MW solar array – this initiative ensures the long-term energy self-sufficiency of the facility and eliminates its removal for the Stage 2 upgrade as proposed in the Reference Design.
- Enhanced the robustness of the inlet works system to accept full 6xADWF under site power failure, thus preventing overflows at network pumping stations when flows into the AWRC exceed 3xADWF during a power failure.
- Flow equalisation for the RO process in the variable volume biological process, therefore reducing volume and associated biofouling potential in the RO Feed Storage as well as improving the biological process though internal flow/load equalisation.

Future opportunities

The masterplan also allows flexibility for the following future opportunities:

- Expansion of the 4MW solar array to 5MW to enhance the energy self-sufficiency of the facility.
- Extend landscaping design of the AWRC greenspace to seamlessly connect the AWRC to the wider Western Sydney green spine precinct.
- Pursue waste to energy processes to recover energy and high-quality biochar product.
- Recover high-value nutrients and chemicals through enhanced treatment processes.
- Produce recycled water for a varied range of uses.

Beyond the treatment of wastewater, the vision of this AWRC facility is for it to provide a sustainable bioresource hub serving the Western Parkland City community. The Stage 1 foundation plant solution provides the flexibility for Sydney Water to realise the long-term vision of the AWRC as a bioresource, which includes the development of a circular economy zone adjacent to the AWRC site that will support the creation of a truly circular economy as the Western Sydney region develops.

CONCLUSION

Adopting a masterplan solution resulted in a number of demonstrated benefits:

- it delivers a value for money TOTEX solution across the project life cycle, saving tens of millions of dollars in capital cost when compared with the reference design solution,
- operational efficiency by reducing the total number of assets and major structures,
- provides a clear pathway to achieve 50% energy self-sufficiency by 2035,
- embeds enhanced sustainability outcomes in its construction and operations phases, and
- delivers efficiency and adaptability for future upgrades through the facility design and layout within a constrained operational footprint.

Utilising a masterplanning approach allowed the team to navigate a complex solution development process, with multiple competing drivers, to ultimately produce a clear and efficient development pathway for the AWRC. Importantly, by taking a longer-term view to the site's development, it ensured that the Stage 1 delivery requirements were met while also embedding flexibility and adaptability for future upgrades and innovations.

ACKNOWLEDGMENT

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We would also like to acknowledge the Traditional Custodians of AWRC site, the Dharug people, for their engagement and generous sharing of knowledge to help shape the masterplanning of the AWRC greenspace.

And lastly, we would like to acknowledge the integrated project team from John Holland, GHD, Jacobs, Tract and Trility who were part of developing and delivering the outcomes described in this paper.

REFERENCES

[1] L Roff, K Smalley, D Solley (2022). The Trade-Offs In Achieving Full Resource Recovery In Wastewater.

Figure 1: Upper South Creek AWRC Render (Stage 1 upgrade)

