Submission on Cost of Stormwater Drainage in the Mamre Road Precinct

IPART Review

3 June 2024

Mamre Road Landowners Group

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1. Introduction

This submission has been prepared on behalf of the Mamre Road Landowners Group (**MLOG)** in response to the request made by the Independent Pricing and Regulatory Tribunal (**IPART**) for public feedback regarding the *Cost of stormwater drainage within the Mamre Road Precinct*.

The MLOG welcomes the opportunity to provide comments regarding the issues paper and assist IPART in its role to assess the proposed regional stormwater scheme and costs submitted by Sydney Water. We support IPART's review into the proposed stormwater developer servicing plan (**DSP**) and stress the importance of ensuring the costs can be supported by industry and delivery of the scheme can be undertaken immediately to respond to the demand for industrial land in NSW.

The MLOG has been active in Mamre Road Precinct (**the Precinct)** since 2019. Since our inception, we have communicated to Government the importance of this area for combating the industrial land supply shortfall within NSW, which has the lowest global vacancy rate of major global cities. We have worked with Government on the rezoning, development control plans, infrastructure contributions and this proposed stormwater developer servicing plan (**DSP**). Whilst engagement with Government has generally been a positive experience within the in the Precinct, we are seeking a detailed review of this stormwater DSP, as the proposed Sydney Water scheme in its current structure is strongly not supported.

A request has been issued to government whereby a workshop is required to provide insights and resolve our concerns (a date is still yet to be determined). Importantly, we require a review of the overall charges and recommend for the introduction of an interim solution to deliver warehousing prior to the completion of any regional system to respond to strong occupier demand. The current proposed scheme places severe financial pressures on a sensitive market, which will subsequently result in adverse effects due to the loss of investment in NSW and land sterilisation for short and medium term. Furthermore, results in the largest cumulative infrastructure contribution burden on record for Western Sydney Region. A series of technical experts have been engaged to inform our position on this proposed DSP, which has been submitted to government for consideration. These reports and technical notes are attached to this submission for transparency and to further assist in IPART's review of the scheme.

Development in the Mamre Road Precinct and wider Aerotropolis will either cease or be significantly reduced if the proposed Sydney Water Regional System and associated DSP is adopted. Therefore, resulting in business investment and employment relocated to other states, where development certainty is provided and the costs to operate are significantly more affordable.

About the MLOG

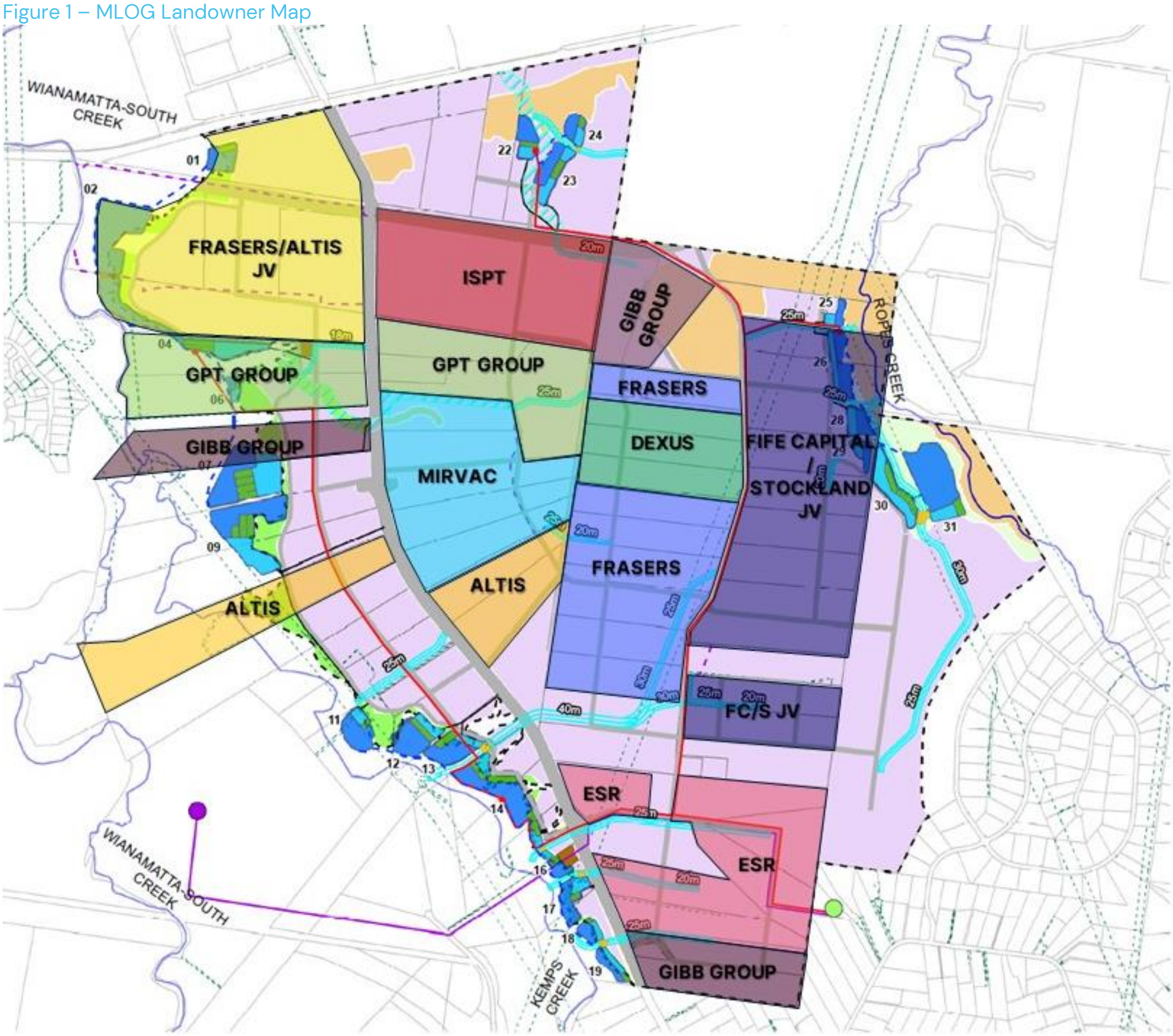
The MLOG includes ten members: ESR, Mirvac, Altis (now Barings), Fife Capital, Stockland, Frasers Property, GPT, Dexus, ISPT and Gibb Group. We do not speak for the entire Precinct, rather it represents the major institutional investors who have made a strategic decision to locate in the Mamre Road Precinct. The Mamre Road Precinct was identified as a strategic location for growth due to lack of zoned and serviced industrial land in NSW, surge in customer demand, and proximity to major infrastructure investment such as the Western Sydney Airport and M12 Motorway.

The MLOG has a substantial track record of developing, investing and managing high quality industrial and warehousing property portfolios across Australia. Each member has a strong commitment to Western Sydney, having developed many high-quality employment estates in the Western Sydney Employment Area (**WSEA**), Sydney Metropolitan Region and interstate markets such as Victoria and Queensland.

The MLOG own approximately 600 hectares (**ha**), approximately 70% of the Mamre Road Precinct. Five developers have received development approvals and are currently delivering warehouses for major international and national customers. The remaining five are in the final stages of assessment with an anticipation for all groups to be under delivery at the end of 2024. Every MLOG member is delivering critical infrastructure, such as water, sewer, and electricity. In addition, significant road packages are underway, in addition to works shortly commencing on major intersections at Mamre Road, upgrade of Abbotts and Aldington Roads and the delivery of new collector roads which connect to the major intersections. These infrastructure projects are all being funded by developers to ensure the Precinct responds to demand of serviced, zoned land in the Precinct.

The MLOG has committed significant resources to unlock Mamre Road Precinct to ensure it meets its objective of providing high quality employment land, suitable to support industrial occupier demand. We propose to further partner with government on this final component to provide our businesses and customers the confidence to invest in the Precinct and NSW whilst fundamentally ensuring the delivery of high quality, sustainable industrial and logistics space that responds to demand.

Figure 1 – MLOG Landowner Map



MLOG Understanding of IPART Review

From review of IPART documentation and the official Terms of Reference for IPARTs review, the MLOG understand that the NSW Government has authorised IPART to provide advice on:

1. Determining the efficient costs of providing stormwater drainage services within the Mamre Road Precinct; and
2. Allocating these costs efficiently between developers, taxpayers, and other stakeholders.

In fulfilling this task, it is understood IPART has been requested to consider:

1. Existing work and instruments regarding governance of stormwater and waterways in and near the Mamre Road Precinct, including:
   a) The Government's Risk-based framework for Considering Waterway Health Outcomes in Strategic Land-Use Planning Decisions:
   b) Review of water sensitive urban design strategies for Wianamatta-South Creek (NSW Government, 2022)
   c) Technical guidance for achieving Wianamatta-South Creek stormwater management targets (NSW Government, 2022)
   d) The Greater Sydney Regional Plan and other associated work, such as Western Sydney Planning Infrastructure Compact (PIC) Program – Initial PIC Area
   e) The Western City District Plan
   f) The Mamre Road Development Control Plan, including the Waterway Health Objectives;
   g) DCCEEW's 2021 strategic business case; and
   h) The existing work of DCCEEW and Sydney Water on identifying cost savings in the delivery of stormwater drainage services in the Mamre Road Precinct and the resulting Discussion Paper.
2. Potential environmental, economic and social impacts of **not** providing regional stormwater drainage services in Mamre Road Precinct compared to alternate pathways
3. The Critical demand for industrial land in Sydney and the NSW Governments growth priorities for Western Sydney
4. Comparative costs of stormwater drainage schemes in:
   a) Greater Sydney and other cities; and
   b) The Mamre Road Precinct and other locations in Greater Sydney
5. The effect and impacts of land tax and any other relevant taxation (eg, income tax) on the efficient costs of providing stormwater drainage services within the Mamre Road Precinct and options available to fund these taxes
6. Any other matters IPART considers relevant.

It is understood that IPART has been requested to consider that other stormwater drainage schemes, may not have the same or similar waterway health targets, objectives and outcomes. Or that any additional costs associated with meeting the waterway health objectives and outcomes for the Mamre Road precinct should be factored in IPARTs review.

In terms of timing, it is understood that IPART must provide a report along with advice to the Secretary of the Department of Climate Change, Energy, the Environment and Water by the end of September 2024.

MLOG comments on IPART Terms of Reference

IPART Terms of Reference item 6: ***Any other matter IPART considers relevant***

The MLOG have significant concern regarding the following statements made by IPART within the IPART '*Cost of Stormwater drainage in the Mamre Road Precinct'* dated 23 April 2024.

The costs of delivering stormwater drainage services in the Mamre Road Precinct are partly driven by the waterway health targets and other objectives that it is designed to meet. The Terms of Reference asks us to factor in all reasonable costs associated with meeting these targets and objectives. ***To the extent that these targets and objectives are binding, they are a standard cost of doing business and Sydney Water should be able to recover the efficient costs of meeting them.***

> *We will confirm what targets Sydney Water must meet and the minimum level of stormwater service that would meet them. Where we find that elements of the plan are discretionary or provide benefits above the minimum level of stormwater service that would meet the statutory targets and objectives, we will consider who should pay the costs of these elements.*
>
> [**Our Emphasis**]

Whilst it is understood that IPART have been requested to factor in all reasonable costs associated with meeting waterway health targets and objectives we draw IPARTs attention to the following key matters as outlined further in detail throughout this report:

1. Document item 1b from the Terms of Reference (*Review of water sensitive urban design strategies for* Wianamatta-South Creek (NSW Government, 2022)) concluded a cost for a regional stormwater scheme of $287,000/Ha of developable land. This document outlines it was this costing to which formed the basis for step 4 (feasibility) of the Government's Risk-based framework for Considering Waterway Health Outcomes in Strategic Land-Use Planning Decisions (Risk-Based Framework). Now that Sydney Water's costing for the regional scheme (>$1,000,000/Ha of Developable Land) and proposed contribution caps to developers of $800,000/Ha of Developable Land have significantly departed from the NSW Government's 2022 feasibility review. The MLOG's understanding is that a revised feasibility assessment should be completed for Step 4 of the Risk-Based Framework and if the risks are deemed not acceptable, then a review of the waterway health targets and objectives must be carried out.

   In this case, the MLOG seek IPART to provide advice to the NSW Government as to whether Step 4 of the Risk-Based framework has been adequately completed given the current scheme costs.

2. The Mamre Road Precinct Development Control Plan (MRP DCP) was prepared by the NSW Government in consultation with industry; however, insufficient background of technical information which informed the waterway health targets were released as part of the MRP DCP. The MRP DCP was adopted 19 November 2021. Exhibited with the MRP DCP was a Sydney Water document which presented a range of on lot controls to achieve the waterway health targets for a national (order of magnitude) cost of $120,000/Ha of Developable land. It was on this basis of $120,000/Ha of Developable Land to which the MLOG provided endorsement to the NSW Government to finalise the MRP DCP. No costing was provided for a regional scheme. Key NSW Government documentation, as included within the IPART Terms of Reference, regarding the waterway health controls were not released to Industry until post adoption of the MRP DCP as follows:
   a) Review of water sensitive urban design strategies for Wianamatta-South Creek (NSW Government, 2022): Released in April 2022, 3 months post adoption of the MRP DCP
   b) Technical guidance for achieving Wianamatta-South Creek stormwater management targets (NSW Government, 2022): Released in September 2022, 10 months post adoption of the MRP DCP

3. Industry and academics have constantly sought clarification from the NSW Government regarding concerns with reference to the validity and robustness of the original data informing the waterway health targets. To date, the MLOG and peak bodies have not been afforded a technical working group with the NSW Government to establish whether the targets for the Mamre Road Precinct are based on sound peer reviewed data, which is suitable, technically supported and economically viable. Industry have requesting a transparent peer review of the background data and controls since they were included within the MRP DCP in 2021 without any supporting information. The MLOG, our engaged consultants and Sydney Water have all noted that the 90th percentile flow parameter is extremely difficult to satisfy. It is important for IPART to note that the adopted 90th percentile target is significantly less than the supported 90th percentile objective requirement. Therefore MLOG strongly believe there is merit in exploring the application of the controls / flexibility in adhering to the objectives which provides a significant opportunity to improve the cost / benefit associated with the scheme – in particular in relation to targets around the 90th percentile.

4. Economic feasibilities provided by both MLOG engaged consultant, Atlas Economics and DPHI engaged consultant, SGS, determined that the proposed stormwater contributions could not exceed $300,000/Ha of developable land without incurring significant economic impact the industrial and therefore NSW market. Importantly, both Atlas Economics and SGS did not include for elongated planning delays or interim abortive costs or sterilisation of land.

2. Key Recommendations for IPART

The MLOG provides the following recommendations for IPART to consider as part of its review. For ease of reference, each recommendation is connected to a section within the MLOG submission. We request IPART to review the detailed submission to understand the context of each recommendation listed below.

1. With reference to the IPART review Terms of References, item 6 ('Any other matter IPART considers relevant'), the MLOG requests IPART to add the following matters for considerations:
    a. Potential environmental, economic and social impacts **of providing** regional stormwater drainage services in Mamre Road Precinct compared to alternate pathways
    b. Whether Step 4 of the NSW Governments Risk-Based Framework has been adequately addressed in consideration of feasibility given current scheme costs
    c. Whether review and revision of the waterway health targets is required. Specifically, the 90th percentile flow control. This is the primary control which is resulting in interim measures, significant sterilisation of land and infeasible scheme design costs.
2. MLOG requests the opportunity to brief IPART as part of their review on the cost of stormwater drainage prior to issuing recommendations report to NSW Government.
3. MLOG requests IPART to recommend to the NSW Government to establish a technical working group with industry and leading specialist engineer to deliver an economically viable stormwater solution for the Mamre Road Precinct and Aerotropolis. Terms of reference should be set up with an understanding to identify an environmental solution that does not sterilise land in lieu of a regional stormwater solution.
4. MLOG requests IPART complete a comprehensive review and peer review of the current Mamre Road Precinct and Aerotropolis targets. Should the review determine these targets are not feasible, a recommendation should be made to NSW Government to re-visit the proposed stormwater controls in accordance with the *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-Use Planning Decisions*.
5. MLOG recommends further investigation is required to explore more effective ways to fund and deliver an efficient stormwater scheme at a cost not to exceed $500,000/ha of net developable area to industry and allow development to progress.
6. Technical working group to be established to determine pathways forward to seek to reduce costs for the scheme, ensure no interim abortive works or land sterilisation and pathways for timely delivery of a regional scheme.

Finally the MLOG note that the IPART recommendations provided to the NSW Government and subsequent final DSP costs adopted for the Mamre Road Precinct will send a clear message to the broader Aerotropolis and will influence further investment decisions within the Aerotropolis which will influence industries ability to meet NSW and Federal Government aspirations of Sydney's 3rd city. Advice received by the MLOG indicates that based on the current Sydney Water Mamre Road Precinct scheme design costs and potential increased costs for the broader Aerotropolis, the entire Sydney Water scheme cost across the entire Aerotropolis (including Mamre Road Precinct) would be in the order of $11 billion dollars. MLOG request that this cost of the scheme be balanced against any forecast economic, environmental or social benefits as result of progressing with the scheme as currented documented.

3. Importance of Industrial Market to the NSW Economy

IPART Terms of Reference item 3: ***The Critical demand for industrial land in Sydney and the NSW Governments growth priorities for Western Sydney***

On 14 August 2019, the MLOG wrote to the then Hon. Rob Stokes, Minister for Planning and Public Spaces regarding the growing industrial land supply shortages in Sydney, the need to protect Western Sydney's competitiveness and unlock required jobs and investment in Western Sydney (**Ministers Letter**).The Ministers Letter (**Appendix A**) highlighted industry concerns regarding the deteriorating affordability for occupiers in Sydney and identified significant risk of losing investment and employment opportunities to other states as a result. Below is an excerpt from the Letter demonstrating the affordability gap:

> *In 2019 the average serviced industrial land values in Sydney were $315/sqm higher than Melbourne (91% higher) and $217/sqm higher than Brisbane (503% higher) and the average prime existing warehouse rents were $58.57/sqm higher than Melbourne (33% higher) and $38.52/sqm higher than Brisbane (141% higher)*
>
> *(% based on the 10-year historical average spread)*

Following issue of this letter, the demand for industrial land was accelerated due to the disruption of COVID-19. As people were isolating at home a significant transition towards online retail and sales, as well as businesses adopting a model of 'just in case' vs. 'just in time', supercharged the demand for warehousing space across Australia.

In November 2019, the NSW Government responded by announcing the rezoning of Mamre Road Precinct. Under the rezoning package, Mamre Road Precinct sought to:

1. Delivery of the blue, green and ochre grid
2. Protecting and enhancing bushland and biodiversity
3. Protecting and delivering transport corridors
4. Protecting the 24-hour operation of the Western Sydney Airport; and
5. Assisting in the creation of around 17,000 jobs as a contribution towards 200,000 new jobs across Western Sydney

In the NSW Government's rationale on why more industrial land is needed, which was included in the November 2019 announcement (**Appendix B**), stated the following:

> *The rezoning of the precinct will assist in delivering the growing demand for industrial land in Western Sydney because industrial land ready to develop in this area could be exhausted within 4 to 5 years.*
>
> *The proposed rezoning and expansion of the precinct should help address the projected demand and provide around 780 hectares of new industrial land for Western Sydney. It will also contribute to opportunities for 'jobs closer to home' and support the NSW economy.*

The MLOG commended Government on the release of the Mamre Road Precinct and was supportive of the quick rezoning in June 2020 to support industrial demand in NSW. By NSW Government rezoning the Mamre Road Precinct, it triggered a signal to the market that this Precinct was ready for investment and development. This resulted in the MLOG growing from 5 to 10 institutional developers ready to respond and deliver warehouses to support the critical demand for industrial land in Sydney and the NSW Governments growth priorities for Western Sydney. The ability to immediately respond and deliver within this newly zoned land was subsequently delayed due to the need for NSW Government to complete the planning framework which included:

1. Precinct-wide Development Control Plan (Finalised in November 2021)
2. Aerotropolis Special Infrastructure Contribution (Finalised March 2022)
3. Section 7.11 Contribution Plan (Finalised April 2022)

These planning components enabled Government to assess and determine planning applications within the Precinct, two years after the initial rezoning. The first development approval (**DA**) for industrial land was achieved in May 2022, another two approvals were received April/May 2023, followed by two more in September/December 2023, with the most recent DA received May 2024. These approvals reflect partial delivery of estates for developers, and do not reflect the full roll of development within these estates and the Precinct.

In 2023, the MLOG engaged Atlas Economics to determine the value of industrial land to Greater Sydney, assess the current market conditions on ability to deliver demand and prepare a comparison on competitiveness between the NSW, Victoria, and Queensland. The purpose of this report was two-fold:

1. Review the current state of the industrial market given the 4-year period from the initial release of the Precinct, which purpose was to combat the dwindling supply of industrial land, by the NSW Government
2. Assess the impacts of the proposed stormwater charge and industrial market's capacity to pay (refer to Section 4 below)

The key Atlas economics findings in relation to importance of industrial land is summarised below and the full report is provided in **Appendix C**.

Demand and Supply of Industrial Lands

All economic indicators point to a severely undersupplied industrial market in Sydney – one with an insufficient supply of land to respond to market demand.

1. Sydney's rents **average** $220/sqm compared to Melbourne ($120/sqm) and Brisbane ($135/sqm)
2. Sydney has the lowest vacancy rate in any global city (>0.2%)
3. Sydney's employment growth in the industrial sector averaged 0.5% over the 2016-2021 period, lagging behind Melbourne (1.2%) and Brisbane (1.1%)

Take-up of Industrial Land and Remaining Supply

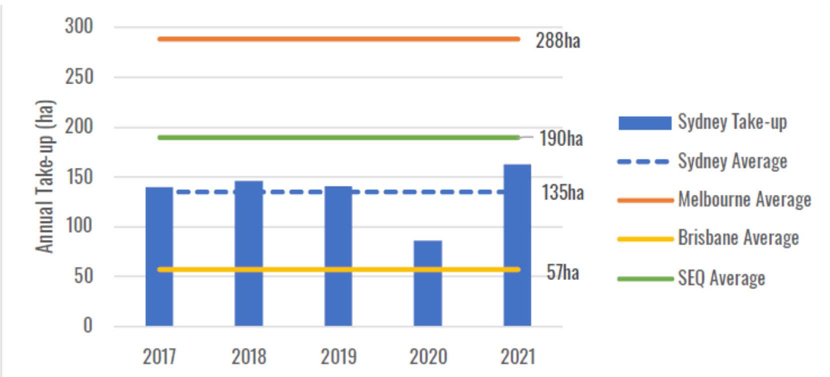
Annual take-up of industrial land in Greater Sydney has averaged 135ha in the 2017-2021 period. In contrast, metropolitan Melbourne's take-up of industrial land has averaged 228ha and Southeast Queensland's 190ha over the same period.

Table 1 Annual Take-up of Industrial Land – Sydney, Melbourne, Brisbane, and Southeast Queensland (2017-2021)

Region	Value of Industrial Sector (IVA)	Population (2021)	Annual Land Take-up (ha)					
			2017	2018	2019	2020	2021	Avg. (2017-2021)
Greater Sydney	$70.0 billion	5.3 million	139.6	145.8	140.2	86.0	163.1	135.0
Metropolitan Melbourne	$62.7 billion	5.0 million	317.8	219.7	324.3	305.8	273.0	288.0
Brisbane Region	$30.3 billion	2.6 million		47.1	70.2	67.7	42.5	56.9
Southeast QLD (SEQ)		3.6 million		185.9	261.3	168.3	146.2	190.4

Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

Figure 2 Sydney Annual Take-up of Industrial Land (2017-2021)

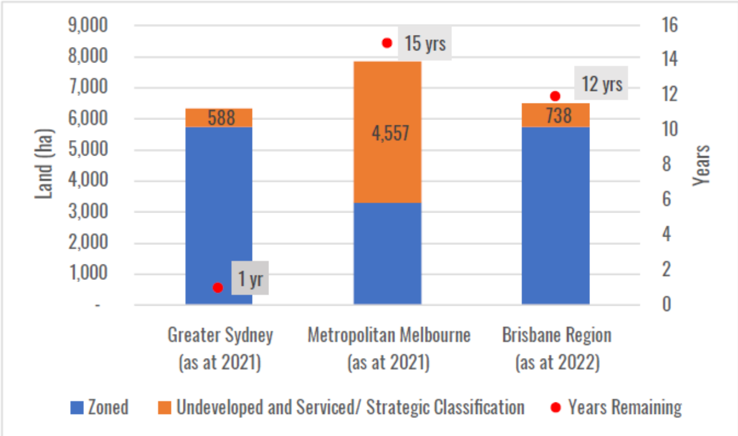


Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

Sydney has the largest population base (5.3 million residents) compared to Melbourne (5.0 million) and Southeast Queensland (3.6 million). Sydney's demand would be similar to Melbourne and much greater than Southeast Queensland. However, Sydney's average annual take-up of land has been less than 50% of Melbourne's 290ha per annum and only 70% of Southeast Queensland's 190ha per annum.

Atlas Economics Report highlights the shortage of serviced land in Sydney, which has subsequently resulted in a constrained market unable to respond to demand and has resulted in escalating rents and almost zero vacancy.

Figure 3 Industrial Land Supply – Sydney, Melbourne and Brisbane



Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

Atlas Economic's Report concluded with less than one-year serviced supply remaining (compared to 15 years in Melbourne and 12 years in Brisbane), there is limited capacity and opportunity for investment, business growth and further employment opportunities.

The industrial market contributes to $70 billion (18% of total activity) to the Greater Sydney Economy and $90.9 billion (18% of total activity) in NSW. Furthermore, also contributing to more than 30% of Greater Sydney and NSW Exports, provides for a large number of jobs, whilst generating a significant portion of economy activity and contributes considerably to the Gross State Product of NSW.

The importance of the industrial market to NSW exceeds past traditional manufacturing and warehousing. A follow up report prepared by Atlas Economics (**Appendix D**) researched the relationship between the housing sector and industrial lands, in response to the National Housing Accord target. The demand from residential construction to meet the Housing Accord targets places additional demands on the industrial sector, storing vital building components and materials required for construction of all new homes and high-density residential developments. The report concluded than between 280 hectares and 380 hectares of additional serviced industrial land is required to meet the National Housing Accords. The current NSW market will be unable to meet this demand due to the lack of available zoned and serviced land.

Greenfield industrial land (like the Mamre Road Precinct), needs to be unlocked to enable delivery. The lack of supply and the demand and pressure for serviced industrial lands creates an extremely sensitive market. Users are transitioning to larger format warehouses circa 60,000sqm, which requires large landholdings approximately 10 hectares. This can only be facilitated in Western Sydney. Further, the strategic location of Western Sydney between Melbourne and Brisbane provides for a strategic location to service the eastern seaboard.

It is requested that IPART review the Atlas Economic's Reports, as it reinforces the understanding of the MLOG's position on land sterilisation for the interim period and the economic impact of Sydney Water's proposed DSP charge. NSW needs a correction in the current trends for this sector and will continue to loose investment to other states; consequently, resulting in added cost of living pressures (due to servicing NSW from adjoining states). Introduction of the current proposed stormwater DSP and land sterilisation for the interim period would cripple this industry further in its ability to reverse these trends. The MLOG remains supportive of the overall environmental objectives of the Precinct, however, believe there is an alternative solution to be investigated jointly with industry and government that will ensure all objectives are met for Mamre Road Precinct.

4. History of Stormwater Management in Mamre Road Precinct

In 2017, the NSW Department of Planning released the report *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-Use Planning Decisions* (*Risk-based framework*) (**Appendix E**). To support decisions on the extent of stormwater management required above the minimum level, the NSW Government released the Risk-based Frameworks. This document includes five key steps as part of a framework to determine waterway health outcomes as part of strategic planning and was the foundation for setting the new stormwater management controls within the Precinct. The authors of this framework noted as Dela-Cruz et al. 2017.

The Mamre Road Precinct rezoning was fast tracked in June 2020 to support industrial demand in NSW. By NSW Government rezoning the Mamre Road Precinct, it triggered a signal to the market that this Precinct was ready and accessible for investment and development.

The Mamre Road Precinct Development Control Plan (MRP DCP) was subsequently prepared by the NSW Government in consultation with industry; however, insufficient background of technical information which informed the waterway health targets were released as part of the MRP DCP. The MRP DCP was adopted 19 November 2021. Exhibited with the MRP DCP was a Sydney Water document which presented various of on lot controls to achieve the waterway health targets for a national (order of magnitude) cost of $120,000 / Ha of Developable land.

The following key NSW Government documentation, as included within the IPART Terms of Reference, regarding the waterway health controls were not released to industry until post adoption of the MRP DCP which included the waterway heath targets:

1. *Review of water sensitive urban design strategies for Wianamatta-South Creek* (Appendix G) (NSW Government, 2022): Released in April 2022, 3 months post adoption of the MRP DCP
2. *Technical guidance for achieving Wianamatta-South Creek stormwater management targets* (Appendix M) (NSW Government, 2022): Released in September 2022, 10 months post adoption of the MRP DCP

Without these documents, industry where unable to provide support for the Mamre Road Precinct DCP. It was on this basis of $120,000/Ha of Developable Land to which the MLOG provided endorsement to the NSW Government to finalise the MRP DCP. No costing was provided for a regional scheme. In February 2022, the NSW Department of Planning released the report titled *Performance Criteria for protecting and improving the blue grid in the Wianamatta-South Creek catchment* (**Appendix F**). Dela-Cruz J remained a consistent author across the two policy documents. It is requested that this document be included for IPART consideration as part of IPART Terms of reference item 6 (Any other matters IPART considers relevant). The *Performance Criteria for protecting and improving the blue grid in the Wianamatta-South Creek catchment* importantly references the *Risk-based Framework* as follows: *In accordance with the strategic plans for the area (GSC 2018a, b; WSPP 2020),* ***standard planning requirements (viz. development controls) to protect and manage the blue grid elements of the Environment and Recreation Zone have been developed using the NSW Government Risk-based Framework*** *for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions (the Risk-based Framework; Dela-Cruz et al. 2017).*

Overall, our approach to developing the performance criteria has been necessarily pragmatic to address key stakeholder concerns related to ***achievability and costs*** *(Appendix F****) in accordance with the strategic impact assessment step of the Risk-based Framework*** *(Dela-Cruz et al. 2017).*

[**Our Emphasis**]

Following the release of the *Performance Criteria for protecting and improving the blue grid in the Wianamatta-South Creek catchment*, the NSW Department of Planning released an additional report titled *Review of water sensitive urban design strategies for Wianamatta-South Creek* **(Appendix G).** This report references the *Risk-Based Framework* as follows and conducted the outcomes based feasibility assessment of achieving the new stormwater management targets. Key extracts below:

> *The targets were developed by the NSW Government via a risk-based framework (DPE, 2022d), in accordance with the NSW Government policy for managing waterways, the Western City District Plan (GSC, 2018b), Western Sydney Aerotropolis Plan (WSPP, 2020) and the State Environmental Planning Policy (Precincts – Western Parkland City) 2021.*
>
> *The NSW Government 'Risk-based framework for considering waterway health outcomes in strategic land use planning decisions' (Risk-based Framework', Dela-Cruz et al. 2017) outlines a process for developing management targets, in consideration of their feasibility of being achieved. As outlined in Step 4 of the Risk-based Framework, feasibility could include aspects of costs of delivery, benefits achieved, site constraints/characteristics, operational requirements, and/or social considerations.*
>
> *In this document, we present the results of the feasibility of achieving the new (outcomes-based) stormwater management targets for Wianamatta-South Creek by comparing a range of water sensitive urban design (WSUD) strategies.*

Importantly the NSW Department of Planning report titled *Review of water sensitive urban design strategies for Wianamatta South Creek* concluded that a regional treatment and reticulated reuse system would cost in the order of $191,000 per hectare for the cost of implementation of WSUD infrastructure with approximately $96,000 per hectare for approximately 87 hectares of land acquisition; therefore, a total of $287,000 per hectare of developable land. It is based on this number that this NSW Department of Planning report titled *Review of water sensitive urban design strategies for Wianamatta South Creek* concluded:

> ***The overall findings of this work demonstrates that financially viable solutions to achieve the stormwater targets can be developed if a trunk drainage manager is established. The findings form Step 4 of the NSW Government Risk-Based Framework (Dela-Cruz et al., 2017)*** *and will assist decisions on institutional arrangements for development and delivery of water infrastructure in the Wianamatta-South Creek catchment.*
>
> [**Our Emphasis**]

The MLOG understand this report was the basis for the NSW Government's recommendation for Sydney Water to be appointed as the waterway health manager. The appointment of Sydney Water was confirmed in March 2022 (**Appendix H**), The MLOG supported the announcement of Sydney Water as the regional stormwater authority under the NSW Government's assumptions and recommendations used to inform this appointment on the understanding of costs being a total of $287,000/Ha of developable land and resulting in no land sterilisation.

On 15 March 2023, Sydney Water wrote to each landowner within the Mamre Road Precinct providing an update on the stormwater servicing in the Mamre Road Precinct **(Appendix I).** The letter advised the estimated cost for the regional system to be $1,300,000 per hectare of developable land. This estimate was 4 times greater than NSW Government's recommendation paper and was a complete shock to industry.

Following this letter, a series of workshops were set up between industry and Sydney Water to collaborate and to identify cost savings towards the scheme.

Majority of the MLOG recommendations were not adopted by Sydney Water. While we understand the overall scheme cost has reduced by approximately $300,000/ ha of developable area, the current stormwater scheme is still significantly more expensive than the original guidance provided by the NSW Government.

To assist government on understanding the impacts of this significant increase in costs, Atlas Economics Report (**Appendix C**) advised on the capacity to pay of infrastructure contributions in the Mamre Road Precinct. The MLOG engaged Atlas Economics due to their previous engagement with NSW Government, which they advised on capacity of targeted precincts, including Mamre Road Precinct, to tolerate a SIC in terms of development feasibility (2020 Study).

In the initial investigations in 2020 under NSW Government engagement, Atlas Economics concluded a SIC rate of $200,000/ha of developable area could be feasibility tolerated in the Precinct. At the time, Penrith City Council was carrying out investigations into local infrastructure and had raised the possibility for a Section 7.11 contribution rate to be in the order of $700,000/ ha of developable area. The initial government report did not factor a stormwater DSP charge, as it was assumed this would be captured under local contributions with Council.

The Atlas Economics updated feasibility assessment reviewed the tolerance of development in the Mamre Road Precinct to the proposed stormwater DSP charge. The objective of feasibility testing was to assess if, after contribution to the stormwater DSP, development margin and project IRR are within an acceptable range. The hurdle rates utilised for the MLOG assessment were consistent with the accepted assumptions in the 2020 Study.

Figure 4 Benchmark Hurdle Rates

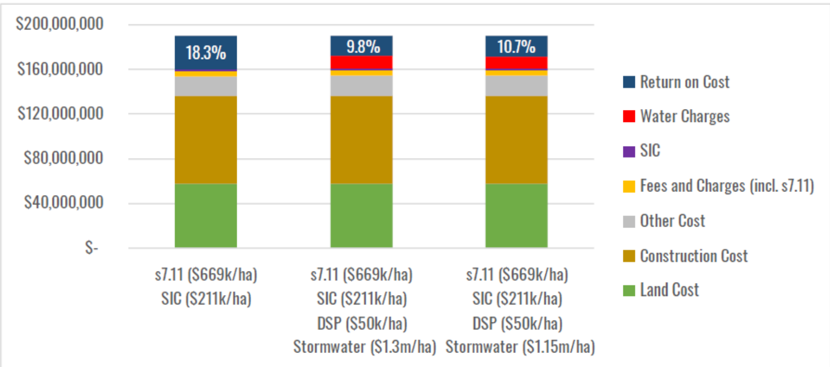
Hurdle Rates	Feasible	Marginal to Feasible	Not Feasible
Return on Cost (Development Margin)	>18%	16%-18%	<16%
Project IRR	>18%	16%-18%	<16%

Source: Atlas

The modelling result indicated that:

1. Development which includes s7.11 contributions and SIC is just feasible – return on cost is 18.3%
2. After inclusion of the proposed DSP and stormwater charges ($1.3m/ha NDA), the development feasibility is severely affected. The return on cost is at 9.8%, which is well below the target of 18%.
3. At a reduced stormwater charge of $1.15m/ha NDA, the return on cost is 10.7%, also below the target of 18%.

Figure 5 Comparison of Feasibility Modelling Results



Source: Atlas

The feasibility modelling demonstrated the proposed stormwater DSP charges are not marginally more, but significantly more than what is tolerated by development. This report was tabled to government, which resulted in a peer review. The peer review by SGS Economics, on behalf of NSW Government confirmed on the capacity to pay analysis (**Appendix J**). The analysis concluded the maximum charge towards stormwater DSP that could be accommodated under a capacity to pay analysis was the original nominated rate at $287,000/ha of developable area. It is critical to note that both industry and NSW Government procured feasibility studies that did not account for interim or abortive stormwater measures or land sterilisation.

The NSW Government acknowledged the capacity to pay challenges; however, noted the stormwater DSP needed to balance other objectives (such as environmental outcome). Therefore, it was requested that the MLOG provide an upper limit to stormwater DSP charge prior to development in the Mamre Road Precinct becoming no longer feasible. The MLOG advised the maximum capacity to pay for a stormwater DSP contribution was $500,000/ha of net developable area (**Appendix K**). However, this charge was contingent on the following:

1. No land sterilisation in the interim. Holding costs on sterilised land, which is not developable, reduces the capacity to pay
2. Commitment to unlock road infrastructure, including commitment for funding of Mamre Road and Southern Link Road, and reversal of limitations placed on SIC WIK credit for road infrastructure
3. Request to identify a solution to these matters within a timeframe via a technical working group

The MLOG requested a technical working group to workshop these items. To date, no NSW Government technical working group has been set up to address the items raised by the MLOG.

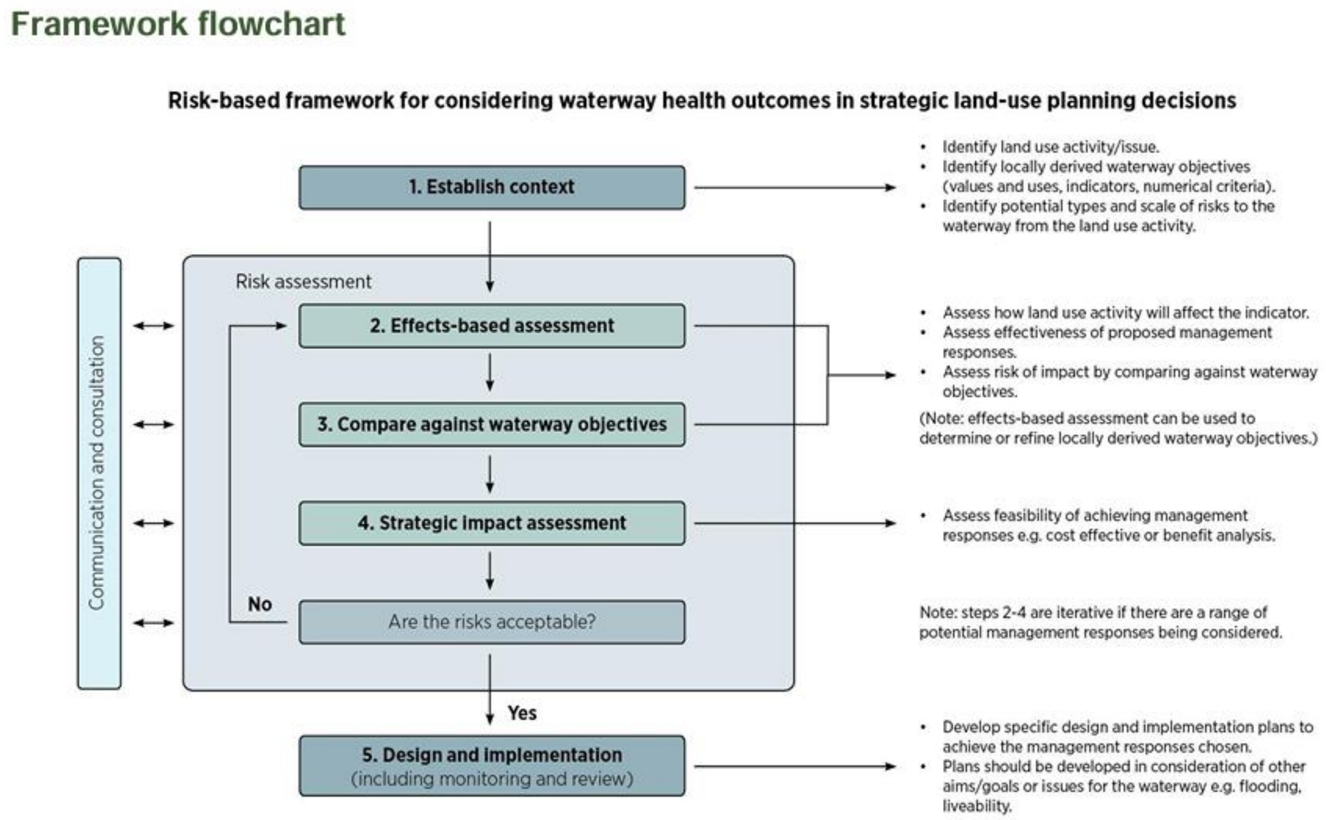
On the 12 January 2024, the NSW Government provided a Ministerial Direction to the Board of Sydney Water Corporation requiring Sydney Water to cap the reasonable security it requires from a developer under section 74(1)(c) of the *Sydney Water Act 1994*. The bonding amount was set to $800,000 per hectare of developable area.

The MLOG understand that the cap of $800,000 per hectare of developable area also provides a ministerial limit in which a DSP charge can be imposed on industry. We understand the Sydney Water costing for the regional stormwater scheme, as submitted to IPART, is more than $800,000/ ha of developable area.

The purpose of outlining the history of stormwater costs in the Mamre Road Precinct is to illustrate to IPART the significant departure in forecast costs and advice to industry which informed investment in the Mamre Road Precinct. The increase from the original NSW Government guidance of $287,000 per hectare of developable land for a regional scheme and the current Sydney Water bonding cap to developers of $800,000 per hectare of developable area is still three times more expensive. Furthermore, there is a gap between the cap on DSP costs to industry of $800,000 per hectare of developable land and the current Sydney Water total scheme cost.

If a stormwater DSP charge cannot be reduced to costs that align with the industry capacity to pay for the Precinct, the MLOG request that Step 4 of the *NSW Government Risk-Based Framework* is pursued, therefore, requiring NSW Government to review the original target should 'risks not be acceptable including costs of delivery'. A flow chart of the *Risk-based framework* steps is set out below for reference.

Figure 5 Risk-based framework flow charge



4. Mamre Road Precinct controls and costs comparison to stormwater services delivered elsewhere

It is understood that IPART will complete a holistic comparative review of stormwater infrastructure charges elsewhere throughout NSW. However, The MLOG wish to inform IPART that the proposed Sydney Water DSP charges are in addition to developers being requiring to meet water quantity (peak flows) discharge requirements through the provision of large-scale on-site detention basins within the various estates. Generally, on an estate basis the costs of works and loss of developable land to deliver on-site detention basis equates to approximately $280,000/Ha of net developable area. This cost is already absorbed by developers on an estate basis; therefore, should be considered within any comparative assessment of costs.

Please refer to MLOG comments within Section 6.3 regarding the Melbourne Water approach and costing to waterway health.

6. MLOG Response to the Issues Paper

6.1 What is your feedback on our approach to this review? What else should we consider?

IPART Terms of Reference item 6: ***Any other matter IPART considers relevant***

The IPART review must be comprehensive and further consider the economic, environmental and social impacts in proceeding with the regional stormwater DSP charge. Economists should review and examine the state of the industrial sector's capacity to pay given the current market. Any introduction of DSP charges, changes to the regional stormwater approach or targets, industry must be consulted and an active participant in forming the policy and delivery of this system to support the Mamre Road Precinct.

The MLOG request IPART to consider the following:

1. The economic implications should the Sydney Water scheme on the viability of delivering industrial lands in Mamre Road Precinct and the Western Sydney Aerotropolis. Refer to Sections 2, 3 and Atlas Economic Reports at **Appendix C** and **D**.
2. The cumulative impact of multiple contribution schemes across Mamre Road Precinct. The MLOG has completed a comparison of infrastructure contributions in employment areas (refer to table 2 below). There is a limit to the amount developers can pay in contributions before it becomes unfeasible to invest in projects. Currently, Mamre Road Precinct contribution framework with adoption of Sydney Water DSP is 4x greater than WSEA and 2x greater than existing greenfield growth areas which include employment uses.