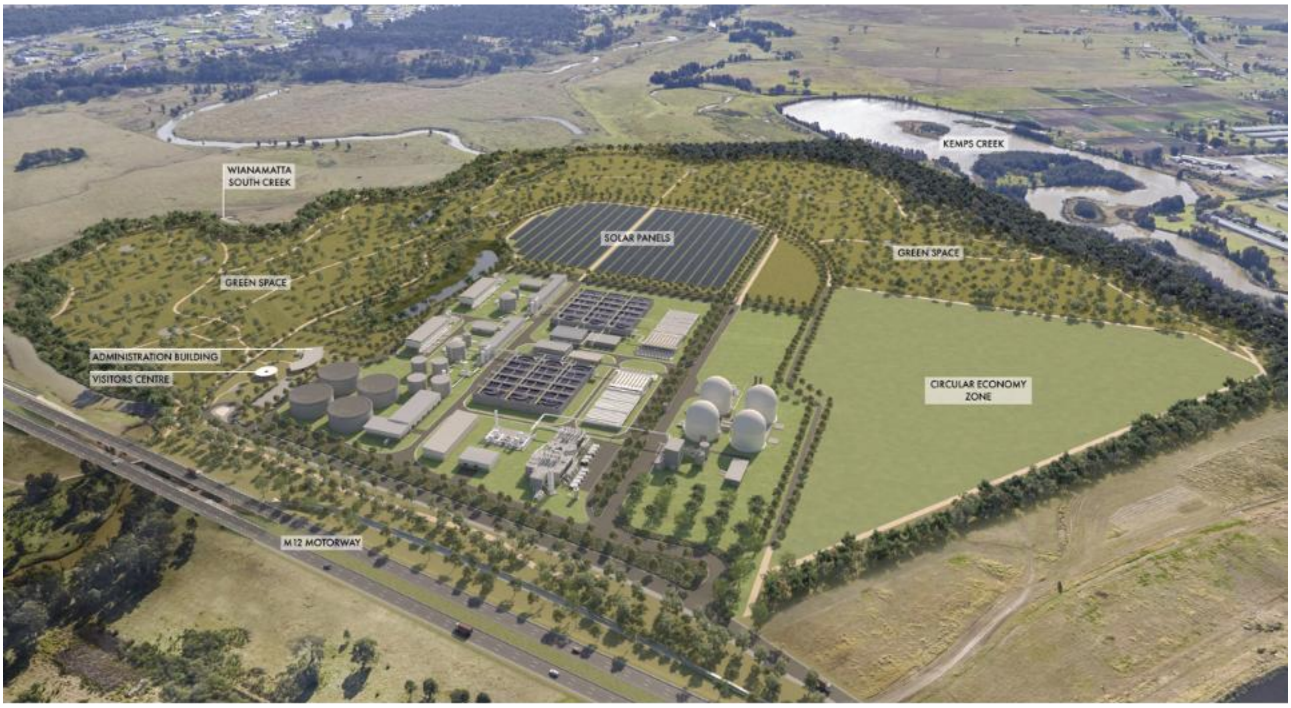

Figure 2: Upper South Creek AWRC Render (Including Stage 2 upgrade)

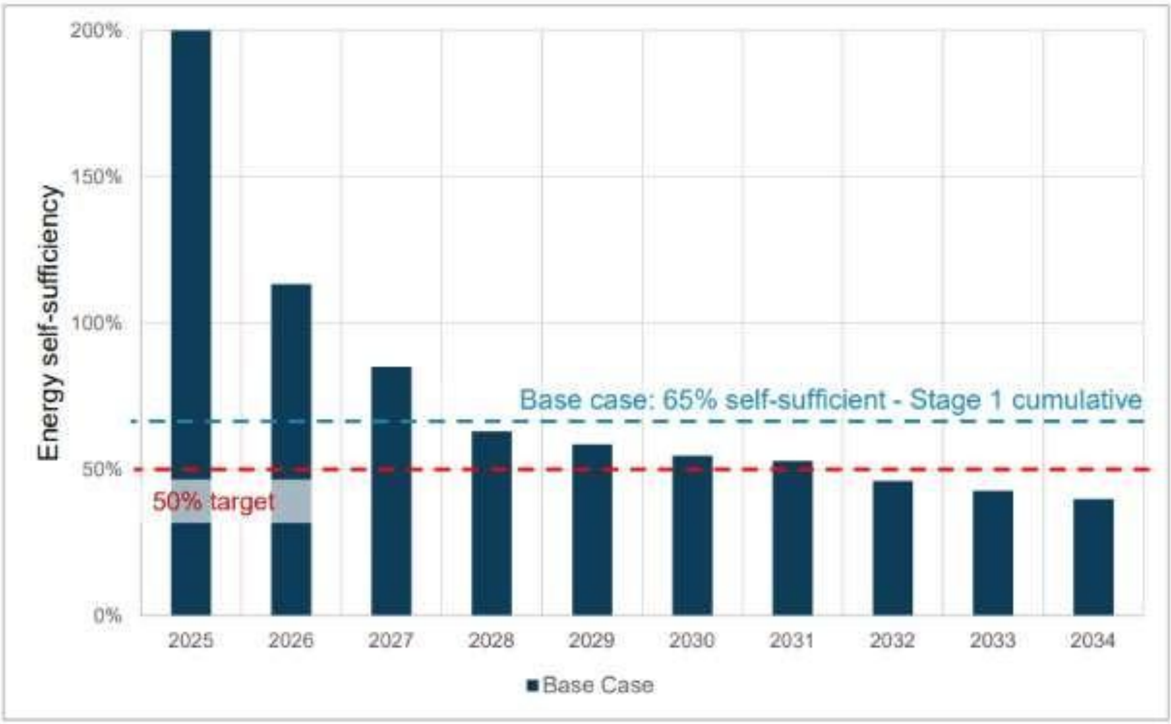

Figure 3: Energy self-sufficiency over Stage 1 for carbon utilisation with solar (Base Case).