Table 2 Cumulative Infrastructure Contribution Comparison

Infrastructure Contribution	Mamre Road Precinct	Western Sydney Employment Area (Penrith LGA)	Leppington (Western Sydney Growth Area)	Marsden Park Industrial (Western Sydney Growth Area)	Aerotropolis	Cranbourne (Victoria)
State Infrastructure Contribution	$226,065 per Ha of NDA ($23 per sqm)	$150,000 per Ha of GFA ($15 per sqm)	$108,631 per Ha of NDA ($11 per sqm)	$108,631 per Ha of NDA ($11 per sqm)	$226,065 per Ha of NDA Ex. Assessment of mixed use zone and station charge ($23 per sqm)	$122,660 per Ha of NDA ($12 per sqm)
Council Contribution (S7.11/S7.12)	$677,699 per Ha of NDA ($68 per sqm)	1% of CIV (Approx. $15 – $30 sqm)	$719,033 per Ha of NDA ($72 per sqm) *Includes delivery of stormwater in contribution	Up to $839,502 per Ha of NDA ($84 per sqm) *Includes delivery of stormwater in the contribution	5.6% of CIV (Approx. $91 - $160 sqm)	$165,000 per Ha of NDA ($17 per sqm)
Regional Stormwater Charge	$1,000,000 - $1,300,000 per Ha of NDA ($100 - $130 per sqm)	N/A	N/A	N/A	$1,000,000 - $1,300,000 per Ha of NDA ($100 - $130 per sqm)	$4.50 per sqm Melbourne Water has a tool to calculate contribution. Does not break down to per sqm
Total Rate per sqm	$190- $220 per sqm	$30 - $45 per sqm	$83 per sqm	$95 per sqm	$214 - $312 per sqm	$33.50 per sqm

Note: Assessed as May 2024, subject to further indexation. Comparison does not include assessment of Sydne Water's Water and Sewer DSP charges which are an additional cost.

1. The NSW Government has issued progressive infrastructure contributions since the Mamre Road Precinct was rezoned. If all contributions were identified at the time of rezoning, businesses would have factored these assumptions into the acquisition land price. Infrastructure agencies, such as Sydney Water, cannot assume developers can fully pay for this contribution as costs have not been factored into the original acquisition of land in Mamre Road Precinct.
2. The original business case by NSW Government identified a regional stormwater scheme to be $28/m2 or $287,000/ha. This business case supported nomination of Sydney Water as the regional stormwater authority. The current regional stormwater rate is 3-4x more expensive.

6.2 How well does Sydney Water's Stormwater Scheme Plan meet the needs of the community in the Mamre Road Precinct and broader Western Sydney Aerotropolis?

The MLOG understands that the broader Western Sydney Aerotropolis will have a stormwater DSP charge and contribute to the regional scheme. Many of the MLOG members have land within both employment growth areas and the comments raised in this report should be considered across both priority employment precincts.

As outlined in Step 4 within the NSW Government's *Risk-based Framework*, feasibility could include aspects of costs of delivery, benefits achieved, site constraints/characteristics, operational requirements, and social considerations. This submission has provided comments of the proposed stormwater DSP and regional stormwater system in relation to each feasibility item consideration below.

Costs of Delivery

The precinct-wide stormwater targets, which is the foundation for the stormwater DSP and regional scheme, was exhibited in November 2020 as part of the Mamre Road Precinct Development Control Plan (MRP DCP). A Sydney Water documentation supported the precinct-wide stormwater targets, which presented a range of lot-based Water Sensitive Urban Design Measures that could achieve the proposed water quantity targets with a notional (order of magnitude) costs of $120,000/ha of developable area. The MLOG commented on the MRP DCP, which raised concerned that the proposed stormwater targets were developed without consultation with industry and reflected development assumptions that were not reflective of market. For example, the development assumptions assumed small lot industrial, which current warehouses in the Precinct sit on 8-10 hectare lots and total approximately 40,000 – 60,000 sqm in warehouse area.

In March 2022, DPE provided updated guidance for notional costs for a regional scheme of $287,000/ha of developable area. As outlined within Section 4 above, the current advice by the NSW Government to industry is that stormwater and recycled water DSP bonds will be capped at $800,000/ha of developable area, which approximately 2.8 times higher than the original estimate by NSW Government for a regional scheme.

When NSW Government recommended a regional solution and estimated the cost of the scheme to be $287,000/ha of developable area, the MLOG provided in principal support. This enabled the confirmation of Sydney Water as the trunk drainage manager for the Mamre Road Precinct. The significant shift in cost is crippling investment within this Precinct. Land acquisition and attracting customers to invest in the Precinct are made with the information available at the time. If the current stormwater DSP cost, policy of interim land sterilisation and Sydney Water assumptions of a developer-led solution were made public at rezoning, decisions by industry would have considered for these risks and potentially not invested within this location. The late adoption of this stormwater DSP at its current rate cannot be absorbed by industry and nor passed onto to tenants.

Site Constraints and Characteristics

The current Sydney Water scheme design and Mamre Road Precinct DCP requires developers to adhere to waterway health targets prior to delivery of a regional stormwater scheme. This requires significant abortive measures to be delivered within each site to maintain compliance with controls in advance of delivery of the regional scheme. An estate under an interim solution must hold and store water within the estate, which results in majority of the land sterilised for irrigation.

A detailed review of timing for delivery of the regional stormwater scheme indicates basins and associated regional infrastructure will not be in place until late 2027 to mid-2028. This assumes a developer-led delivery with start to end delivery including acquisition, approvals, construction and commissioning. This extended lead time creates increased uncertainty in a Precinct, which was rezoned in 2020.

Further, the scheme proposes a series of reginal basins servicing the north ease of the precinct that are located on land owned by 2 established schools and a retirement village. With the timing to relocate these establishments unknown and certainly in the longer term, its clear servicing of this land (in excess of 80 hectares) cannot be provided via a regional system and vast amounts of this land will remain sterilised.

Prior to finalisation of the stormwater DSP, the NSW Government needs to provide a commitment on programme, delivery and timing of the stormwater system, whilst illustrating how this regional scheme can be delivered without the reliance on the private sector. Furthermore, it is encouraged to include a strategy on how interim arrangements facilitate the delivery of development. Sydney Water collects the infrastructure contribution via Section 73 certificates. These are issued prior to occupation certificate for warehouse buildings. If development cannot proceed, Sydney Water will fail on collecting funds to deliver the regional stormwater system. This is a critical item which needs to be resolved prior to adoption of the stormwater DSP.

Operational Requirements

MLOG understands the Sydney Water operational requirements are included within the upfront DSP costs. Noting the significant cost associated with the proposed DSP charge, it is requested that consideration be provided for actual (regulated) costs for operating the scheme be claimed back via Sydney Water quarterly rates rather than being costed and claimed upfront.

Social Considerations

Sydney Water must clarify if the proposed stormwater scheme includes public activation of Water Sensitive Urban Design (**WSUD**) areas. WSUD provides opportunity for social connectivity throughout the Wianamatta-South Creek. Therefore, it is questioned whether the proposed Sydney Water stormwater scheme plan provides and social benefit directly towards the community in the Mamre Road Precinct and broader Western Sydney Aerotropolis.

The MLOG's assessment on the criteria under the *NSW Government Risk-Based Framework* identifies the proposed scheme and stormwater targets currently are not acceptable based on cost of delivery, benefits achieve, site constraints and characteristics, operational requirements and social considerations. Given the stormwater DSP and targets do not pass the risk-based framework, it is requested for IPART to recommend to the NSW Government to revisit Steps 2-4 and work with developers to identify a feasible solution.

6.3 Are there alternative stormwater management methods or works that would deliver better outcomes for the Mamre Road Precinct and broader Western Sydney Aerotropolis community?

The MLOG in various submissions to the NSW Government have identified alternative methods and solutions that would deliver better, more affordable stormwater outcomes for the Mamre Road Precinct and Western Sydney Aerotropolis. summary of these alternative options is provided below and it is encouraged for IPART to investigate these items further.

Melbourne Water's Regional Stormwater Controls

Regional Stormwater infrastructure and the adoption of a Mean Annual Runoff Volume (MARV) as a control for measuring stormwater is not new in Australia, with a regional system developed and implemented in the Melbourne metropolitan area in 2018.

These stormwater controls were developed in consultation with other government departments (including the local councils) and industry to ensure the outcomes were peer reviewed, appropriate for the specific catchments and affordable for developers. The consultation comprised of over 630 individuals, representing 230 organisations via 23 workshops and demonstrated a partnership approach for determining controls that were (like in Mamre Road) a step change to previously adopted standards

Melbourne Water's stormwater controls were linked to the current condition of the catchment and receiving waterways. For implementation, the overall catchment was divided into **5 major waterway catchments.** Each of the 5 major waterway catchments were divided into numerous sub-catchments (**69 sub-catchments in total**), featuring varying physical, environmental and socio-economic characteristics and conditions.

Each sub-catchment was categorised as either a "priority" catchment or an "other" catchment. The classification depended on the level of degradation and ecological value of the receiving watercourse. Catchments identified as "priority" catchments were generally at the upstream end of watercourses and had experienced little, if any, impacts from urbanisation. The "other" catchments were those that had experienced souring impacts as a result of urbanisation and could therefore cater for larger flows within their banks before being impacted by stormwater discharges.

The "priority" catchments adopted a 68% reduction in MARV, which translates into a MARV of 2ML/ha/Year for the Aerotropolis and is the current control in the Mamre and Aerotropolis Development Control Plans (DCP). "Other" catchments adopted a 27% reduction in MARV, which would yield an approximate MARV in the Aerotropolis of 4ML/ha/Year. Water quality targets across all catchments remained unchanged.

Stormwater contributions for the Melbourne Water sub-catchments range between $200,000/ha - $300,000/ha, with some catchments as low as $100,000/ha.

In contrast, stormwater controls adopted in the Mamre Road Precinct and Aerotropolis were developed by NSW Government without any consultation with industry and without a peer review, which is in complete contrast to the Melbourne Water experience. This is reflected by the blanket MARV control across all catchments in the Aerotropolis, which is similar to what was adopted in Melbourne as a "priority catchment". Wianamatta-South Creek, which is the main receiving waterway in the Aerotropolis has been degraded over time by urbanisation, has banks impacted by erosion caused by flooding. Advise received from several industry experts including stormwater engineers noted Wianamatta-South Creek cannot not be categorised as a pristine waterway.

It is requested that the NSW Government to follow the approach by Melbourne Water and adopted a MARV control commensurate to the actual condition of Wianamatta-South Creek, the size and scale of stormwater infrastructure would significantly reduce, (by up to 70%). This would result in an affordable DSP solution to be delivered by Sydney Water and would create no interim land sterilisation prior to any regional system becoming operational.

It is strongly recommended that IPART consider the Melbourne Water process in developing stormwater targets.

Rooftop Irrigation

The MLOG has engineered and proposed an alternate option to managing stormwater in Mamre Road Precinct, which is developer delivered and managed. This solution is irrigation on top of warehouse roofs, where stormwater is captured onsite, is cleaned via bioretention or mechanical methods and this “clean” water discharged as a fine mist into the atmosphere

With their large area and generally higher temperatures, warehouse roofs provide an excellent opportunity to install these innovative irrigation systems, which are cost effective when compared to the proposed DSP and will be delivered and maintained by developers at no cost to government.

Stormwater engineers AT&L were commissioned by the MLOG to model rooftop irrigation as a way to achieve the current stormwater targets, resulting in a compliant solution on-lot at a cost of c$300,000/ha. Further to this modelling, AT&L completed a trial of the irrigation system on a warehouse in Erskine Park (adjacent to the Mamre Road Precinct), which further validated the modelling results (**Appendix L**).

This system was fully documented and included in 5 of the early Mamre Road Precinct SSDA applications. This proposed system was rejected by NSW Government.

Rooftop irrigation has been extensively used in the mining industry and is also used in the United States of America for similar applications. The MLOG requests that IPART reconsider this solution if stormwater DSP cannot be reduced and/or targets cannot be amended as per Melbourne Water example.

6.4 How should the costs of delivering Sydney Water's Stormwater Scheme Plan be funded? Are there elements that should be paid by developers, taxpayers or other parties?

As referenced in Section 4 of this submission, an economic feasibility assessment for the Mamre Road Precinct was completed by Atlas Economics which confirmed capacity to pay for a stormwater DSP charge to be maximum $300,000/ha of developable area. This analysis was agreed by NSW DPE engaged consultants and SGS Economics. However, following preparation of this report, industry provided correspondence at request of NSW Government outlining minimum feasibility for development within the Mamre Road Precinct could be met with a stormwater DSP of no greater than $500,000/ha of net developable area subject to the following:

1. Increased certainty on planning approval timeframes to no greater than six (6 months)
2. Funding and delivery of regional road upgrades for Mamre Road upgrade and Southern Link Road; and **most importantly**
3. No abortive costs for interim compliance or sterilisation of developable land in advance of delivery of a regional stormwater scheme

Noting the affordability and feasibility considerations within the Mamre Road Precinct and more broadly the Aerotropolis, in the absence of or prior to the NSW Government completing a review of the waterway health targets in line with the *Risk Based Framework,* the MLOG provide the following recommendations, which will allow development to proceed immediately:

1. Direct developer contribution cannot exceed $500,000/ha of net developable area
2. Ongoing charges via Sydney Water rates to be investigated given the proposed stormwater DSP and regional scheme assumes a 100-year lifecycle
3. A broader contribution catchment to be investigated, as the regional stormwater scheme benefits areas greater than the Mamre Road Precinct and Western Sydney Aerotropolis. This can be funded by the NSW Government or taxpayers.
4. Land tax should be exempt from Sydney Water's DSP costs

SWC DSP threshold:	Description
$500,000 /Ha Net Developable Land	Paid by developers to Sydney Water prior to release of Section 73 certificate/ Occupancy Certificate.
$500,000 - $800,000 /Ha Net Developable Land	Contributed by NSW Government/tenants/asset owners/broader Sydney Water customers as part of quarterly or yearly Sydney Water rates notices based on a 100-year life cycle
>$800,000/Ha Net Developable Land	Any and all costs in addition to $800,000/Ha of net developable land solely by NSW Government via any reasonable measures.

6.5 What environmental, economic or social outcomes would be lost if Sydney Water's Stormwater Scheme Plan for the Mamre Road Precinct did not go ahead in its current form?

The proposed stormwater DSP and the current stormwater targets contained in the MRP DCP cannot be supported in their current form. As detailed in this submission, the new stormwater targets are a disproportionate change from what has been adopted in NSW to date and have resulted in a requirement for large scale, inefficient and unaffordable infrastructure proposed by Sydney Water in the Mamre Road Precinct.

If the stormwater DSP and regional scheme does not proceed and current stormwater targets remain, development in the Mamre Road Precinct and Aerotropolis will halt. In contrast if the current stormwater DSP charge proceeds and interim land sterilisation remains, investment and development will also terminate within these priority locations.

This submission identifies fundamental issues associated with the cost of the proposed Sydney Water scheme, which includes delays to development of zoned and serviced land prior to the scheme plan being built and operational. The MLOG has provided a breakdown of the environmental, economic, and social ramification associated with the proposed stormwater DSP.

Environmental

The waterway health targets were developed by a Brisbane-based civil engineer with support from a local ecologist. There has been limited information shared to industry on the assumptions which informed the waterway health targets. The targets were not peer reviewed and no engagement with industry occurred during its development, which is contrast to the Melbourne Water example.

The MLOG have submitted requests to understand categorisation and condition of the major waterway (Wianamatta-South Creek), data collected at points along the waterway and the stormwater model. The initiation of a technical working group with government, industry and leading stormwater experts has been requested and remains unanswered by the NSW Government.

The MLOG support the environmental objectives trying to be achieved in the Wianamatta-South Creek catchment. However in lieu of the requested information, we question if the current proposed targets which informed the Sydney Water scheme, produce the best outcome from an environmental, social and economic perspective.

The limited transparency and information sharing between industry and government has made it impossible to quantify whether there will be real and significant environmental impacts (particularly Wianamatta-South and Ropes Creek) if the Stormwater Scheme Plan does not proceed or if the waterway health targets are relaxed.

With a forecast cost to industry of c$11 billion over the Mamre Road Precinct and Aerotropolis, without adequate consultation or justification, it is strongly recommended that IPART commission a full peer review of the stormwater targets and complete a cost benefit analysis prior to providing any endorsement of the Scheme Plan. The MLOG also welcome the opportunity to form a technical working group with government to resolve the concerns raised in this submission.

Economic

Economic implications will occur should the Sydney Water scheme proceed. It will also have a negative effect to the economy if it is not delivered and no change to current policy. To assist in justifying the economic implications of both scenarios, refer to the following summary outlining the potential economic cost for each scenario:

<u>Without Sydney Water</u>

If the Sydney Water Scheme Plan does not proceed and current stormwater targets are maintained, developers in the Mamre Road Precinct and Aerotropolis will need to treat stormwater on lot. To comply with these new targets, a series of large-scale stormwater retention basins, biofiltration ponds and land irrigation systems are required to be built on developable land, which are generally up to 55% of the total developable area. This broad scale sterilisation of developable industrial land for on lot stormwater infrastructure will result in Mamre Road Precinct not meeting its purpose, which is to provide supply of land in a constrained market.

Developers that own land in the Mamre Road Precinct and Aerotropolis cannot continue to invest in projects with half of developable land sterilised. It will force businesses to invest in other projects that can offer reasonable returns with less risk. This is especially important given the current global economic environment.

Therefore, an economically feasible regional scheme is required.

<u>With Sydney Water</u>

If the proposed stormwater DSP proceeds in its current form, there is a similar economic outcome to 'without Sydney Water. Land sterilisation will still impact developments in the short and medium term and estate viability is at risk.

If this investment is not made in Western Sydney or NSW, it will result in the following:

1. Loss of employment;
    a) The Mame Road Precinct was forecasted to deliver 17,000 jobs and the wider Aerotropolis 200,000 jobs.
    b) Without investment and development, these job targets will significantly reduce, with other states benefiting from interstate migration of construction projects and businesses. As outlined within this submission, Sydney has the highest rents as a result of low vacancy to support these high rates.
2. Loss of investment; The industrial sector is a major contributor to the NSW economy and as identified in section 3 of this submission, contributes more than $70 billion to the NSW economy, which is 18% of the total. This investment will decline if the sector cannot grow and businesses relocate to other states, which will in turn affect tax revenue for the state government
3. Supply Chain Disruption; with a growing population and international migration forecast to be c90,000 people annually, there is a need for additional industrial space to support the increase in population. This is coupled with a shift in the way people are shopping and the rise of E-Commerce, where consumers are purchasing products online, increasing the need for warehousing space. If NSW becomes increasingly reliant on products and materials being transported from other states, this will result in product delays, material shortages and an overall cost of products, passed onto the consumer. The Atlas Economics report identified Sydney as having the lowest global vacancy rate at 0.8% and only 1 year of industrial supply. The Mamre Road precinct was the short-term solution to this issue, with c800 hectares of land suitable for industrial development and the ability to maintain efficient supply chains. Without the supply generated from the Mamre Road Precinct, the costs associated with supply chain disruptions will be passed over to consumers and further add to the cost of living crisis.
4. Success of the Western Sydney Airport; The development of the Western Sydney Airport is a once in a generational opportunity to create a vibrant third city within Sydney and act as a catalyst for employment and residential growth. The Airport itself must be supported by complementary development, including industrial, commercial, recreational and retail amenity, attracting businesses that can co-locate and provide support functions to the airport operations (e.g. engineering industries, catering, warehousing). With airport operations set to commence in 2026, industrial industries in the Mamre Road Precinct would be the first of these supporting businesses, followed by land closer to the airport site itself. If development and investment is no longer feasible in the Aerotropolis, the Western Sydney Airport will fail and essentially be a runway surrounded by paddocks, not the vision set by the federal and state governments.

Further detail around the critical industrial land supply shortage in Sydney and economic consequences of not delivering affordable industrial solutions are contained in Atlas Economic Report contained in **Appendix C**.

Social

There are significant social impacts associated with the Sydney Water Scheme Plan and without the plan these are broad and far reaching, including;

1. Reduction in employment opportunities within Western Sydney, particularly in areas that have the highest unemployment rates in Sydney. Residents in Western Sydney will continue to rely on vehicular commuting to work, increasing traffic on the roads and leading to a decline in mental health. Certainly, the governments vision for a "30-minute city" outlined in the region plan will not be achieved.
2. Delays to receiving goods and materials due to supply chain issues, with more of these products being transported from other states. This will affect the consumer due to cost increases (associated with increased transport costs) and businesses as they face issues with the delay in receiving goods and materials essential to run their operations
3. Disruption to the health sector, with critical health infrastructure like pharmaceutical manufacturing and storage facilities located in other states, leading to potential shortages of vaccines, medicines and other key health products, which have traditionally been housed in facilities within the Sydney metro area
4. Impacts to achieving the Government's current housing supply targets (200,000 new dwellings per annum). There is a direct correlation between the delivery of housing and the amount of industrial storage / manufacturing space, facilities that store and manufacture building products. Atlas Economics has investigated this vital link and has confirmed that for every single dwelling, a significant percentage of industrial space is required to support construction activities (Refer Atlas Economics report within Appendix D) . With the cost of living a national crisis and housing affordability a major component, the only solution is to create more supply, which must be supported by the industrial sector. The Atlas Economics Report is contained in **Appendix C**
5. Significant increases in carbon emissions associated with transporting goods from other states. The NSW government has recently set net zero carbon emissions targets for the state (by 2041) which will be severely impacted by additional trucks on the road travelling for longer distances on a more consistent basis.
6. Inability for government to achieve the open space and blue green grid aspirations contained in the region and deliver the vision for the "Western Parkland City". If development within the Mamre Road Precinct and Aerotropolis does not progress due to affordability constraints, none of the open space, health, retail and open space amenity will be constructed, leaving large areas of the region void of employment and areas where residents can recreate.

6.6 Are there any other related issues you would like to tell us about?

IPART to consider the following items, which impact the viability of the stormwater system:

1. The IPART review must consider the assessment of the proposed Stormwater DSP charge against the *Risk-based framework for considering waterway health outcomes in strategic land-use planning decisions* prepared by Office of Environment and Heritage and NSW EPA in 2017.
2. The development of the stormwater targets and nomination of Sydney Water of the regional stormwater authority need to follow this framework based on the significant infrastructure costs and land sterilisation.
3. Under Step 4 of this framework, it requires a strategic impact assessment to be undertaken prior to design and implementation. This assessment requires a robust vetting to ensure *'selected management responses are reasonable, practical and cost-effective.'* The LOG view is this criterion has not been met as:
   a) Land sterilisation creates significant cost burden on holding costs for landowners and prevents the Precinct on delivering its objective for employment uses in the short and medium term.
   b) Significant cost burden of stormwater infrastructure, which is more than double of cumulative costs under State and local infrastructure contributions. Both contributions cover a range of infrastructure projects including land acquisition, roads, public open space, environmental conservation areas, etc.
   c) Sydney Water's assumptions used under the proposed DSP cost assume a developer-led delivery of the stormwater infrastructure. This assumption is not appropriate and currently there is no appetite for developers to deliver this infrastructure due to the current land sterilisation and costs.
   d) The delivery of the regional stormwater scheme assumes developer's own land to create basins. This is not appropriate as majority of the land is not within ownership of the MLOG. Our businesses will not support an acquisition of land that has environmental constraints, which majority of the basins are located.
   e) If a reasonable regional stormwater system is progressed, it needs to have an acquisition strategy to getting basins online as soon as possible to align with development outcomes for the Precinct. There

needs to be a strategy presented by the regional stormwater authority on how they will acquire land, especially in the Kemps Creek catchment and the northern catchment adjacent to the existing school and aged care facility. Sydney Water cannot assume developers will acquire constrained land to build basins.

f) Sydney Water has assumed delivery of stormwater infrastructure is to be undertaken by Part 4 of the *Environmental Planning and Assessment Act 1979* (**EP&A Act**). This would require a developer to lodge a development application for the delivery of works. This is not a supportive avenue for approvals. The regional stormwater scheme must enable Part 5 planning pathway, which allows an infrastructure agency to grant approvals for infrastructure services.

g) Sydney Water is proposing a current works-in-kind arrangement for developers to deliver regional stormwater infrastructure. This policy does not work and historically has not enabled full recovery of costs for the works undertaken.

h) The delivery of basins by developers needs to be an open book process with the ability to tender and recover full costs. Further, developers need to be able to offset costs off DSP charge to incentivise delivery of stormwater infrastructure.

i) Trunk drainage channels form part of the regional stormwater system. If they offer benefit to the system, they should be acquired by the regional stormwater authority. The current policy requires an easement to be created to allow Sydney Water to maintain the channel, but the land remains in private ownership.

7. Conclusion

The LOG appreciates the opportunity to comment on IPART's review of the cost of stormwater drainage in the Mamre Road Precinct. The outcomes of IPART's review are critical to the Precinct's viability and ability to respond to the industrial supply shortfall in NSW.

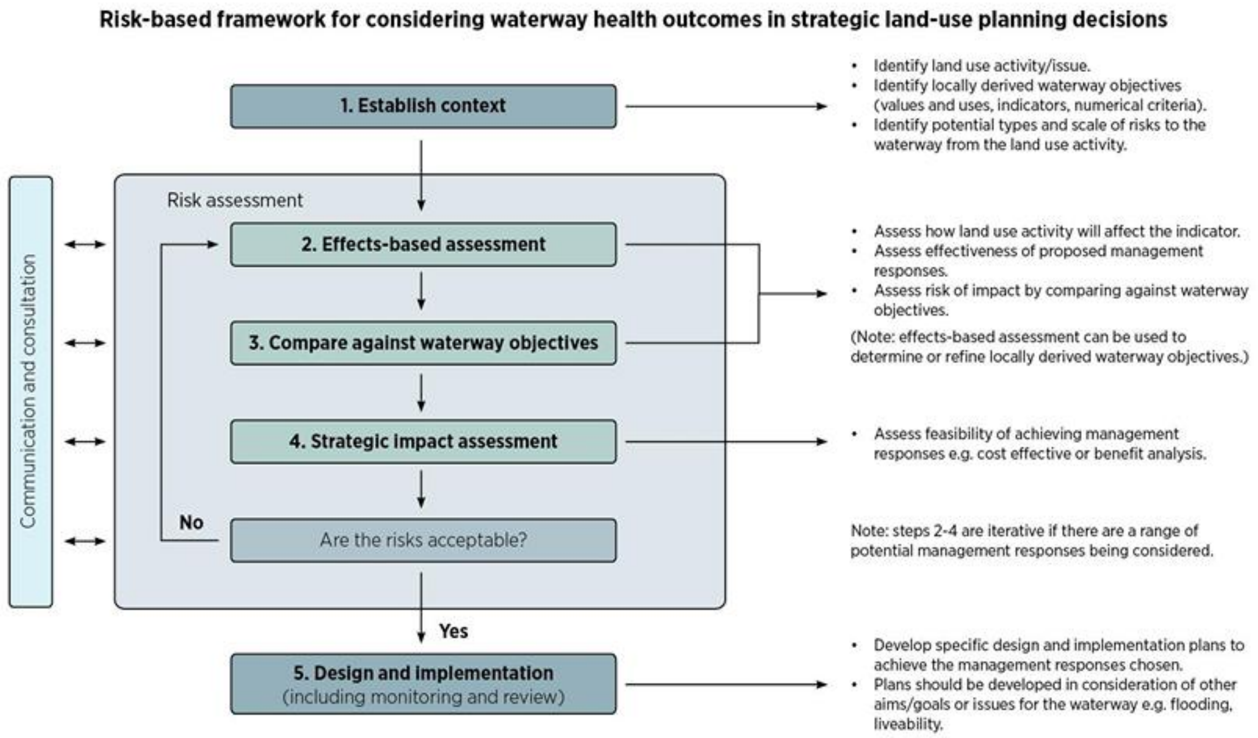
The stormwater DSP is one of the last remaining items required to be resolved to provide confidence in the market to roll out delivery of industrial facilities within the Precinct. The MLOG have an extensive history advocating for a balanced outcome on stormwater that allows government to meet environmental objectives but also provides a pathway for delivery and investment of industrial, warehousing and logistics customers.

The acceptance by government on the land sterilisation has been disappointing, as the Precinct was initially rezoned to combat the shortfall of zoned, serviced industrial land in NSW. This position is not supported by the MLOG and has been continuously advocated to the NSW Government.

Further, a cost-benefit analysis utilising government policy needs to be undertaken. It is not acceptable for government to assume all infrastructure costs to be paid by developers. This stormwater system proposed by Sydney Water has a regional benefit.

Noting the above key extracts on history of stormwater management within the Mamre Road Precinct, the significant departure in forecast costs to both industry and potentially to the NSW Government or taxpayers between the $287,000 per hectare assessed within the NSW Department of Planning report *Review of water sensitive urban design strategies for Wianamatta-South Creek* and the current Sydney Water costs or cap to developers of $800,000 per hectare, the LOG request that Step 4 of the NSW Government Risk-Based Framework is revised and made publicly available. As part of this revision should the Step 4 risks not be acceptable (feasibility could include aspects of costs of delivery, benefits achieved, site constraints/characteristics, operational requirements, and/or social considerations) then it is requested that the NSW Government follow it's Risk-Based framework and reviews Steps 2 to 4 of the framework to determine waterway health targets and regional scheme that is feasible without providing further delay to development within the Mamre Road Precinct or resulting in developable land sterilisation. The framework flowchart from the NSW Government Risk-Based Framework is provided below for ease of reference.

Framework flowchart



Industry simply cannot afford to continue investing into the Mamre Road Precinct or Aerotropolis unless a reasonable and cost-effective solution is provided, which has serious consequences for the NSW economy and residents of Sydney.

The MLOG remains committed to working with NSW Government, including Sydney Water, on a reasonable resolution of the stormwater scheme. We would appreciate a meeting with IPART on the matters raised in this submission to assist in clarifying any items raised in the submission.

Should you have any questions, please do not hesitate to contact the MLOG.

Appendix A
Ministers Letter

mirvac FRASERS PROPERTY FIFECAPITAL Stockland ALTIS PROPERTY PARTNERS

14 August 2019

The Hon. Rob Stokes, MP
Minister for Planning and Public Spaces
52 Martin Place
SYDNEY NSW 2000

Dear Minister

Re: Release of employment land in the Mamre Road Precinct, Western Sydney Employment Area

We write to request the release and rezoning of the Mamre Road Precinct within the Western Sydney Employment Area ('WSEA') for employment purposes, in order to address the growing employment land supply shortage, protect Western Sydney's competitiveness and unlock much needed jobs and investment in Western Sydney.

Together, Mirvac, Frasers Property, Fife Capital, Stockland and Altis have formed a Mamre Road Precinct landowners group to collaboratively progress this request with Government given the scale and urgency of the land supply challenge is one that we all face.

We seek to advance the Mamre Road Precinct rezoning in a proponent led, funded and co-ordinated manner working collaboratively with the Department of Planning, Industry and Environment (DPIE) and other authorities.

1. Mamre Road Precinct

The Mamre Road Precinct represents approximately 778 ha of Gross Developable area, of which approximately 45% is controlled by the major institutional developers and managers of industrial assets within the landowner group.

The Mamre Road Precinct is governed by the existing *State Environmental Planning Policy (Western Sydney Employment Area) 2009* ("SEPP WSEA"), however currently, the Precinct is within the remaining unzoned component of the SEPP WSEA known as the Broader WSEA, as shown in white in Figure 1 below. Importantly, the Precinct is located immediately adjacent to land that has recently been rezoned and largely developed (Mamre West Precinct), to employment uses to the north as shown in purple in Figure 1.

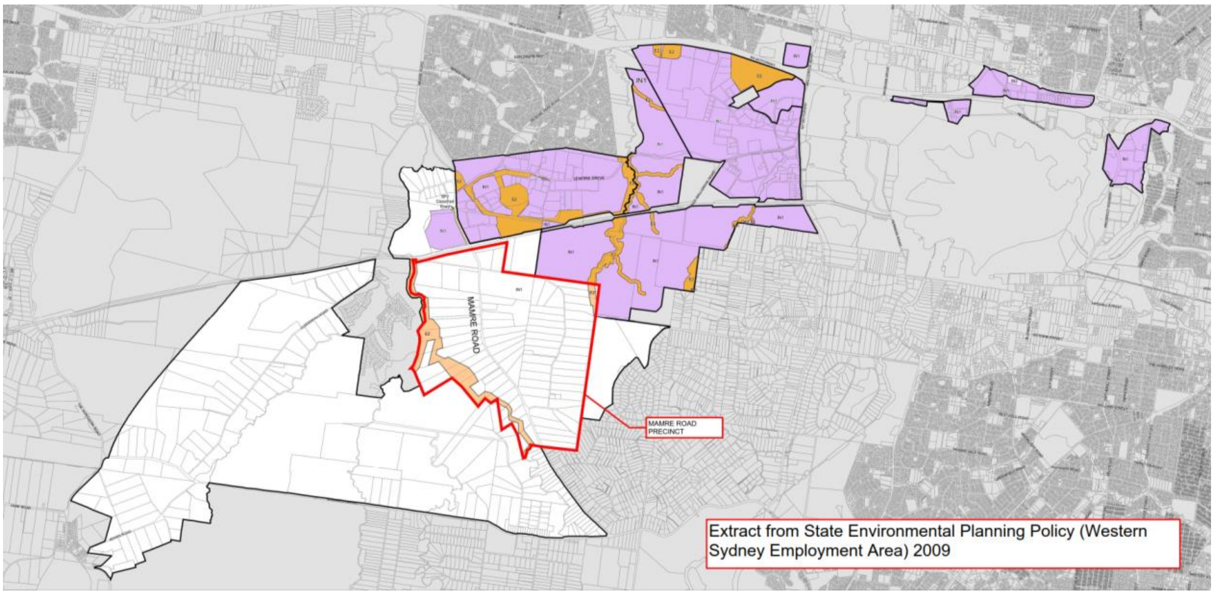


Figure 1. Extract from SEPP WSEA Land Zoning Map

The Mamre Road Precinct is also identified in the 'Western Sydney Aerotropolis Land Use and Infrastructure Implementation Plan (LUIIP) Stage 1: Initial Precincts' ("Stage 1 LUIIP") as shown in Figure 2 below. Within the Stage 1 LUIIP, the precinct is nominated for 'Flexible Employment' land uses (blue in Figure 2).

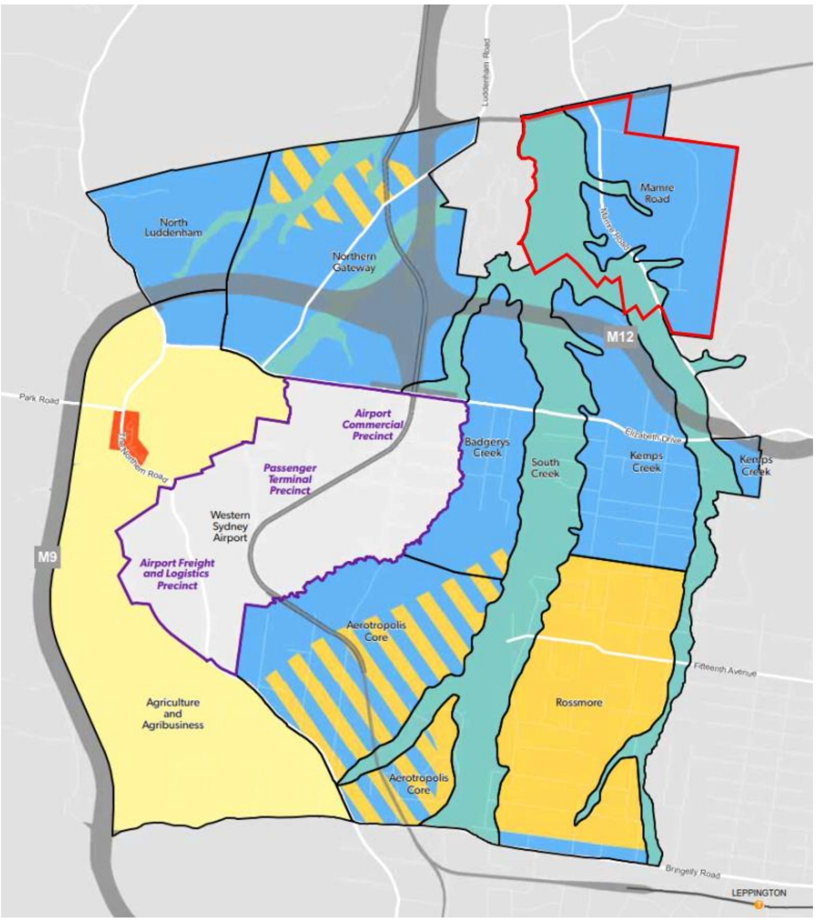


Figure 2. Extract from Aerotropolis Stage 1 LUIIP

2. The Challenge

2. 1 Western Sydney is facing an employment land shortage

As you may be aware, the Western City is currently facing a critical undersupply of serviced, zoned employment land. This is evidenced by the following:

- Gross take up of industrial floor space has increased to an average of 998,750 sqm per annum over the last three years, above the 10-year average of 751,550 sqm per annum, demonstrating sustained demand above historic rates.
- Strong demand for new industrial developments is expected to continue, as occupiers are forced to modernise their operations to improve efficiency and implement higher order technologies (e.g. automation).
- The rapid growth of ecommerce (approx. 20% per annum) will also drive sustained demand for industrial floor space with ecommerce currently only approximately 6-9% of all retail sales in Australia, compared to 15% in the US and 22% in the UK. CBRE estimate that online retail sales typically require three times the amount of industrial floor space than that required for traditional bricks and mortar retail sales.

- The existing WSEA (purple in Figure 1) is now almost fully developed with the limited remaining undeveloped land in the WSEA primarily controlled by a very small number of private landowners who have not demonstrated significant advancement of development to date. The remaining undeveloped land is therefore unlikely to meet the projected demand.

- Consequently, there is a critical shortage of serviced, zoned employment land with numerous recent studies (see studies by PCA, UDIA, Colliers and JLL) estimating there is only approximately 2 - 4 years remaining of zoned employment land based on average historical take-up rates.

- The combined effect of increasing demand and lack of serviced and zoned employment land supply is already being felt in the market, with extremely low vacancy rates (~1%) and increased land and rental values, which has worsened affordability for occupiers. Specifically:

  - Sydney average serviced industrial land values in June 2019 are:
    - $315/sqm higher than Melbourne, or **91% higher** than the 10-year historical average spread.
    - $217/sqm higher than Brisbane, or **503% higher** than the 10-year historical average spread.
  - Sydney average prime existing warehouse rents in June 2019 are:
    - $58.57/sqm higher than Melbourne, or **33% higher** than the 10-year historical average spread.
    - $38.54/sqm higher than Brisbane, or **141% higher** than the 10-year historical average spread.

- As a result, we are concerned that this is worsening Sydney's competitiveness and ability to attract investment. <u>In recent history, we have witnessed a number of major businesses such as Ceva Logistics, National Tiles, Woolworths, Coles and Asahi choosing to either move or prioritise interstate investment which represents a key risk for loss of future employment and investment outcomes for NSW</u>.

2.2 Need for jobs in Western Sydney

1 in 10 Australians live in Western Sydney, however approximately 43% travel outside of the region every day for work (compared to 22% in the Eastern City). Additionally, the unemployment rate for Western Sydney is currently 6.8% (compared to 5.4% in the Eastern City). (Source: ABS, Deloitte and Corview).

Facilitating the development of employment lands, as well as the ongoing jobs that will result, will address both these issues. Presently, approximately 32% of the resident workforce is employed in an 'industry or manufacturing' occupation. New employment construction would be a natural boost to both these sectors and help to offset slowing residential construction volumes.

3. The Proposed Solution

The Mamre Road Precinct is a logical extension to the existing employment zoned land within SEPP WSEA. The Precinct has long been identified as future employment lands, as reflected in the approved Amendment to SEPP WSEA dated December 2014, which extended the WSEA boundary to include the subject lands. The proposed employment land use for the Precinct is consistent with the approved 2014 Amendment to the SEPP WSEA, 2018 Stage 1 LUIIP and is appropriate zoning given the Precinct is largely contained within the proposed Western Sydney Airport ANEF 20 noise contours.

Based on employment density projections completed by the Department of Planning as part of the Broader WSEA Structure Planning process, the Mamre Road Precinct (at approximately 778 ha Gross Developable Area) is capable of providing approximately 15,500 – 20,000 full time operational jobs and 11,000 construction jobs.

As previously mentioned, approximately 45% of the total Mamre Road Precinct gross developable area is controlled by the major institutional developers authorising this letter who have a proven track record of delivering employment outcomes and are prepared to advance the precinct rezoning in a proponent led and funded co-ordinated manner.

Consultation with utility authorities (Endeavour Energy and Sydney Water) has confirmed the Mamre Road Precinct is capable of being serviced, based on general industrial demand loading. However, utility authorities have advised that further capital expenditure, planning and delivery of infrastructure is entirely dependent on clarity from Government about land release direction and timing. As the delivery of infrastructure will involve significant lead times, the timing of Government direction about the next release of employment lands within WSEA is critical.

The time required for the planning and delivery process means it will take time to have any measurable impact on land supply, making the case for action even more pressing.

4. The Proposed Planning Pathway

Given the urgency of the land supply issue, we respectfully submit that the following represents the most expeditious planning pathway:

1. Removal of the Mamre Road Precinct from the Aerotropolis LUIIP; and
2. Concurrent proponent led and funded amendments to the existing SEPP WSEA, to rezone the Mamre Road Precinct.

This would prevent further delays incurred in the preparation of new planning instruments, as the land release could simply be completed through an amendment to the existing SEPP WSEA which already applies to the Mamre Road Precinct.

We believe this pathway would help address the increasing unmet demand for zoned industrial land in Western Sydney, support the new Aerotropolis, and expedite planning outcomes and provision of jobs in this crucial region in the most efficient way possible.

5. Conclusion and Next Steps

Immediate release and rezoning of the Mamre Road Precinct under SEPP WSEA will address current critical employment land supply constraints prevalent in Western Sydney and enhance employment opportunities for residents of Western Sydney.

We would welcome a meeting to discuss these important issues for employment generation and economic development within Western Sydney.

If you have any questions, please don’t hesitate to contact Richard Seddon on 0424 186 095 or Richard.Seddon@Mirvac.com

Kind Regards,

The Mamre Road Precinct Land Owners Group

Richard Seddon

General Manager – Industrial

mirvac

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General Manager, Northern Region

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Managing Director

FIFECAPITAL

Louise Mason

Group Executive & CEO Commercial Property

Stockland

Shaun Hannah

Director

ALTIS PROPERTY PARTNERS

Appendix B

NSW Government Announcement on Mamre Road Precinct

November 2019

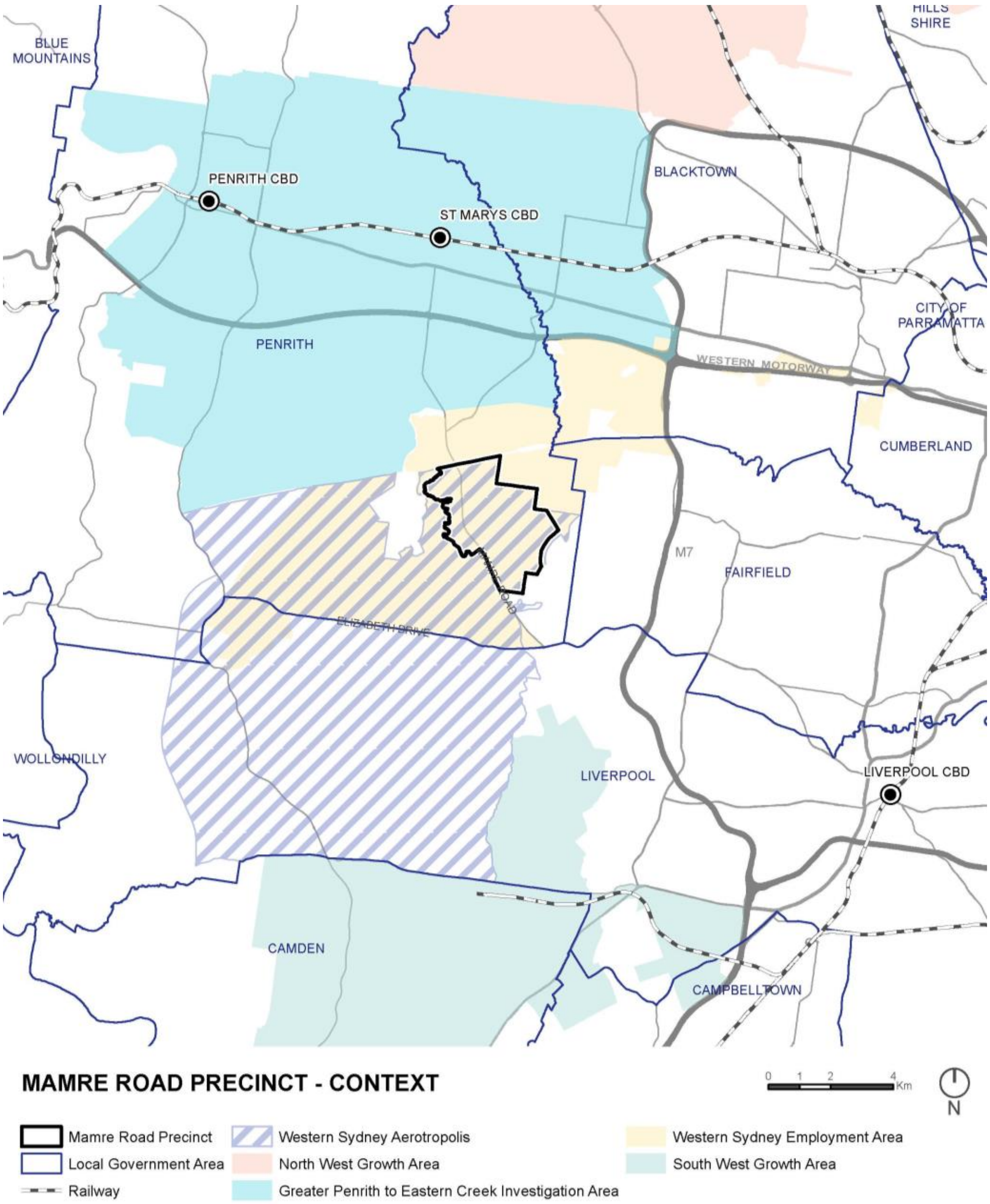
Proposed rezoning of the Mamre Road Precinct

This document answers frequently asked questions regarding the proposed rezoning of the Mamre Road Precinct as an extension of the Western Sydney Employment Area.