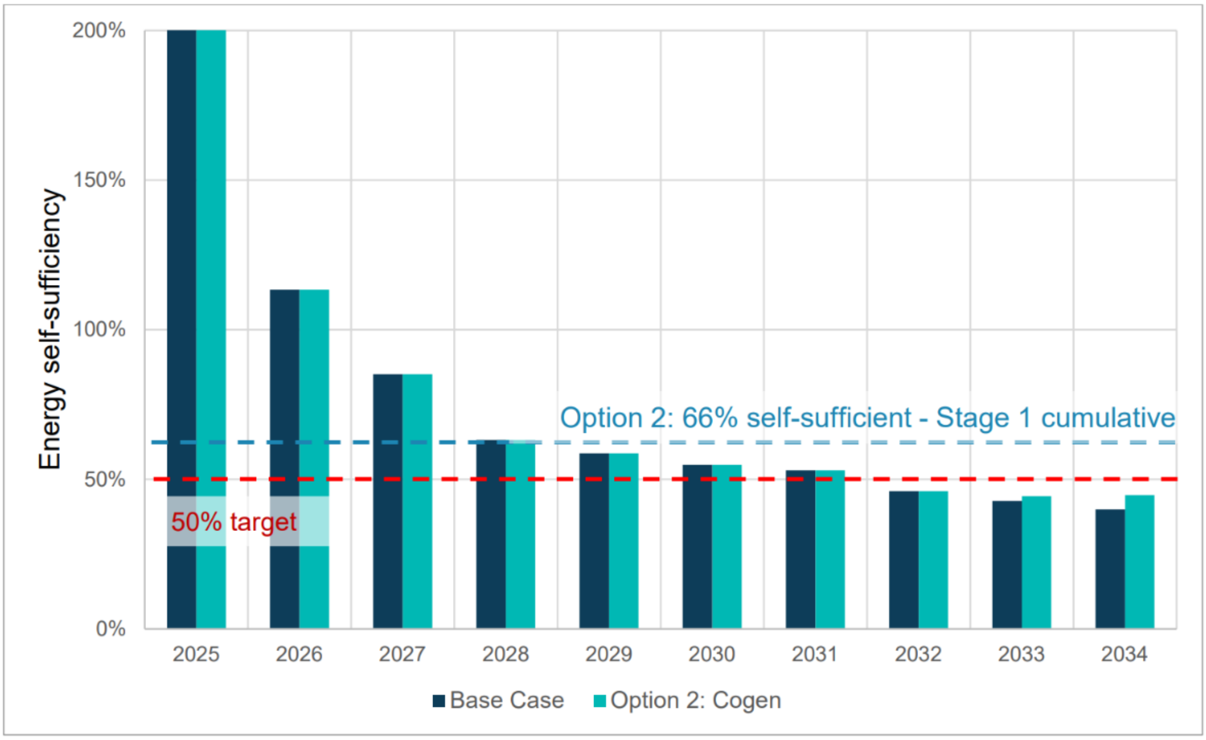

Figure 4: Comparison of energy self-sufficiency over Stage 1 between carbon utilisation with solar (Base Case) and carbon diversion with cogeneration (Option 2: Cogen).

Figure 5: Considering the AWRC visual impact amelioration and landscape (Tract)

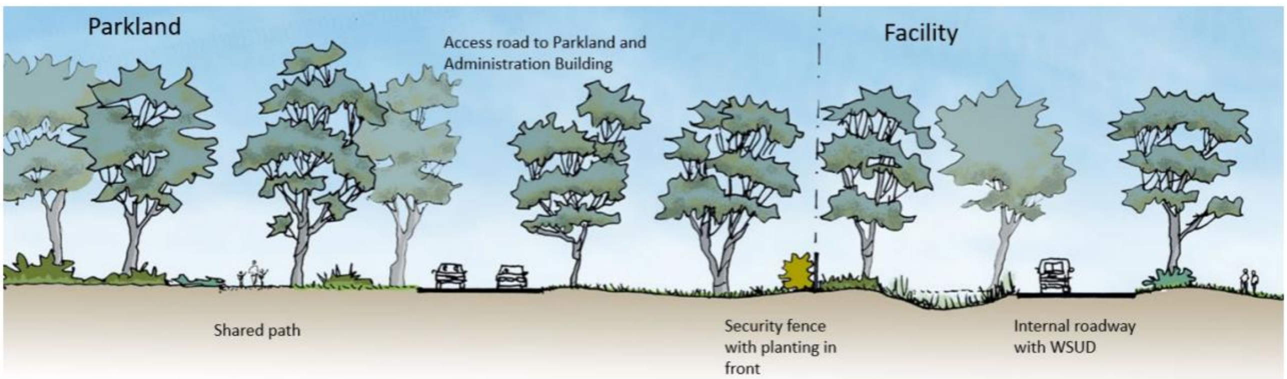

Figure 6: Conceptual landscape screening between AWRC Operational site and greenspace (Tract)

Figure 7: USC ARWC approaching the end of construction (February 2026)

Figure 8: USC ARWC approaching the end of construction (February 2026)