Where is the Mamre Road Precinct?

The Mamre Road Precinct is in the Penrith local government area, south of the Warragamba water supply pipelines. It includes parts of the suburb of Kemps Creek as well as the north-western portion of Mount Vernon.

The precinct is located within the Western Sydney Employment Area and within the proposed Western Sydney Aerotropolis growth area. A map of the precinct's location is below:



What does the proposed rezoning do?

The draft rezoning package will guide the industrial development of the precinct. It establishes controls to guide the high-quality design and location of suitable industrial development while providing open space and transport infrastructure.

The package has been developed by the Department of Planning, Industry and Environment in consultation with Penrith City Council, Fairfield Council, Transport for NSW (including Roads and Maritime Services), Sydney Water and other government agencies to make sure the precinct has the services and infrastructure to support its proposed development.

What is proposed for the Mamre Road precinct?

The draft Mamre Road structure plan maps out new land uses and key infrastructure in the precinct. It also identifies areas for environmental conservation and recreation.

The precinct provides the opportunity to deliver key principles for the Western Parkland City including:

- delivery of the blue, green and ochre grid;
- protecting and enhancing bushland and biodiversity;
- protecting and delivering transport corridors;
- protecting the 24-hour operation of the Western Sydney Airport; and
- assisting in the creation of around 17,000 jobs as a contribution towards 200,000 new jobs across Western Sydney.

Why is more industrial land needed?

The rezoning of the precinct will assist in delivering the growing demand for industrial land in Western Sydney because industrial land ready to develop in this area could be exhausted within 4 to 5 years.

The proposed rezoning and expansion of the precinct should help address the projected demand and provide around 780 hectares of new industrial land for Western Sydney. It will also contribute to opportunities for 'jobs closer to home' and support the NSW economy.

How will Mamre Road be serviced by infrastructure?

The rezoning and ongoing development within the precinct will be supported by transport infrastructure, including:

- the proposed Western Sydney Freight Line
- a potential Intermodal Terminal (subject to a potential NSW Government business case)
- the proposed upgrade of Mamre Road
- the proposed Southern Link Road

NSW Government agencies are working together to deliver infrastructure to support the safe and efficient movement of materials including freight within the precinct and regionally as well as minimise the impact of traffic on adjoining residential suburbs.

What is the Western Sydney Intermodal terminal?

An intermodal terminal (IMT) is a facility along the supply chain that provides for the transfer of freight from one transport mode to another. A potential IMT in Western Sydney is being investigated to facilitate the transporting of freight. The IMT would enable the movement of containers with freight destined for western Sydney to be moved from the port by rail, rather than using the motorway network. This offers a sustainable and practical transport solution to meet the challenge of Sydney's growing freight volume.

The NSW Freight and Ports Plan 2018-2023 (the Plan) highlights the need to identify, protect and provide access to future intermodal terminals in Western Sydney. The Plan also includes targets for moving an increasing percentage of goods by rail to international gateways. Metropolitan intermodal terminals are critical for managing the rapidly growing import container trade and enabling more freight to be moved by rail.

The NSW Government has a target of increasing the proportion of freight delivered by rail with a rail mode share target of 28 percent by 2021. NSW Ports 30-year masterplan has a target of 40 percent by 2045. To achieve these targets, the creation of more intermodal terminal capacity in Sydney and regional NSW is required.

The Mamre Road Precinct has been identified as a potential site for an IMT and the preferred site has been identified within the draft structure plan which would be serviced by the Western Sydney Freight Line. The precinct would provide an effective and efficient connection to the proposed Western Sydney Freight Line, and major roads such as the M4 and M7 Motorways. The precinct can provide the necessary space (approximately 100ha), is largely flood free and protected from incompatible land uses. An intermodal terminal in this location will be subject to a potential NSW Government business case.

My land is affected by a zoning overlay, what does this mean?

Zoning overlays have been identified for key potential transport infrastructure within the precinct. This includes potential Southern Link Road, the proposed Western Sydney Freight Line and the potential Western Sydney IMT.

The zoning overlay triggers a requirement for development applications on land affected by or adjoining the zoning overlay to be sent to Transport for NSW for concurrence. Transport may choose to concur with the proposal, suggest that it be refused or suggest that conditions be imposed on any consent. Proposals cannot proceed without Transport's concurrence.

TfNSW will continue to undertake more detailed investigations to determine refined locations and suitable planning controls for infrastructure purposes. Land identified in future as required for State transport infrastructure purposes could be acquired by the State government in the future.

The introduction of an infrastructure zoning would occur only after further consultation with affected landowners.

What will be done to protect the environment?

Proposed zoning and controls will protect areas of native vegetation and creeks. The proposed rezoning contributes to creating a green network with cycle and pedestrian links and over 50 hectares of open space connecting the precinct to the South Creek corridor.

The proposed zoning also seeks to protect areas of native vegetation which may be included within the potential Cumberland Plain Conservation Plan (CPCP) in future. More information about the CPCP is available on our website.

Some land has been identified for Environmental Conservation as it has high environmental values and/or is part of a creek network. Identifying these areas is important to ensure these sites are protected into the future.

How has flooding in the area been considered?

The precinct is affected by flooding from South Creek, Kemps Creek and Ropes Creek.

Areas located below the 1 in 100 chance per year flood level are proposed for compatible land uses and activities, which means no urban land uses will be permitted on land classified as flood prone below this flood level.

Additional planning controls are also proposed to ensure that development on flood prone land, including land below the probable maximum flood (PMF) level does not result in any adverse impacts for the floodplain. Consent authorities will have to take the cumulative impact of development on the flood plain into account and protect the existing flood functions to avoid worsening flood events/ levels on other land in the catchment.

Studies in progress will provide more information about the controls that will apply in the area between 1 chance in 100 per year and the PMF levels. This may mean the extent of land identified as zoned industrial is reduced before the plan is finalised. Alternatively, it may involve additional DCP controls to guide what land uses and building forms are possible in this area. Filling in this area to the PMF may need to be limited and large structures that could impede the flood conveyance may be unsuitable. At grade uses such as car parking and storage of (non-hazardous) plant and equipment may be suitable.

How will local infrastructure be provided?

Penrith City Council does not yet have a local contributions plan that applies to industrial development within the precinct. Council is developing a plan for the Aerotropolis that could extend to this precinct to enable local contributions to be levied to fund local infrastructure in the area. If any development applications are determined before a plan is in place, developers will need to negotiate a voluntary planning agreement with Council.

How will regional infrastructure be provided?

The Department is working with the Greater Sydney Commission on a Growth Infrastructure Compact (GIC) for the Aerotropolis, which includes the Mamre Road Precinct. The GIC will identify regional infrastructure requirements and funding mechanisms, which will include a potential Special Infrastructure Contribution (SIC). The current draft SIC for the WSEA does not cover the costs of infrastructure required for this precinct and the rate will need to be increased should the cost of required infrastructure be fully recovered from development.

Developers within the precinct will need to make satisfactory arrangements to contribute towards State and/or regional infrastructure prior to the Aerotropolis SIC being in place. Developers can make contributions towards State/regional infrastructure under Voluntary Planning Agreements (VPAs) and may need to include provisions to require contributions up to the value of future SIC rate.

The transport infrastructure requirements for the precinct are being investigated as part of a wider network strategy which will inform the proposed developer contributions for precinct.

How does the proposal relate to the Western Sydney Aerotropolis?

The Mamre Road Precinct is located within the Western Sydney Aerotropolis, approximately 6km northeast of the Aerotropolis Core.

The Western Sydney Aerotropolis Stage 1 Land Use and Infrastructure Implementation Plan (Aerotropolis LUIIP) was exhibited in August 2018 and incorporates this area known as the broader Western Sydney Employment Area.

The Aerotropolis LUIIP builds on the objectives of the WSEA to promote employment in Western Sydney. However, as result of submissions received on the Aerotropolis LUIIP, the Government has decided to retain the precinct in WSEA and rezone the employment lands separately to the Aerotropolis.

I live in a residential area near the Mamre Road Precinct, how has this been considered?

The proposed planning controls include a requirement for a transition area between industrial development and residential areas. These controls will ensure the design and management of industrial uses to ensure that they do not affect adjoining residential areas in Capitol Hill, Fairfield and Mount Vernon. Examples of measures include:

- Appropriate building designs to consider compatibility with the character of existing residential areas
- Plant and equipment required to be appropriately stored and screened from view;
- Building elevations adjoining homes are to be attractive;
- Insulation of noise generating equipment;
- Controls on hours of operation;
- Suitable parking controls
- Landscaping of setbacks
- Road locations to separate residential and industrial traffic.

Why is this precinct released ahead of others in the Aerotropolis?

This precinct package addresses an urgent need to provide additional industrial land. It relates more directly to the WSEA and the planning controls in the WSEA SEPP. There is a commitment to release planning information for other precincts within the aerotropolis by the end of 2019.

How can I have my say?

The draft rezoning package will be on exhibition for 28 days from **20 November 2019 to 18 December 2019** for community review and feedback.

Help shape the future character of Mamre Road Precinct by:

- Viewing the draft structure plan and associated rezoning documents until **18 December 2019**
- Online: www.planning.nsw.gov.au/wsea

- Making a submission during the exhibition period.

A formal submission allows you to provide feedback and ideas which address specific points in the draft structure plan. Your submission will be published but you may request that your name and address are not displayed on the Department's website or alongside your submission.

Who is invited to give feedback?

Feedback is welcomed from anyone, from Mamre Road landowners and residents, to anyone in the broader community.

How can I find out more information?

Call on 1300 305 695.

If English isn't your first language, please call 131 450. Ask for an interpreter in your language and then request to be connected to our Information Centre on 1300 305 695.

Visit our webpage at www.planning.nsw.gov.au/wsea

What are the next steps?

Following the exhibition period, submissions will be reviewed and any required amendments incorporated into the final rezoning package.

The Department will then make a recommendation to the Minister for Planning and Public Spaces for his determination.

Appendix C
Atlas Economics
Mamre Road Precinct
Feasibility Analysis and Value to Greater Sydney

7 July 2023

To Whom It May Concern

Re: Mamre Road Precinct Feasibility Analysis and Value to Greater Sydney

Altas Economics (Atlas) is engaged by the Mamre Road Precinct Landowners Group (LOG) to examine the impacts of proposed stormwater infrastructure charges on development feasibility, rents and competitiveness of Mamre Road Precinct.

Sydney Competitiveness

Sydney has the lowest industrial vacancy rate in the world (less than 0.2%), which has led to significant increases in industrial rents and land rates when compared to other states. The current market conditions have created a disparity on market affordability, when compared to Melbourne and Brisbane. The gap between Sydney rents is up to $100/sqm or 80% compared to Melbourne ($120/sqm) and $85/sqm or 65% compared to Brisbane ($135/sqm).

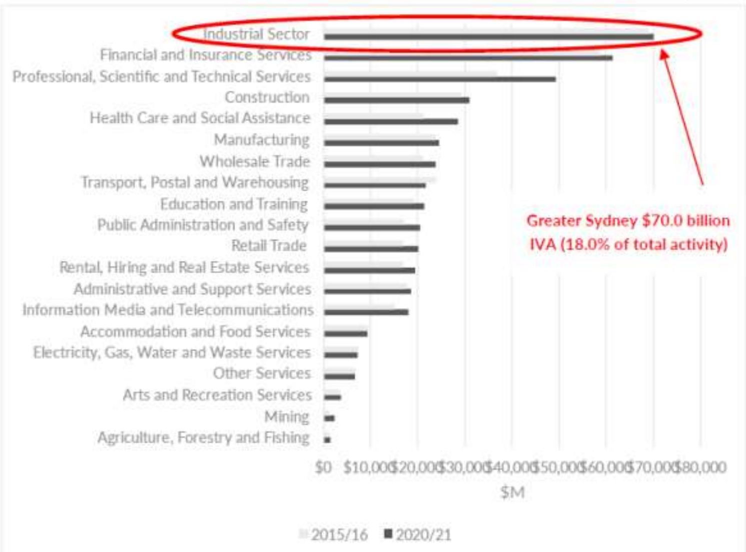
Sydney has the largest population base (5.3 million residents) compared to Melbourne (5.0 million) and South East Queensland (3.6 million). Sydney's container throughput (a significant driver for the logistics sector) is similar to Melbourne and much greater than Brisbane. Despite these factors, Between 2012-2021 Sydney's average annual take-up of industrial land has been less than 50% of Melbourne's 290ha per annum and only 70% of South Ease Queensland's 190ha per annum. This highlights the shortage of zoned and serviced industrial land throughout Sydney and the need to ensure project feasibility. The lack of serviced land supply in Sydney has constrained its ability to respond to demand and has resulted in escalating rents and almost zero vacancy.

The Mamre Road Precinct has the ability to alleviate the current market trends in relation to critical industrial land supply shortages within Sydney so long as project feasibility can be maintained, and land is not unnecessarily sterilised through interim management measures associated with meeting NSW Government waterway health measures.

Impact to the NSW Economy

The industrial sector plays an important role in the NSW economy. It contributes $70 billion to the Greater Sydney economy and $90 billion in NSW. In Greater Sydney, it comprises of 18% of all activity in the region (refer to Figure 1 below).

Figure 1: Greater Sydney Value Add (2015/16 and 2020/21)



Source: NIEIR (2022)

This report outlines the significant potential contribution of the Mamre Road Precinct to the Greater Sydney Economy. The LOG land alone is estimated to result in a total increase in economic activity through direct and indirect (flow-on) annually:

- ~$12.1 billion additional output (incl. ~$5.5 billion in direct activity).
- ~$6.0 billion additional in contribution to GVA (incl. ~$2.5 billion in direct activity).
- ~$3.1 billion additional in incomes and salaries paid to households (incl. ~$1.4 billion directly) and up to $169.1 million payroll tax contribution.
- ~28,448 additional FTE jobs (incl. ~12,144 additional FTE jobs directly related to activity within the Precinct).

Mamre Road Precinct Feasibility Analysis - Summary of Results

Atlas was previously involved in preparing a feasibility study for the NSW Government to support the finalisation of state contributions (SIC) for the Mamre Road Precinct. This analysis concluded that infrastructure contributions could not exceed $900,000/ha NDA without undermining project feasibility.

As included within the attached analysis, as of March 2023, the SIC & local S7.11 contributions totalled ~$880,000/ha NDA with subsequent indexation to 1 July 2023 not yet accounted for within the attached modelling. The current Sydney Water DSP charges of $1.154 million/ha NDA would take the total contribution requirements (as of March 2023) to ~$2,034,000/ ha NDA and therefore along with other market conditions results in the entire Mamre Road Precinct not feasible to develop.

The modelling outlined within the report finds there is provisional capacity to pay up to $287,000/ha NDA (NDA being allotment areas excluding roads / basins, etc.) for DSP charges if rents were increased to $195/sqm (from current $185/sqm), however this is subject to:

- No interim abortive costs or land sterilisation associated with meeting waterway health controls in advance of a regional scheme; and
- Tenants agreeing to a higher net rent of $195/sqm (from current $180-$185/sqm); and
- Market yields (and capitalisation rate) softening by no more than 25bps; and
- Developments achieving a 57.5% GFA site coverage; and
- No further increases to construction costs beyond $1,200/sqm (currently modelled at $1,150/sqm); and
- Funding and delivery of required infrastructure (i.e. Mamre Road upgrade and Southern Link Road) to service the precinct in a timely manner to facilitate development.

Noting the above, this report currently remains as draft and is unable to be finalised until industry advises on potential to obtain higher rents within the Mamre Road Precinct of $195/sqm and the NSW Government support of an interim waterway solution is confirmed to negate the need for abortive works or land sterilisation.

It is Atlas' understanding that approximately 70% of site area would be sterilised by interim waterway health measures in advance of a regional waterway health scheme by Sydney Water. The cost of works and holding costs associated with this sterilisation of land (loss of developable area) has not been considered as part of the feasibility analysis.

Were an interim waterway solution to be required in the Mamre Road Precinct, the cumulative impact of the loss of developable area ***and*** additional cost associated with the interim solution would result in development that is not feasible.

Please contact the undersigned should you require clarification.

Yours sincerely

Esther Cheong
Director
T: 02 72537601
E: esther.cheong@atlaseconomics.com.au

Mamre Road Precinct

Feasibility Analysis and Value to Greater Sydney

Mamre Road Landowners' Group

June 2023

Atlas Economics
ANALYSIS. INSIGHTS. OUTCOMES.

Document Control

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Document Name: Mamre Rd Feasibility Analysis and Value to Sydney Economy final

Last Saved: 2/07/2023 5:21 PM

Version	Date	Prepared by	Reviewed by
Draft	15 June 2023	Matthew Kelly, Michael Campbell	Esther Cheong
Final	30 June 2023	Matthew Kelly, Michael Campbell	Esther Cheong

Executive Summary

BACKGROUND

The Mamre Road Precinct (**the Precinct**) was rezoned under the *State Environmental Planning Policy (Western Sydney Employment Area 2009* in June 2020. The Precinct comprises about 800ha of industrial land. Since the rezoning, there has been significant market interest amid low levels of supply in Sydney. Over 20 businesses have committed (signed heads of agreements) with many more seeking to secure a premises in the Precinct if there was certainty and rents were affordable.

Precinct Planning and Rezoning

The Precinct rezoning facilitated capacity for up to 17,000 jobs (depending on the nature of development proposals) with a focus on freight and logistics uses as reported by NSW Government.

The rezoning of the Precinct was identified (in 2019) as needed to assist delivering the growing demand for industrial land in Western Sydney because "***industrial land ready to develop in this area could be exhausted within 4 to 5 years***" (DPE, 2019). The rezoning of the Precinct sought to:

- Address the projected demand in Greater Sydney.
- Provide around 800ha of new industrial land for Western Sydney.
- Contribute to opportunities for 'jobs closer to home' and support the NSW economy.

A Special Infrastructure Contribution (SIC) was identified to be required to fund regional infrastructure for the Precinct. Until such time the Aerotropolis SIC was in place, developers were required to make contributions towards state/ regional infrastructure under Voluntary Planning Agreements.

In 2022 NSW Government and Penrith City Council finalised infrastructure contributions (SIC and s7.11) which totals approximately $800,000/ha NDA (not indexed). This was supported by a feasibility study prepared for NSW Government which concluded infrastructure contributions could not exceed $900,000/ha NDA.

Proposed Water Infrastructure Charges

Sydney Water has recently announced a charge of $1.3 million per hectare (stormwater and recycled water) and $50,000 per hectare (DSP - drinking and waste water) in the Precinct. This is an added unforeseen cost with significant implications for development feasibility. Atlas understands a rate of $1.15 million per hectare could apply if recycled water was excluded.

Atlas Economics (Atlas) is engaged by the Mamre Road Landowners' Group to examine the impacts of the proposed water infrastructure charges on development feasibility, rents and competitiveness.

The overarching objective of the Study is to understand the implications of the proposed water infrastructure charges and the urgency of enabling large scale servicing of industrial zoned land and development that is feasible.

The Study develops scenarios for the purposes of estimating the economic impacts of the Precinct. These are developed with reference to committed occupier data. An industry mix is also developed from this occupier data, enabling Atlas to estimate the future direct and indirect impacts from investment foregone were the Precinct not developed as envisaged.

DEMAND AND SUPPLY OF INDUSTRIAL LANDS

All economic indicators point to a severely undersupplied industrial market in Sydney - one with insufficient supply of land to respond to market demand.

- Sydney's rents average $220/sqm compared to Melbourne ($120/sqm) and Brisbane ($135/sqm). Rents in Western Sydney and the Precinct average $185/sqm (which are lower than rents in prime markets in South Sydney and Botany).
- Sydney has the lowest vacancy rate in any global city (0.2%).
- Sydney's employment growth in the Industrial sector averaged 0.5% over the 2016-2021 period, lagging Melbourne (1.2%) and Brisbane (1.1%).

Take-up of Industrial Land and Remaining Supply

Annual take-up of industrial land in Greater Sydney has averaged 135ha in the 2017-2021 period. In contrast, metropolitan Melbourne's take-up of industrial land has averaged 288ha and Southeast QLD (SEQ)'s 190ha over the same period.

Table ES-1: Annual Take-up of Industrial Land - Sydney, Melbourne, Brisbane and SEQ (2017-2021)

Region	Value of Industrial Sector (IVA)	Population (2021)	Annual Land Take-up (ha)					
			2017	2018	2019	2020	2021	Avg. (2017-2021)
Greater Sydney	$70.0 billion	5.3 million	139.6	145.8	140.2	86.0	163.1	135.0
Metropolitan Melbourne	$62.7 billion	5.0 million	317.8	219.7	324.3	305.8	273.0	288.0
Brisbane Region	$30.3 billion	2.6 million		47.1	70.2	67.7	42.5	56.9
Southeast QLD (SEQ)		3.6 million		185.9	261.3	168.3	146.2	190.4

Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

Figure ES-1: Sydney Annual Take-up of Industrial Land (2017-2021)

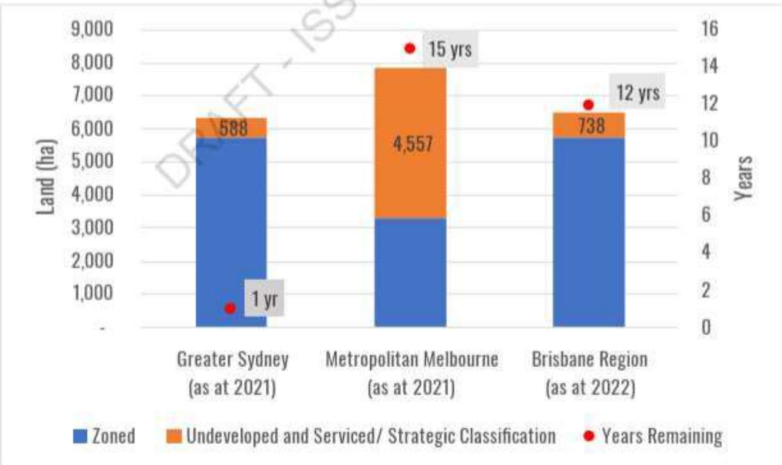
Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

Sydney has the largest population base (5.3 million residents) compared to Melbourne (5.0 million) and SEQ (3.6 million). Sydney's container throughput (a significant driver for the logistics sector) is similar to Melbourne and much greater than Brisbane. Despite these factors, Sydney's average annual take-up of land has been less than 50% of Melbourne's 290ha per annum and only 70% of SEQ's 190ha per annum.

The analysis highlights the shortage of serviced land in Sydney. The lack of serviced land supply in Sydney has constrained its ability to respond to demand and resulted in escalating rents and almost zero vacancy.

Figure ES-2 shows a comparison of Sydney's remaining industrial land supply, Metropolitan Melbourne, and Brisbane region.

Figure ES-2: Industrial Land Supply - Sydney, Melbourne and Brisbane



Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

With land supply being close to exhaustion, the Precinct therefore is important to easing Sydney's chronic capacity issue.

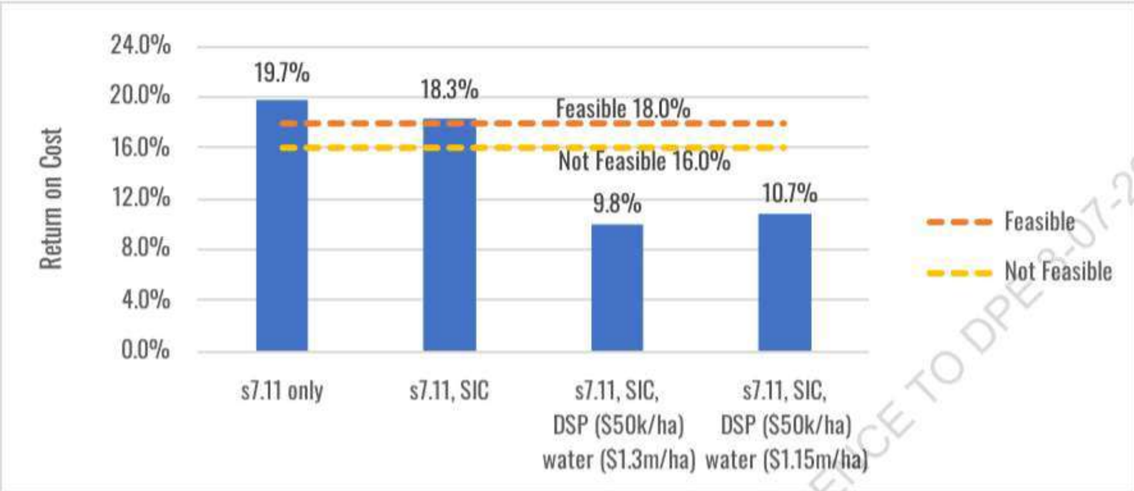
FEASIBILITY ANALYSIS OF MAMRE ROAD PRECINCT

Impact of Proposed Water Infrastructure Charges

Feasibility testing shows that after including the proposed DSP and stormwater charges, development is no longer feasible. At current conditions, development has no capacity to pay for water charges at the proposed rates.

- At the proposed water charges ($1.35m/ha NDA), the return on cost is at 9.8%.
- At a reduced stormwater charge of $1.15m/ha NDA, the return on cost is 10.7%.

Figure ES-3: Comparison of Feasibility Modelling Results



Source: Atlas

The assumed return on cost hurdle of 18% is in line with market expectations, consistent with Atlas' previous work for DPE. The testing ***does not*** include the cost of interim stormwater infrastructure that will reduce developable land/ be redundant.

Scope for Water Infrastructure Charges

Atlas understands that NSW Government published a report in 2022 named *Review of Water-sensitive Urban Design Strategies for Wianamatta – South Creek*, which provided estimates of regional stormwater costs and indicative levies. The report concluded a $191,000/ha (infrastructure works) and $96,000/ha (land acquisition costs) to facilitate delivery of a regional stormwater system. This totals $287,000/ha for stormwater levies.

Given that development feasibility is marginal even before any water infrastructure charges, a cost of $287,000/ha would require the charging of higher rents. The earlier feasibility modelling assumed net rents of $185/sqm and capitalisation rate of 4.75% to arrive at a capital value of $3,900/sqm. A rent of $195/sqm capitalised at 4.75% would result in $4,105/sqm.

Atlas notes that capitalisation rates have been at historic lows and the assumed 4.75% rate is not sustainable long term.

Table ES-2 tests the sensitivity of building capital values to net rents and softer capitalisation rates (5.0% and 5.25%). A softening to 5% reduces value from $4,105/sqm to $3,900/sqm, extinguishing any value increase from the higher rent.

Table ES-2: Sensitivity of Building Capital Values to Rents and Capitalisation Rates

Net Rent capitalised at	4.75%	5.0%	5.25%
$185/sqm	$3,895	$3,700	$3,524
$195/sqm	$4,105	$3,900	$3,714

Source: Atlas

If the recommendations of the 2022 report were adopted and a stormwater charge of $287,000/ha were required, an increase in rent to at least $195/sqm would be required. Rents at this level are however not tested with the market.

New tenants ***may*** be willing to pay $195/sqm if they can be assured of the delivery of warehouse premises in the time required, i.e. that all infrastructure required (road and utilities infrastructure) was certain to be delivered in a timely manner.

The modelling finds there is provisional capacity to pay a $287,000/ha charge if rents were increased to $195/sqm (from $185/sqm), however this is subject to:

- Tenants agreeing to a higher net rent of $195/sqm.
- Market yields (and capitalisation rate) softening by no more than 25bps.
- Construction cost at no more than $1,200/sqm.
- No other water infrastructure costs (e.g. interim on-site infrastructure and/ or loss of developable area).
- All infrastructure required to deliver the Precinct (not just utilities infrastructure but road and other infrastructure) in a timely manner is certain.

Rents in the Precinct currently average $185/sqm which are 50% more than three years ago. This is 55% more than average Melbourne rents ($120/sqm) and 37% more than average Brisbane rents ($135/sqm). There is little capacity for tenants to pay much higher rents as they grapple with the rising cost of fuel and energy and reduction in demand for non-essential goods.

Any increase in rents in the Precinct will either be met with resistance (i.e. tenants will remain in current, smaller premises or pursue development opportunities in other states) or if accepted, the higher rent is expected to be passed onto their customers.

SYDNEY'S NATIONAL COMPETITIVENESS

The lack of serviced industrial land has clearly constrained Sydney's take-up of land. Over the 2017-2021 period, Sydney has averaged 135ha per annum whereas Melbourne and SEQ have averaged 290ha and 190ha per annum respectively.

Analysis of ELDM and ABS data affirms that a constrained land supply situation has 'held back' investment and growth of the Industrial sector, with employment growth in Greater Sydney averaging 0.5% per annum over the 2016-2021 period compared to Melbourne's annual average of 1.2% and Brisbane's annual average of 1.1% over the same period.

With less than one year of serviced supply remaining (compared to 15 years in Melbourne and 12 years in Brisbane), there is no room for business investment, business growth and further employment opportunities.

In 2019 when progressing the rezoning of the Mamre Road Precinct, DPE identified 4-5 years of land remaining. Since then, there has been no large scale servicing of land and structural changes following the COVID-19 pandemic have turbo-charged land demand. The low stock levels have now been depleted. This has been met with near zero vacancy and skyrocketing rents. This has severely affected Sydney's national competitiveness and added to the cost of living.

Businesses that want to invest in Western Sydney cannot. The Mamre Road Precinct is therefore an important part of the solution to easing Sydney's chronic capacity issue of having less than one year's supply of land remaining.

Government Intervention Required

Feasibility testing highlights that development of land in the Precinct is not financially viable after the introduction of the water charges (even after a reduction to $1.15m/ha) - factoring in current rents, capitalisation rates, and construction costs.

Given the lack of serviced supply of industrial land in Greater Sydney, businesses that are committed to premises in the Precinct cannot invest in other parts of the Sydney region due to the shortage of serviced industrial land. These businesses with either simply not expand their Sydney operations and/ or reconfigure their operations to expand in other cities (most likely Melbourne) to cater for future growth in Sydney. This means that the economic activity that is foregone in the Precinct will represent a ***net loss*** to the Greater Sydney economy.

The economic impacts to Greater Sydney's economy should development of the Precinct not occur due to poor feasibility would result in foregone business investment, employment opportunities and economic output.

There are more than 20 businesses who have already committed to the Precinct (approx. 204ha of land). There are many more seeking to secure a premises in the Precinct if there was certainty and rents were affordable.

The Landowners' Group controls 550ha zoned land (equivalent to approximately 466ha NDA). More than 200ha of the developable land has been committed to (referred to as **Stage 1**), with the remaining 263ha for future development (referred to as **Stage 2**).

Immediate development (Stage 1) would facilitate the following annual economic activity through direct and indirect (flow-on) impacts associated with operations in the Precinct:

- $3.0 billion in output (including $1.3 billion in direct activity).
- $1.5 billion contribution to GVA (including $615.9 million in direct activity).
- $781.3 million in incomes and salaries paid to households (including $360.3 million in direct income) and up to $36.6 million in payroll tax depending on the share of wages paid above the payroll tax threshold.
- 7,433 ongoing FTE jobs (including 3,333 FTE directly related to activity in the Precinct).

Stage 1 has the ability to generate economic impact to the regional economy of $1.5 billion in the first year of operations, which would be recurring annually. The direct private construction investment of circa $1.5 billion will enable over 6,600 jobs during construction and approximately 7,400 full time jobs annually in operations (directly and indirectly).

The Proposal (Stage 1 and Stage 2) is estimated to result in a total increase in economic activity (including committed and future developments once fully developed and occupied) through direct and indirect (flow-on) annually at:

- $12.1 billion additional in output (including $5.5 billion in direct activity).
- $6.0 billion additional in contribution to GVA (including $2.5 billion in direct activity).
- $3.1 billion additional in incomes and salaries paid to households (including $1.4 billion directly) and up to $169.1 million payroll tax contribution.
- 28,448 additional FTE jobs (including 12.144 additional FTE jobs directly related to activity in the Precinct).

The economic impacts estimated in this section demonstrates the Proposal has economic merit, having the ability to contribute significantly to the Greater Sydney economy.

During construction of Stage 1 alone, the following economic activity is estimated:

- $3.3 billion in output (including $1.5 billion in direct activity).
- $1.3 billion contribution to GVA (including $472.8 million in direct activity).
- $671.6 million in incomes and salaries paid to households (including $233.9 million in direct income) and up to $36.6 million in payroll tax depending on the share of wages paid above the payroll tax threshold.
- 6,679 FTE jobs (including 2,501 FTE directly employed in construction activity).

If NSW Government chooses to proceed with implementation of the proposed water charges, this economic potential is at risk of not being realised. The unlocking of the Mamre Road Precinct will add 3 years of industrial land supply to the market. While it does not solve the broader pipeline issue, it provides a short-term relief to solve the medium and long term supply.

With less than one year remaining of serviced vacant industrial land, Sydney's competitive position is at significant risk of losing $1.5 billion in business investment and 7,400 ongoing employment opportunities for Western Sydney and Sydney more broadly. Government intervention to enable development in the Precinct is critical.

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Terms and Abbreviations

Terms

Development Margin	Development Margin is profit divided by total costs (including selling costs).
Growth Area	An area identified for urban development; as defined under the State Environmental Planning Policy (Industry and Employment) 2021 and (Precincts - Western Parkland City) 2021
Industrial Sector	Sectors critically reliant on industrial lands to directly support operations based on ANZSIC categories - Manufacturing, Wholesale Trade & Transport, Logistics & Warehousing
Initial Precincts	Rezoned precincts in the Aerotropolis - Aerotropolis Core, Badgerys Creek, Northern Gateway, Wianamatta-South Creek, Agribusiness Precinct
Project IRR	Project IRR is the project return on investment, where the discount rate where the cash inflows and cash outflows are equal.
Residual Land Value	The Residual Land Value is the maximum price a developer would be prepared to pay for a site in exchange for the opportunity to develop the site, whilst achieving target hurdle rates for profit and project return
Return on Cost	used interchangeably with Development Margin
The Aerotropolis	Western Sydney Aerotropolis
The Precinct	Mamre Road Precinct

Abbreviations

ANZSIC	Australia New Zealand Standards Industry Classification
DPE	Department of Planning and Environment
DSP	Development Servicing Plan
ELDM	Employment Lands Development Monitor
FSR	Floor Space Ratio
FTE	Full-time Equivalent
GFA	Gross Floor Area
GLA	Gross Lettable Area
GVA	Gross Value Added
IRR	Internal Rate of Return
IVA	Industry Value Added
LGA	Local Government Area
NDA	Net Developable Area
PoW	Place of Work
RLV	Residual Land Value
SEPP	State Environmental Planning Policy
SIC	Special Infrastructure Contributions
TEU	Twenty-foot equivalent unit
WSA	Western Sydney Airport

1. Introduction

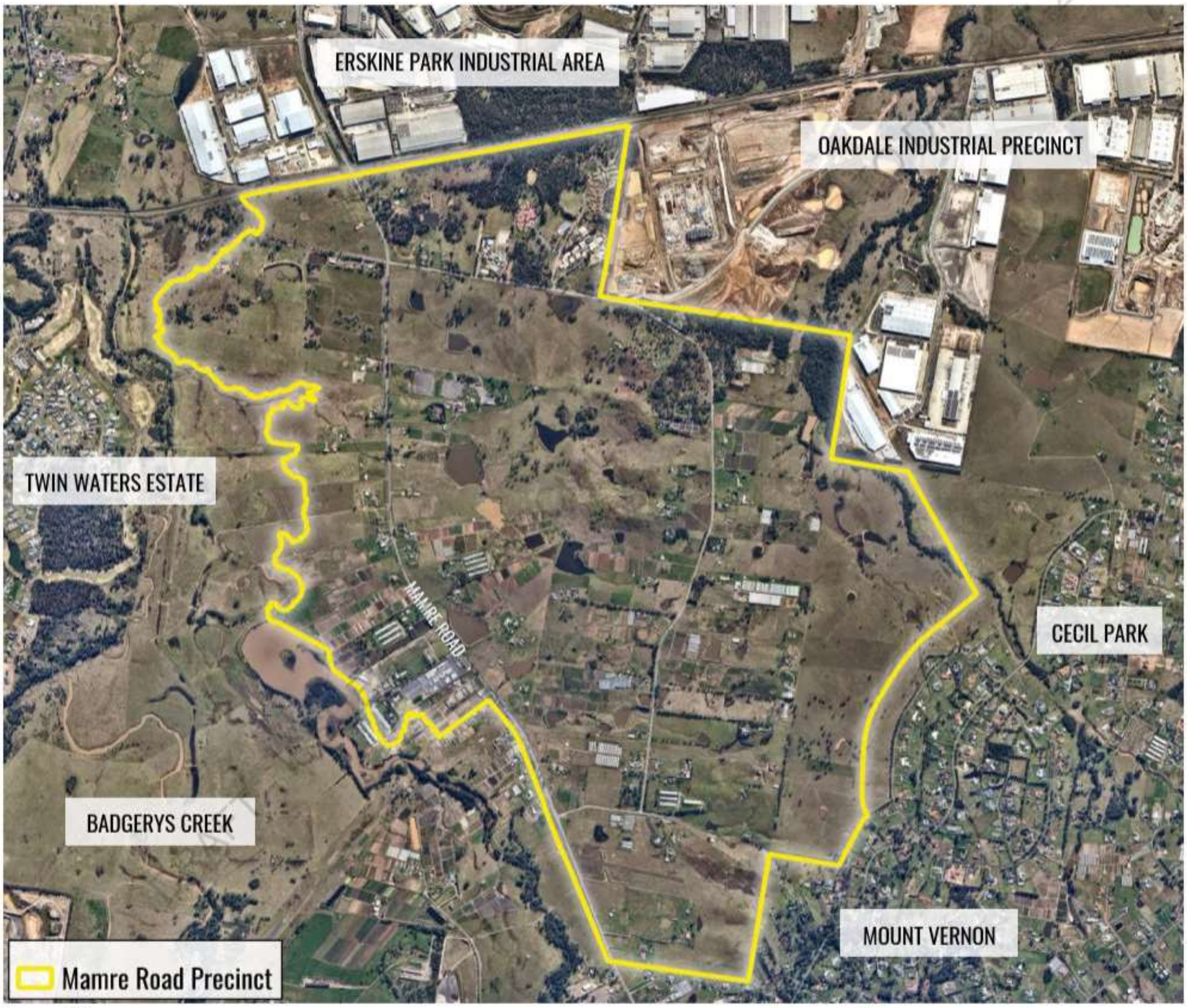
1.1 Background and Overview

The Mamre Road Precinct (**the Precinct**) was rezoned by the State Environmental Planning Policy (Western Sydney Employment Area) 2009, now known as the Industry and Employment SEPP 2021 in June 2020. The Precinct accommodates about 800ha of gross zoned industrial land.

The Precinct is located within the Penrith LGA and some 12km southeast of the Penrith City Centre. The Precinct has historically been a peri-urban area characterised by a mix of rural residential and small-scale farming operations. Compared to other precincts in the Aerotropolis, the Precinct is less fragmented with 100 allotments with a median lot size of 10ha. There are nine major landowners who control approximately 550ha of gross zoned land in the Precinct.

Figure 1.1 illustrates the formal boundaries of the Precinct and nature of surrounding land uses.

Figure 1.1: Mamre Road Precinct



Source: Atlas

Precinct Planning and Rezoning

The rezoning documentation prepared by Department of Planning and Environment (DPE) identified capacity for up to 17,000 jobs (depending on the nature of development proposals) with a focus on freight and logistics uses. The rezoning supports delivery of a potential intermodal terminal to service the existing Western Sydney Employment Area (WSEA) and Western Sydney Aerotropolis and provides protection for Wianamatta-South Creek precinct.

The rezoning of the Precinct was identified (in 2019) as needed to assist delivering the growing demand for industrial land in Western Sydney because "***industrial land ready to develop in this area could be exhausted within 4 to 5 years***" (DPE, 2019). The rezoning of the Precinct was essential to:

- Address the projected demand.
- Provide around 800ha of new industrial land for Western Sydney.
- Contribute to opportunities for 'jobs closer to home' and support the NSW economy.

A Special Infrastructure Contribution (SIC) was identified to be required to fund regional infrastructure for the Precinct. Until such time the Aerotropolis SIC was in place, developers were required to make contributions towards state/ regional infrastructure under Voluntary Planning Agreements.

Determination of a SIC

In 2020, DPE commenced investigations into design and implementation of a SIC for the Aerotropolis including the Precinct.

Atlas Economics (**Atlas**) was engaged by DPE to assess the capacity of the targeted precincts to tolerate a SIC in terms of development feasibility (the 2020 Study). The 2020 Study carried out a wide-ranging assessment of different development typologies that could be developed in the Aerotropolis and the Precinct and their tolerance range for a potential SIC. The Study additionally considered the cumulative impact of other contributions that would be payable (i.e. local contributions).

In its investigations for a potential SIC in the Precinct, the 2020 Study found that a SIC rate of $200,000/ha of NDA could be feasibly tolerated in the Precinct. At the time, Penrith City Council (**Council**) were carrying out investigations into local infrastructure and had raised the possibility for a s7.11 contribution rate to be in the order of $700,000/ha NDA.

The 2020 Study was informed of this potential local infrastructure contribution and tested the impact of $700,000/ha rate. The Study found that if a s7.11 rate of $700,000/ha NDA were implemented, development feasibility would be undermined.

In November 2020 DPE publicly exhibited proposed rates for the Aerotropolis SIC and Atlas' 2020 Study. The Aerotropolis SIC for the Precinct was determined at $200,000/ha and came into effect in March 2022. A SIC rate of $200,000/ ha of NDA henceforth applied in the Precinct before 1 July 2022 to be indexed to the Consumer Price Index on 1 July annually.

In March 2022, Council adopted the Mamre Road Development Contributions Plan 2022. A s7.11 contribution rate of $599,225/ha NDA was to apply in the Precinct (expressed in September 2021 dollars). The rate was to be subject to annual indexation (Consumer Price Index for works and House Price Index for land acquisition). According to the 2020 Study's findings, the adopted SIC and s7.11 rate would have been 'just' tolerated in the Precinct.

1.2 The Issues

Demand v Deliverable Supply

Sydney's industrial market had been growing for a number of years in the lead up to the initial outbreak of COVID-19 in March 2020. The outbreak of COVID-19 has amplified economic demand drivers with a convergence of tailwinds driving some of the strongest market conditions in the industrial sector on record.

Western Sydney's industrial market has been subject to strong market demand driven by a combination of infrastructure and building construction activity, population growth and the petetration of online retail.

Despite demand for industrial floorspace, serviced lot production has regrettably not kept pace with demand, leading to escalating land values in a highly competitive context. The non-alignment of services, utilities and road infrastructure with the rezoning of land in Western Sydney is a key driver of these escalating prices and rents.

Analysis of DPE's Employment Land Development Monitor (ELDM) shows that as at January 2022:

- In the Western City, there was 5,576ha of zoned vacant land but only 375ha was serviced (6.7%).
- In Greater Sydney, 588ha of undeveloped land was serviced, the Western City contributing 375ha (64%) of that supply.

Data for industrial land take-up for 2022 is not available from the ELDM, however published industry data highlights that industrial take-up in Western Sydney was 290ha in 2022 (Colliers, Q1 2023). This indicates the availability of serviced land in the Western City is now much lower than 375ha reported in the ELDM at January 2022.

In 2019, DPE identified Western Sydney's stock of serviced land could be exhausted in 4-5 years. Since that time in 2019, structural changes following the COVID-19 pandemic have amplified demand for employment lands and there has been little to no servicing of zoned employment lands. The supply that was identified in 2019 has now been depleted to critical lows. This has been met by a corresponding collapse in vacancy rates and sharp escalation of rents and prices.

Unless there is large scale servicing of zoned land, the rapidly escalating prices in Western Sydney (and elsewhere in Sydney) will continue amid a shrinking pool of serviced land. This has serious consequences for Sydney's competitiveness and the industrial sector's ability to expand.

Feasibility of Development

The Precinct is identified in strategic planning and market commentary as required to address a lack of supply in Sydney.

Major landowners in the Precinct have secured commitments from business occupiers ready to occupy more than 200ha of land (>1 million sqm floorspace). Some of these occupiers are new entrants to the Sydney market, others have smaller facilities across Sydney and seek expanded facilities at the Precinct to cater to current and future growth.

Sydney Water has announced charges in the Precinct - stormwater and recycled water ($1.3 million per ha) and drinking and wastewater ($50,000 per ha). This is a significant cost with significant implications for development feasibility.

If development in the Precinct is no longer feasible, there are far-reaching ramifications not just for the Precinct, but Sydney's capacity to receive business investment and generate new jobs. Even though there is investment committed to the Precinct, that investment will be unrealised if the Precinct is not developed in timeframes that those businesses require.

Land availability in Melbourne and Brisbane (and broader Southeast Queensland) at much lower prices is already having the effect of drawing business investment away from Sydney. Given the almost nil supply of serviced employment land remaining, if the Precinct is not serviced and available for development in the short term, there are serious risk implications for Sydney's competitiveness and its cost of living.

1.3 Scope of the Analysis

Atlas Economics (Atlas) is engaged by the Mamre Road Landowners' Group to examine the impacts of the proposed water infrastructure charges from the perspective of:

1. The developer - development feasibility in the context of existing fees and charges (SIC, s7.11).
2. The occupier/ user - additional rent required for cost-recovery to enable feasible development.
3. Market competitiveness of the Mamre Road precinct - before and after additional rents for cost-recovery.
4. Significance of the Mamre Road precinct and economic impacts of non-delivery to the city and state of NSW.

The overarching objective of the Study is to understand the implications of the proposed water infrastructure charges and the urgency of enabling large scale servicing of zoned land and development that is feasible. It reviews Sydney's national competitiveness and considers why Do-Nothing is not a tenable option.

The Study is structured as follows:

- Chapter 2 reviews and estimates the size and significance of the Industrial sector in Greater Sydney and NSW. It also compares the scale and contribution of the Industrial sector to the capital cities of Melbourne and Brisbane.
- Chapter 3 examines the patterns of supply and demand of industrial lands in Greater Sydney, its market indicators and provides a snapshot of remaining land supply.
- Chapter 4 carries out feasibility analysis of development, with and without the proposed water infrastructure charges. It also considers the quantum of additional rents required for cost-recovery of the proposed water charges.
- Chapter 5 considers the economic impacts from development in the Precinct and were business investment to be foregone in circumstances where development is no longer feasible to undertake.

The Study develops scenarios for the purposes of estimating the economic impacts of the Precinct. These are developed with reference to committed occupier data from the Landowners' Group. An industry mix is developed from this occupier data, enabling Atlas to estimate the direct and indirect impacts from investment foregone were the Precinct not developed.

2. Size and Significance of the Industrial Sector

This chapter reviews the industrial employment sector for Greater Sydney and NSW, considering key economic indicators and overall significance to provide context for the need to deliver development of the Mamre Road Precinct.

2.1 Defining the Industrial Sector

This analysis considers the following key users of industrial employment space, based on Australia and New Zealand Standard Industrial Classification (ANZSIC) categories:

- Manufacturing.
- Wholesale trade.
- Transport, logistics and warehousing.

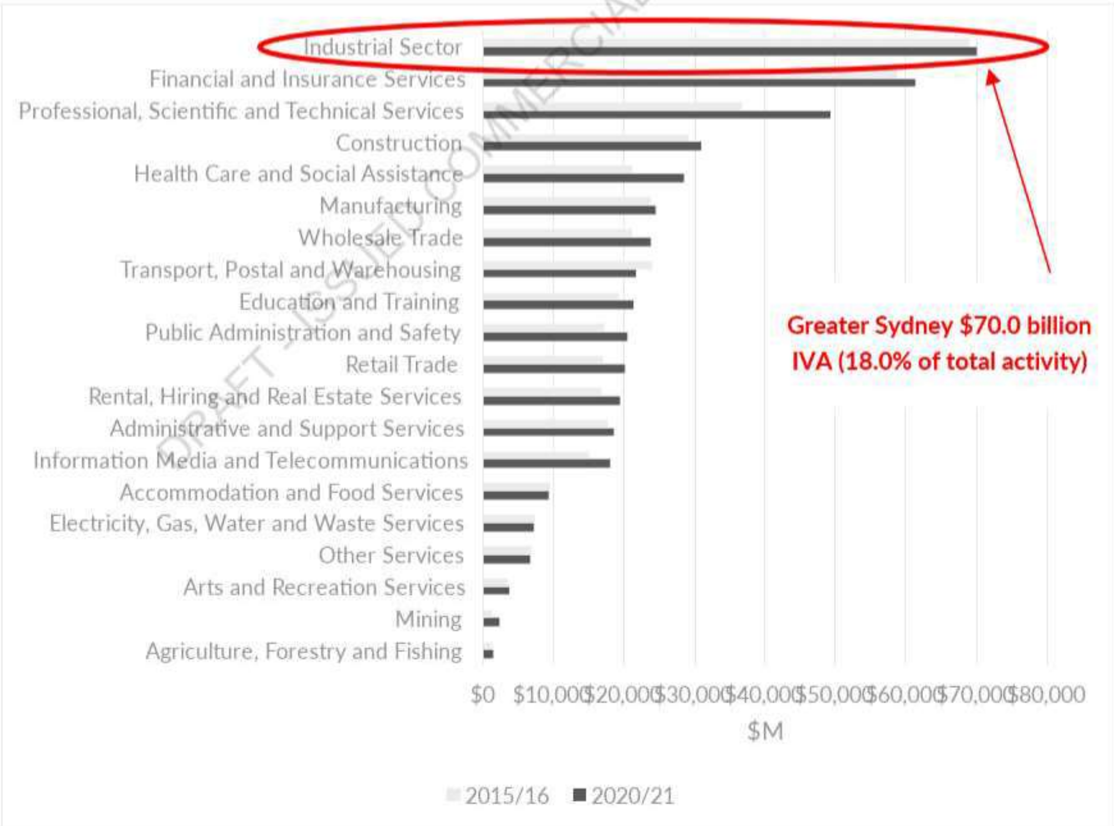
Atlas highlights that industrial land development facilitates economic activity across a broad range of sectors (beyond those modelled in this analysis). For example, distribution centres provide large retail chains with stock for sale instore, which is required for these businesses to function, and restaurants and cafés rely on the delivery of a wide range of products from various warehouses around the region. At the same time, industrial activity is becoming an increasingly diverse employment area due to changing business models and market factors including scale and affordability. The core aim of this analysis is to highlight the employment sectors which are most critically reliant on industrial lands to directly support operations.

2.2 Direct Economic Contribution

2.2.1 Industry Value Added

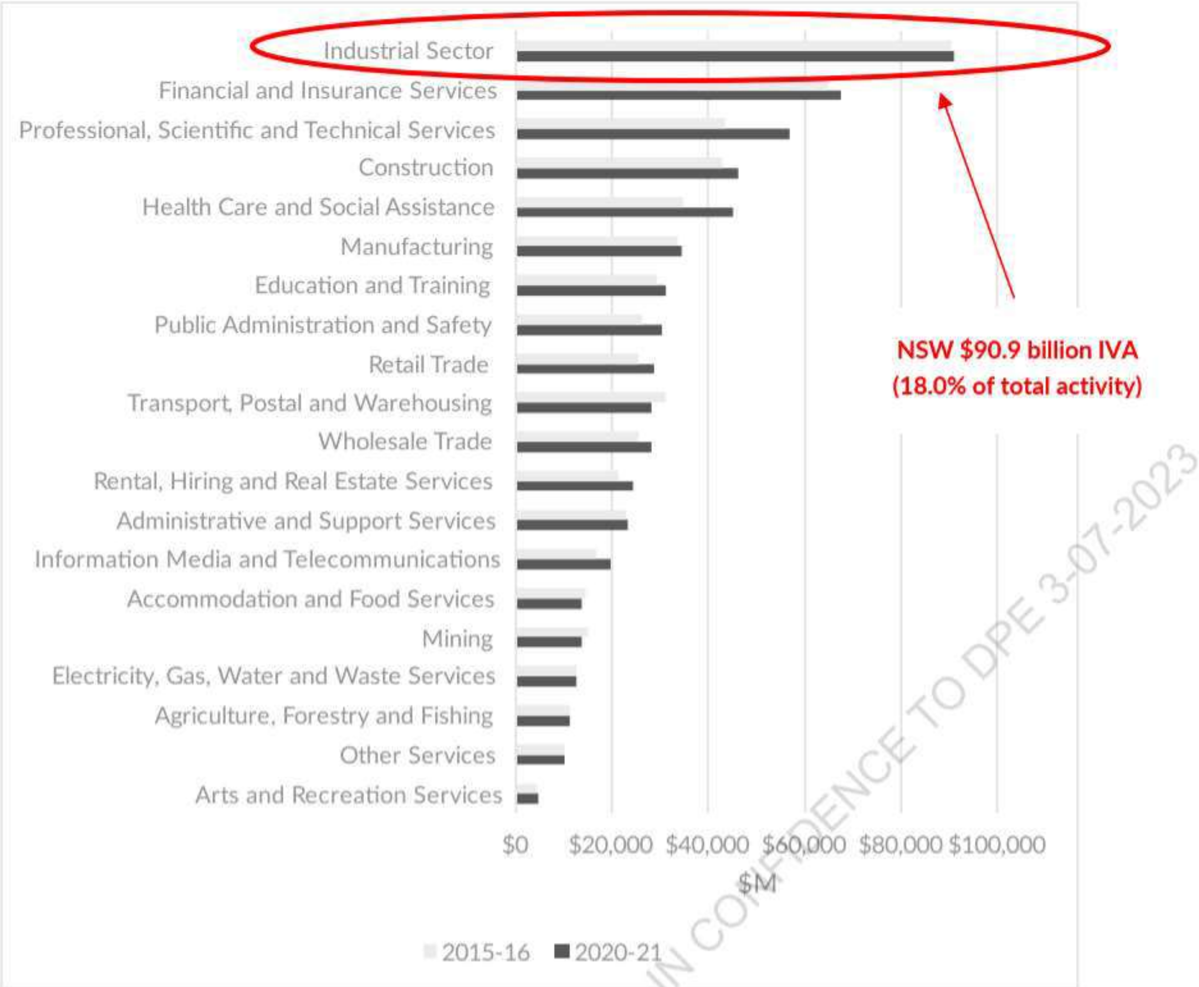
Across NSW, the industrial sector contributed almost $91 billion in 2020-21, with five-year average annual growth of 0.1%. Industry Value Add (IVA) for the Greater Sydney region and NSW is presented in **Figure 2-1** and **Figure 2-2**.

Figure 2-1: Greater Sydney Industry Value Add (2015/16 and 2020/2021)



Source: NIEIR (2022)

Figure 2-2: NSW Industry Value Add (2015/16 and 2020/21)



Source: NIEIR (2022)

During 2020-21 the industrial sector contributed an estimated $70.0 billion (18.0%) to the Greater Sydney economy. Over the past five years the sector's contribution has grown by just over $1.1 billion (0.3% per annum) compared to total Industry Value Added (IVA) growth of 2.3% per annum.

Key drivers of industrial sector activity included:

- **Manufacturing ($24.4 billion contribution, 0.5% p.a. growth over the past five years)**

  New advanced manufacturing opportunities and global supply chain disruptions through the COVID-19 pandemic are driving a strong case for greater local production. This has created the opportunity for a new wave of manufacturing industry growth in Greater Sydney and NSW against a longer-term historical trend of outsourcing/ global production and reduced employment through automation/mechanisation in the sector.

- **Wholesale trade ($23.9 billion, 2.5% p.a. growth)**

  The wholesale sector has been the main source of industrial growth over the past five years, the sector has a strong growth outlook due to the shift to online retail and distribution models.

- **Transport, postal and warehousing ($21.7 billion, -1.9% p.a. growth)**

  The sector was temporarily impacted through the COVID-19 pandemic. The road transport sector is currently suffering from a shortage of drivers at a time when demand is surging.

Combined, the wholesale trade and transport, postal and warehousing industries would represent the logistics sector.

2.2.2 Employment

During the 2021 Census period the industrial sector was shown to be contributing just over 318,000 jobs (by Place of Work (PoW)) to the Greater Sydney economy (14.8% of total jobs). The majority of jobs were provided in the Manufacturing (123,000 jobs, 5.8% of total employment), and Transport, Postal & Warehousing (116,000 jobs, 5.4% of total employment) sectors, with Wholesale Trade accounting for 77,000 local jobs (3.6% of total employment).

Changes in industrial employment levels during the 2021 Census period were notably different to IVA activity, and it should be noted that the COVID-19 pandemic and JobKeeper payments program (aimed at allowing employers to maintain staff through the worst of the pandemic) substantially impacted the employment data[1].

Employment for the Greater Sydney region and NSW is presented in **Table 2-1** and **Table 2-2** respectively.

Table 2-1: Employment by Industry, Greater Sydney (2016-2021)

Industry	2021		2016		Change	Average Annual Growth
	No.	%	No.	%	2016 - 2021	2016 - 2021
Agriculture, Forestry and Fishing	8,338	0.4%	8,107	0.4%	231	0.6%
Mining	4,573	0.2%	4,487	0.2%	86	0.4%
Manufacturing	*124,704*	*5.8%*	*123,858*	*6.2%*	*846*	*0.1%*
Electricity, Gas, Water and Waste Services	18,870	0.9%	16,541	0.8%	2,329	2.7%
Construction	159,632	7.4%	143,607	7.2%	16,025	2.1%
Wholesale Trade	*77,071*	*3.6%*	*79,918*	*4.0%*	*-2,847*	*-0.7%*
Retail Trade	199,227	9.3%	194,687	9.8%	4,540	0.5%
Accommodation and Food Services	121,793	5.7%	140,563	7.0%	-18,770	-2.8%
Transport, Postal and Warehousing	*116,311*	*5.4%*	*107,103*	*5.4%*	*9,208*	*1.7%*
Information Media and Telecommunications	57,120	2.7%	61,460	3.1%	-4,340	-1.5%
Financial and Insurance Services	168,811	7.9%	143,409	7.2%	25,402	3.3%
Rental, Hiring and Real Estate Services	44,759	2.1%	42,000	2.1%	2,759	1.3%
Professional, Scientific and Technical Services	260,415	12.1%	218,211	10.9%	42,204	3.6%
Administrative and Support Services	67,990	3.2%	69,734	3.5%	-1,744	-0.5%
Public Administration and Safety	128,091	6.0%	119,826	6.0%	8,265	1.3%
Education and Training	188,796	8.8%	172,334	8.6%	16,462	1.8%
Health Care and Social Assistance	295,725	13.8%	239,942	12.0%	55,783	4.3%
Arts and Recreation Services	33,150	1.5%	35,227	1.8%	-2,077	-1.2%
Other Services	68,913	3.2%	73,377	3.7%	-4,464	-1.2%
Industrial Sector	***318,086***	***14.8%***	***310,879***	***15.6%***	***7,207***	***0.5%***
Total	**2,144,289**	**100.0%**	**1,994,391**	**100.0%**	***149,898***	**1.5%**

Note: Excludes inadequately described and not stated responses.
Source: ABS (2022)

Table 2-2: Employment by Industry, NSW (2016-2021)

Industry	2021		2016		Change	Average Annual Growth
	No.	%	No.	%	2016 - 2021	2016 - 2021
Agriculture, Forestry and Fishing	75,236	2.1%	73,132	2.3%	2,104	0.6%
Mining	34,646	1.0%	30,443	1.0%	4,203	2.6%
Manufacturing	*201,894*	*5.8%*	*196,910*	*6.2%*	*4,984*	*0.5%*
Electricity, Gas, Water and Waste Services	35,516	1.0%	31,695	1.0%	3,821	2.3%
Construction	314,158	9.0%	280,552	8.8%	33,606	2.3%

[1] Though it should be noted that the JobKeeper program had concluded by the time of the 2021 Census survey.

Industry	2021		2016		Change	Average Annual Growth
	No.	%	No.	%	2016 - 2021	2016 - 2021
Wholesale Trade	*105,052*	*3.0%*	*103,955*	*3.2%*	*1,097*	*0.2%*
Retail Trade	330,780	9.4%	325,234	10.2%	5,546	0.3%
Accommodation and Food Services	227,806	6.5%	238,757	7.5%	-10,951	-0.9%
Transport, Postal and Warehousing	*169,619*	*4.8%*	*158,294*	*4.9%*	*11,325*	*1.4%*
Information Media and Telecommunications	68,521	2.0%	73,036	2.3%	-4,515	-1.3%
Financial and Insurance Services	195,139	5.6%	167,192	5.2%	27,947	3.1%
Rental, Hiring and Real Estate Services	62,384	1.8%	59,304	1.9%	3,080	1.0%
Professional, Scientific and Technical Services	326,550	9.3%	272,194	8.5%	54,356	3.7%
Administrative and Support Services	117,944	3.4%	116,824	3.7%	1,120	0.2%
Public Administration and Safety	213,284	6.1%	196,609	6.1%	16,675	1.6%
Education and Training	320,474	9.1%	280,281	8.8%	40,193	2.7%
Health Care and Social Assistance	528,476	15.1%	419,986	13.1%	108,490	4.7%
Arts and Recreation Services	51,395	1.5%	51,516	1.6%	-121	0.0%
Other Services	124,764	3.6%	123,842	3.9%	922	0.1%
Industrial Sector	***476,565***	***13.6%***	***459,159***	***14.3%***	***17,406***	***0.7%***
Total	**3,503,638**	**100.0%**	**3,199,756**	**100.0%**	**303,882**	**1.8%**

Note: Excludes inadequately described and not stated responses.
Source: ABS (2022)

2.2.3 Exports

The industrial sector in Greater Sydney generated approximately $100 billion in exports (sales of goods and services to non-resident households, businesses and other organisations, outside Greater Sydney boundaries) during 2020-21 and was responsible for approximately 30% of total Greater Sydney and NSW exports produced.

Over the past five years Greater Sydney's industrial sector exports has grown by 1.5% per annum. Estimates of exports by industry for Greater Sydney and NSW are presented in **Table 2-3** and **Figure 2-3**.

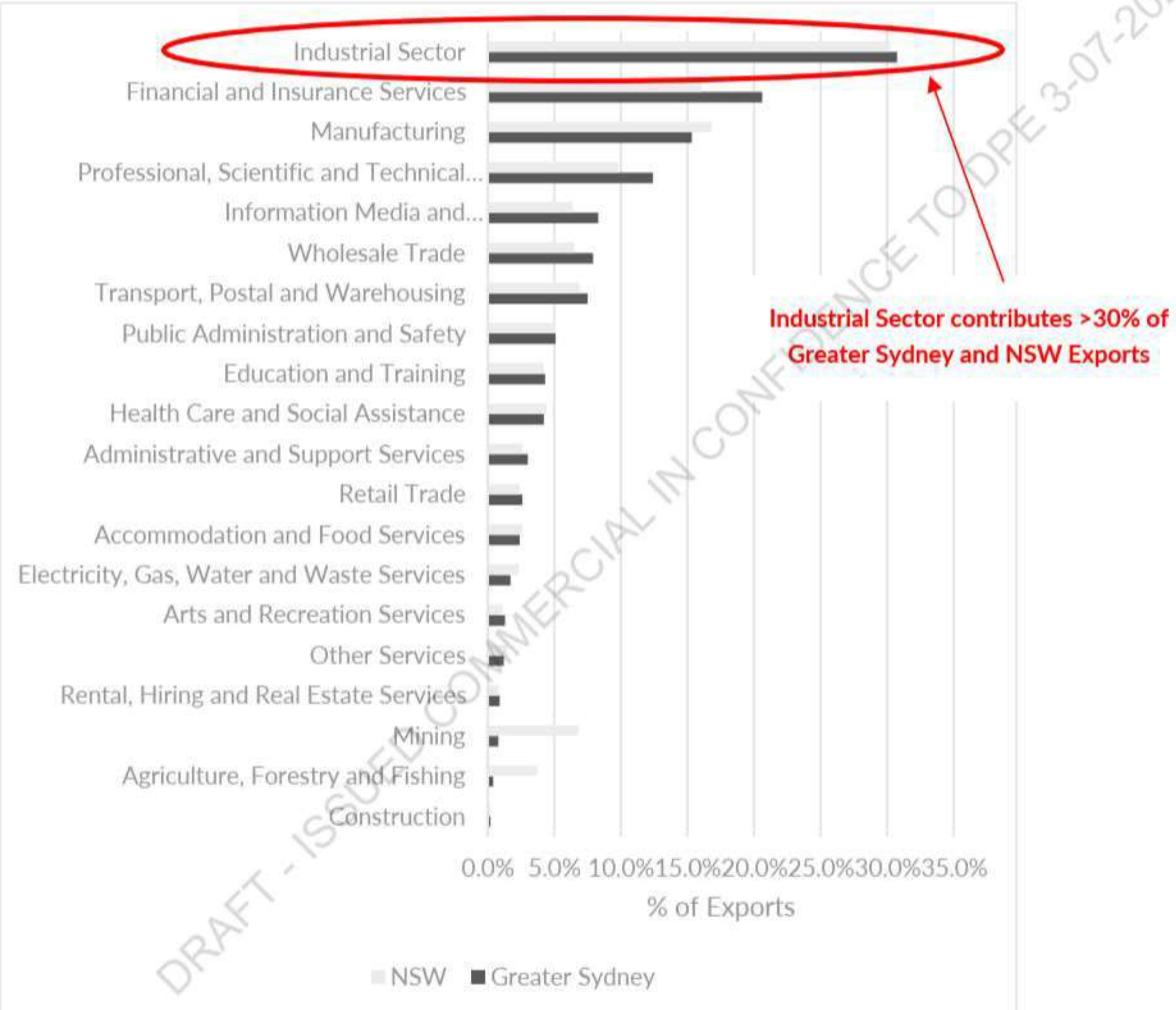
Table 2-3: Exports by Industry, Greater Sydney and NSW (2015/16 and 2020/21), $M

Industry	2020/21			2015/16			2015/16 to 2020/2021	
	Greater Sydney	% Greater Sydney	% NSW	Greater Sydney	% Greater Sydney	% NSW	Change	Avg. Annual Growth
Agriculture, Forestry and Fishing	$1,314.9	0.4%	3.7%	$904.5	0.3%	3.7%	$410.4	7.8%
Mining	$2,551.6	0.8%	6.8%	$2,059.0	0.7%	8.4%	$492.6	4.4%
Manufacturing	$49,738.0	15.3%	16.8%	$45,083.3	15.6%	16.4%	$4,654.8	2.0%
Electricity, Gas, Water and Waste Services	$5,693.1	1.7%	2.3%	$5,995.9	2.1%	2.5%	-$302.8	-1.0%
Construction	$657.4	0.2%	0.2%	$403.6	0.1%	0.2%	$253.8	10.2%
Wholesale Trade	$25,772.1	7.9%	6.5%	$21,492.6	7.4%	5.9%	$4,279.5	3.7%
Retail Trade	$8,434.6	2.6%	2.4%	$7,428.9	2.6%	2.3%	$1,005.7	2.6%
Accommodation and Food Services	$7,793.8	2.4%	2.6%	$7,761.8	2.7%	3.0%	$32.0	0.1%
Transport, Postal and Warehousing	$24,467.6	7.5%	6.9%	$26,213.0	9.1%	8.1%	-$1,745.4	-1.4%
Information Media and Telecommunications	$26,916.8	8.3%	6.4%	$20,302.5	7.0%	5.3%	$6,614.3	5.8%
Financial and Insurance Services	$67,301.5	20.6%	16.0%	$62,574.5	21.6%	16.2%	$4,727.0	1.5%
Rental, Hiring and Real Estate Services	$2,835.9	0.9%	0.8%	$2,896.5	1.0%	0.9%	-$60.7	-0.4%
Professional, Scientific and Technical Services	$40,410.5	12.4%	9.8%	$32,108.5	11.1%	8.7%	$8,302.0	4.7%
Administrative and Support Services	$9,731.6	3.0%	2.6%	$9,990.9	3.5%	3.1%	-$259.3	-0.5%

Industry	2020/21			2015/16			2015/16 to 2020/2021	
	Greater Sydney	% Greater Sydney	% NSW	Greater Sydney	% Greater Sydney	% NSW	Change	Avg. Annual Growth
Public Administration and Safety	$16,533.1	5.1%	5.0%	$13,248.1	4.6%	4.6%	$3,285.0	4.5%
Education and Training	$14,124.3	4.3%	4.2%	$11,863.8	4.1%	4.1%	$2,260.5	3.5%
Health Care and Social Assistance	$13,539.5	4.2%	4.4%	$10,174.7	3.5%	3.7%	$3,364.7	5.9%
Arts and Recreation Services	$4,363.9	1.3%	1.1%	$4,626.0	1.6%	1.3%	-$262.2	-1.2%
Other Services	$3,905.4	1.2%	1.5%	$4,212.3	1.5%	1.5%	-$307.0	-1.5%
Industrial Sector	***$99,977.7***	***30.7%***	***30.2%***	***$92,788.9***	***32.1%***	***30.4%***	***$7,188.9***	***1.5%***
Total	**$326,085.6**	**100.0%**	**100.0%**	**$289,340.7**	**100.0%**	**100.0%**	**$36,744.9**	**2.4%**

Source: NIEIR (2022)

Figure 2-3: Exports by Industry, Greater Sydney and NSW (2020/21)



Source: NIEIR (2022)

The Industrial sector is important to the Greater Sydney and NSW economies. The sector provides a large number of jobs, generates a significant portion of economy activity and contributes considerably to Gross State Product of NSW.

The sector is also a significant source of exports, providing a valuable input to the state and national economy.

2.2.4 Payroll Tax

Published data from the NSW Department of Customer Service (2019) indicates the NSW industrial sector contributed approximately $2.1 billion in payroll tax during 2017-18 (approximately 21% of total payroll tax collected).

Based on the share of employment located within Greater Sydney around two-thirds of this tax revenue ($1.4 billion) is estimated to have been contributed by businesses operating within then Greater Sydney region.

Table 2-4: NSW Payroll Tax by Industry (2017-18)

ANZSIC	Payroll Tax Paid 2017-18	% of Payroll Tax
Agriculture, Forestry and Fishing	$65,241,085	0.7%
Mining	$183,137,361	1.9%
Manufacturing	$798,754,337	8.1%
Electricity, Gas, Water and Waste Services	$121,748,768	1.2%
Construction	$584,134,100	5.9%
Wholesale Trade	$719,036,894	7.3%
Retail Trade	$623,796,934	6.3%
Accommodation and Food Services	$235,624,447	2.4%
Transport, Postal and Warehousing	$546,826,083	5.5%
Information Media and Telecommunications	$332,599,067	3.4%
Financial and Insurance Services	$1,343,196,495	13.6%
Rental, Hiring and Real Estate Services	$231,164,904	2.3%
Professional, Scientific and Technical Services	$1,087,934,926	11.0%
Administrative and Support Services	$880,161,507	8.9%
Public Administration and Safety	$1,177,694,424	11.9%
Education and Training	$353,910,358	3.6%
Health Care and Social Assistance	$272,538,188	2.8%
Arts and Recreation Services	$86,124,402	0.9%
Other Services	$123,275,130	1.2%
Unknown	$98,211,746	1.0%
Industrial Sector	***$2,064,617,314***	***20.9%***
Total	**$9,865,111,156**	**100.0%**

Source: NSW Department of Customer Service (2019)

Given the significant employment in the Industrial sector, these businesses pay a meaningful amount of payroll taxes.

As the Industrial sector continues to grow and expand, so too will the payroll taxes it pays. Payroll taxes received by the State Government go to fund a number of important local services.

2.3 Indirect Economic Contribution

Beyond its direct economic contribution, the industrial sector forms a critical component of regional and State supply chains, including purchases of upstream materials and services as well as supplying the downstream retail and services industries. Specifically, all parts of the economy rely on the logistics sector to a certain extent.

The current flow-on contribution of the industrial sector has been estimated utilising Input-Output multipliers. Input-Output modelling considers economic activity through examining four types of impacts as described in **Table 2-5**.

Table 2-5: Economic Indicators

Indicator	Description
Output	The gross value of goods and services transacted, including the cost of goods and services used in the development and provision of the final product. Care should be taken when using output as an indicator of economic activity as it counts all goods and services used in one stage of production as an input to later stages of production, thus overstating economic activity.
Gross Value Added	The value of output after deducting the cost of goods and services inputs in the production process (less the impact of net taxes on final production). Gross Value Added (GVA) defines a net contribution to economic activity.
Incomes	The wages and salaries paid to employees either directly or indirectly.
Employment	Employment positions generated by the Project or Proposal (either full time or part time, directly or indirectly). Employment is reported in terms of Full-time Equivalent (FTE) positions or person-years.

Source: Atlas

Input-Output modelling estimates show the impacts of direct spending in a particular industry as well as from production-induced impacts (Type I) or consumption-induced impacts (Type II).

- **Production-induced impacts (Type I)** show the effects of industrial support effects of additional activities undertaken by supply chain industries increasing their production in response to direct and subsequent rounds of spending.
- **Consumption-induced impacts (Type II)** estimate the re-circulation of labour income earned as a result of the initial spending, through other industry impacts, and impacts from increased household consumption.

The estimates of economic impacts consider production and consumption-induced flow-on impacts consumption-induced (Type II) impacts are commonly considered to overstate economic activity and therefore the types of flow-on impacts are reported separately.

Flow-on impacts have been estimated based on the direct economic activity (IVA/GVA) for the 2020-21 financial year as reported in section 2.2, which were applied in the Input-Output model as the driver of direct activity. The resulting flow-on economic activity results are reported in **Table 2-6**.

Across Greater Sydney the industrial sector is estimated to contribute through additional flow-on activity:

- $210 billion in output.
- $109 billion in GVA.
- $53 billion in incomes and salaries paid to Greater Sydney workers.
- Approximately 505,000 FTE jobs.

Across NSW the industrial sector is estimated to contribute through additional flow on activity:

- $360 billion in additional output.
- $181 billion in GVA.
- $88 billion in wages and salaries paid to NSW workers.
- Approximately 876,000 FTE jobs.

Beyond the direct impacts of the Industrial sector, the industry is also very important as it impacts and supports the general supply chain across all industries. Almost all businesses in the State will be impacted by the logistics sector in some way. The Industrial sector is very important to the functioning of the regional and State economies.

Table 2-6: Industrial Sector Indirect Economic Contribution (2020-21)

Impact	Output ($M)	GVA ($M)	Incomes ($M)	Employment FTE*
Greater Sydney				
Flow-on Type I	$104,913	$49,637	$27,642	241,145
Flow-on Type II	$104,921	$59,042	$25,543	264,064
Total Indirect Impact	**$209,834**	**$108,680**	**$53,185**	**505,209**
New South Wales				
Flow-on Type I	$183,508	$84,290	$44,911	420,614
Flow-on Type II	$176,669	$97,088	$43,121	455,786
Total Indirect Impact	**$360,178**	**$181,378**	**$88,032**	**876,401**

*Input-Output modelling estimates of direct FTE employment should not be compared with Census employment estimates as Census counts are an undercount of total population, some people don't state their workforce status or industry, counts by place of work exclude those with no fixed workplace address.
Source: Atlas

2.4 Comparison with Select Capital Cities

For comparative purposes the direct contribution of the Greater Sydney industrial sector is benchmarked against the Greater Melbourne and Brisbane regions. Key points of note include:

- While Greater Sydney hosts the largest Industrial sector at $70 billion, the industrial sector contributes a greater share of activity in Greater Melbourne and Brisbane (approx. 19.5% of IVA in both compared to 18.0% in Greater Sydney).
- The Industrial sector also contributes a significantly higher share of total exports (approximately 40% of Greater Brisbane exports and nearly 70% Greater Melbourne compared to 30% Greater Sydney).
- Greater Sydney has experienced comparable industrial sector growth to Greater Brisbane, while Greater Melbourne declined by 0.2% per annum over the past five years.
- Industrial employment growth in Greater Sydney (0.5% per annum) has significantly lagged Greater Melbourne (1.2% per annum) and Greater Brisbane (1.1% per annum) between 2016 and 2021.

Headline industrial sector statistics comparing Greater Sydney, Melbourne, and Brisbane are presented in **Table 2-7**.

Table 2-7: Industrial Sector Comparison

Indicator	Greater Sydney	Greater Melbourne	Greater Brisbane
Resident Population (2021)	5.3 million	5.0 million	2.6 million
IVA (2020-21)	$70.0 billion	$62.7 billion	$30.3 billion
% of Total IVA	18.0%	19.4%	19.6%
IVA Growth (2016-2021)	0.3% p.a.	-0.2% p.a.	0.4% p.a.
Employment (PoW, 2021)	318,086	360,149	165,725
% of Total Employment	14.8%	15.9%	14.8%
Employment Growth (2016-2021)	0.5% p.a.	1.2% p.a.	1.1% p.a.
Exports (2020-21)	$100.0 billion	$22.5 billion	$41.9 billion
% of Total Exports	30.7%	68.7%	39.6%
Exports Growth (2016-2021)	0.5% p.a.	-0.2% p.a.	-0.5% p.a.
Port Container Throughput (2021-22)	2.8 million TEUs	3.2 million TEUs	1.5 million TEUs

Source: NIEIR (2022), ABS (2016, 2022), NSW Ports (2023), Port of Melbourne (2023), Port of Brisbane (2023)

Even though Sydney is a much larger capital city (5.3 million residents compared to 5 million in Melbourne and 2.6 million in Brisbane) and has a much more significantly sized Industrial sector ($70 billion compared to $62.7 billion in Melbourne and $30.3 billion in Brisbane), employment growth has been less than half that of the other cities.

Container throughput (a significant driver for the logistics sector) in Sydney is similar to Melbourne and much greater than Brisbane.

3. Demand and Supply of Industrial Lands

3.1 Market Conditions

Demand for industrial floorspace is influenced by a broad set of macro-economic factors - at the global and domestic level. Population and economic growth, infrastructure investment, changing consumer patterns and technological advancements are some of these core drivers which guide businesses' floorspace requirements and how floorspace is utilised.

Understanding the broader context in the industrial sector operates is essential to understanding the drivers of value and ultimately what the market is prepared to pay for industrial property in the Mamre Road Precinct.

Sydney's industrial market had been growing for a number of years in the lead up to the initial outbreak of COVID-19 in March 2020. The outbreak of COVID-19 has amplified these demand drivers with a convergence of tailwinds driving some of the strongest market conditions in the industrial sector on record. Looking forward, industrial market conditions in Sydney's industrial sector are expected to remain strong due to the following key drivers:

- Large scale transport infrastructure projects and residential development underway and in the pipeline stimulating industrial activity, particularly in Western Sydney.
- Continued development of manufacturing sectors particularly advanced manufacturing.
- Continued uptake of e-commerce platforms by consumers and businesses, driving significant demand for freight and logistics floorspace.
- Population growth driving demand in the food and beverage and urban services sector (e.g. waste recycling, automotive services, utilities, small scale manufacturing).
- Further growth in internet usage driving demand for data storage in large, purpose-built facilities (i.e. data centres).

These strong tailwinds have resulted in significant investment interest into industrial assets across Greater Sydney in recent years, as institutional investors and real estate trusts seek to increase their exposure to the industrial sector (predominantly freight and logistics). This investment focus is expected to continue and strengthen moving forward.

3.2 Demand and Take-up of Industrial Lands

In line with the broader investment market, demand for industrial land in Western Sydney was significant in 2021 with approximately $1.5 billion trading across multiple deals. By area, the land sales in 2021 represent just over three million sqm with the average price being $802/sqm. In 2022 market activity was more cautious given higher funding costs.

Land Value and Building Capital Value Movements

The adequacy of land to meet demand can be observed through market signals. Market indicators such as rising prices, falling incentives, falling vacancy rates, etc. suggest a market that is undersupplied.

Table 3-1 outlines the rapid growth of land values in the Outer West region of Sydney, averaging between 10% and 31% increase between 2020 and 2022.

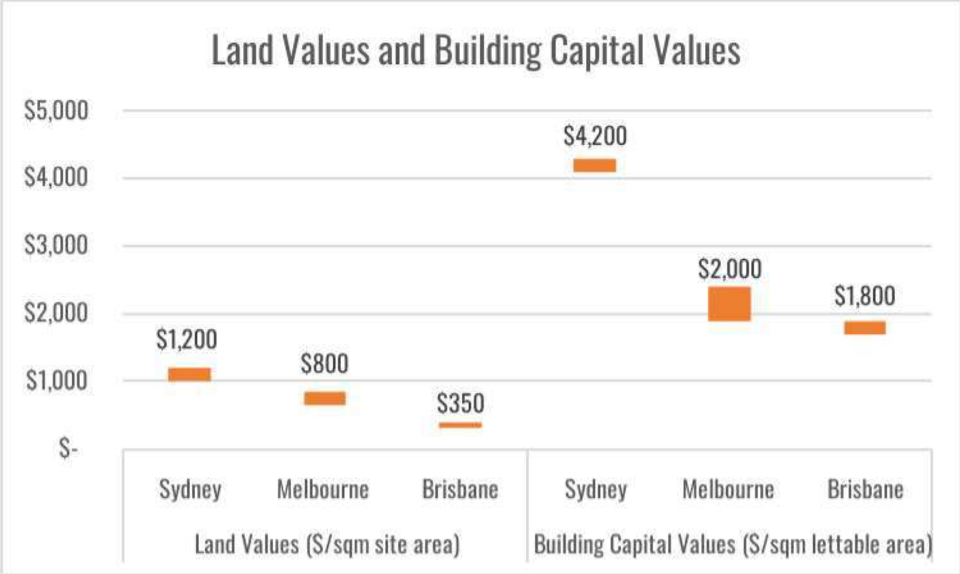
Table 3-1: Vacant Land Values, Outer West (2020-2022)

Outer West region	2020	2021	2022	Avg. Ann Growth (2020-2022)
<2,000sqm	$1,000	$1,000	$1,201	10%
2,000sqm to 5,000sqm	$800	$800	$1,101	17%
5,000sqm to 10,000sqm	$650-$700	$750-$850	$1,000-$1,200	31%
>10,000sqm	$650-$700	$750-$850	$1,000-$1,200	31%

Source: Cushman and Wakefield (2020, 2021, 2022)

Figure 3-1 shows a comparison of land values and building capital values between Sydney, Melbourne and Brisbane. It is evident that Sydney has a serious affordability issue.

Figure 3-1: Land Values and Building Capital Values - Sydney, Melbourne, Brisbane (2022)



Source: Cushman and Wakefield (2020, 2021, 2022)

Rents and Vacancy Rates

Table 3-2 outlines the rapid growth of rents in the Outer West region of Sydney, averaging between 22% and 26% increase between 2020 and 2022.

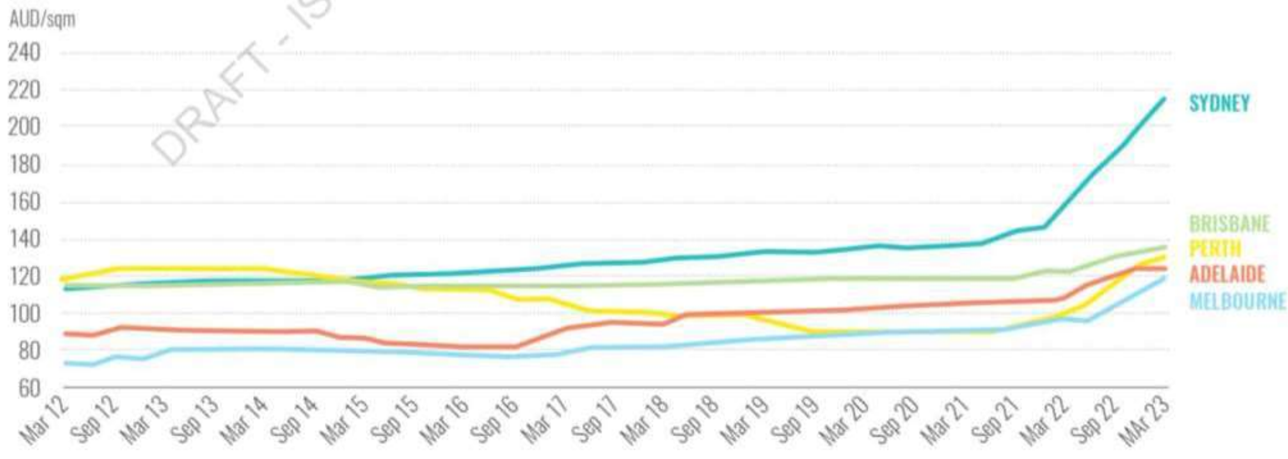
Table 3-2: Prime Net Rents, Outer West (2020-2022)

Outer West region	2020	2021	2022	Avg. Ann Growth (2020-2022)
<2,000sqm	$130-$140	$140-$150	$200-$250	24%
2,000sqm to 5,000sqm	$125-$140	$125-$140	$200-$250	26%
5,000sqm to 10,000sqm	$125-$135	$125-$135	$185-$225	22%
>10,000sqm	$120-$130	$120-$135	$185-$225	23%

Source: Cushman and Wakefield (2020, 2021, 2022)

Figure 3-2 illustrates the significantly higher rents in Sydney compared to the rest of the country, highlighting further Sydney's affordability problem for businesses. The rapid scale of the increases in industrial rents in Sydney demonstrates the extent of the industrial land shortage.

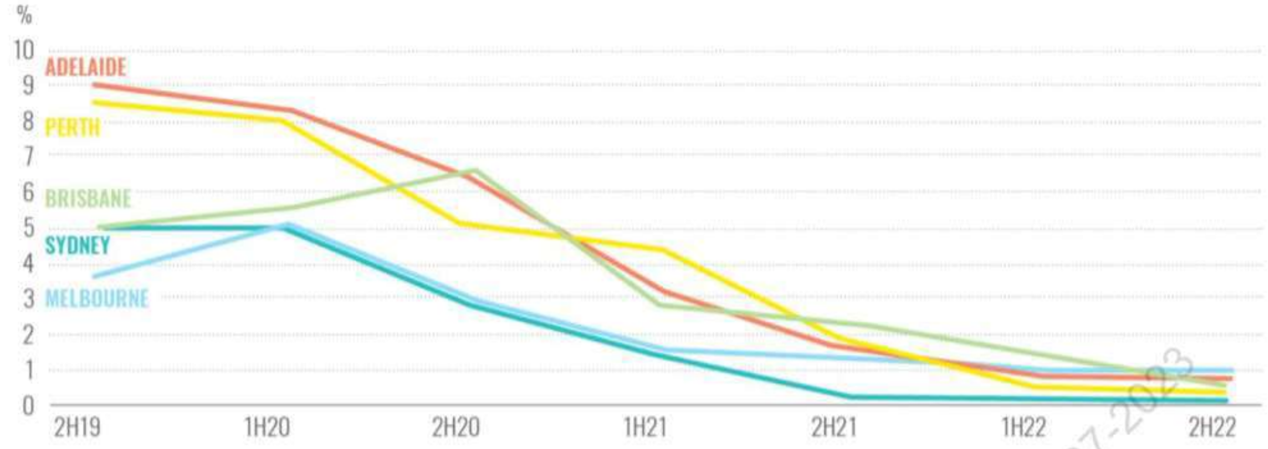
Figure 3-2: Prime Net Rents, Australian Major Markets (2022)



Source: CBRE (2023)

The shortage of industrial land in Sydney is so severe, not only does Sydney have the lowest industrial vacancy rate in Australia, but the world. **Figure 3-3** shows Sydney's vacancy level at 0.2%, which is cited to be the lowest in any global city.

Figure 3-3: Vacancy Rates, Australian Major Markets (2022)



Source: CBRE (2023)

All market indicators point to a severely undersupplied industrial market in Sydney - one that has insufficient supply of land to respond to market demand.

Take-up of Industrial Land

Annual take-up of industrial land in Greater Sydney has averaged 135ha in the 2017-2021 period. In contrast, metropolitan Melbourne's take-up of industrial land has averaged 288ha and Southeast QLD (SEQ)'s 190ha over the same period.

Table 3-3 and **Figure 3-4** compare the relative sizes of the capital city markets against their annual take-up of land.

Table 3-3: Annual Take-up of Industrial Land - Sydney, Melbourne, Brisbane and SEQ (2017-2021)

Region	Value of Industrial Sector (IVA)	Population (2021)	Annual Land Take-up (ha)					
			2017	2018	2019	2020	2021	Avg. (2017-2021)
Greater Sydney	$70.0 billion	5.3 million	139.6	145.8	140.2	86.0	163.1	135.0
Metropolitan Melbourne	$62.7 billion	5.0 million	317.8	219.7	324.3	305.8	273.0	288.0
Brisbane Region	$30.3 billion	2.6 million		47.1	70.2	67.7	42.5	56.9
Southeast QLD (SEQ)		3.6 million		185.9	261.3	168.3	146.2	190.4

Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

Figure 3-4: Annual Take-up of Industrial Land (2017-2021)

Source: DPE (2022), DELWP, DSDMIP, CBRE, Atlas

Sydney has the largest population base (5.3 million residents) compared to Melbourne (5.0 million residents) and SEQ (3.6 million residents). Furthermore, container throughput in Sydney is similar to Melbourne and much greater than Brisbane. Despite these factors, Sydney's average annual take-up of land has been less than 50% of Melbourne's 290ha per annum and only 70% of SEQ's 190ha per annum, a region that is less than 70% the size of Sydney.

The analysis highlights that a lack of serviced land supply in Sydney has constrained its ability to respond to demand and resulted in escalating rents and almost zero vacancy.

Data for industrial land take-up for 2022 is not available from the ELDM, however discussions with real estate professionals as well as published data from agency firms highlights that industrial take-up was 290ha in 2022 (Colliers, Q1 2023).

The next section explores Sydney's ability to meet demand by examining its remaining supply of industrial lands.

3.3 Remaining Supply of Industrial Lands

<u>Land Supply</u>

As at January 2022, the DPE's Employment Land Development Monitor (ELDM) showed the supply of undeveloped zoned and serviced land in Greater Sydney was 588ha (only 8% of total undeveloped zoned land). The Western City had 374ha of zoned and serviced land (which was less than 7% of zoned land).

Currently (at the time of writing in June 2023), the amount of serviced land is even lower after allowing for take-up and development of land during 2022 and 2023. Based on published research from agency firms as well as with industry, currently, industrial land stocks would be close to exhaustion.

Figure 3-5 illustrates the supply of undeveloped land in Greater Sydney (serviced and not serviced) as at January 2022.

Figure 3-5: Undeveloped Zoned Land and Serviced Land, Greater Sydney (January 2022)

Source: DPE (2022)

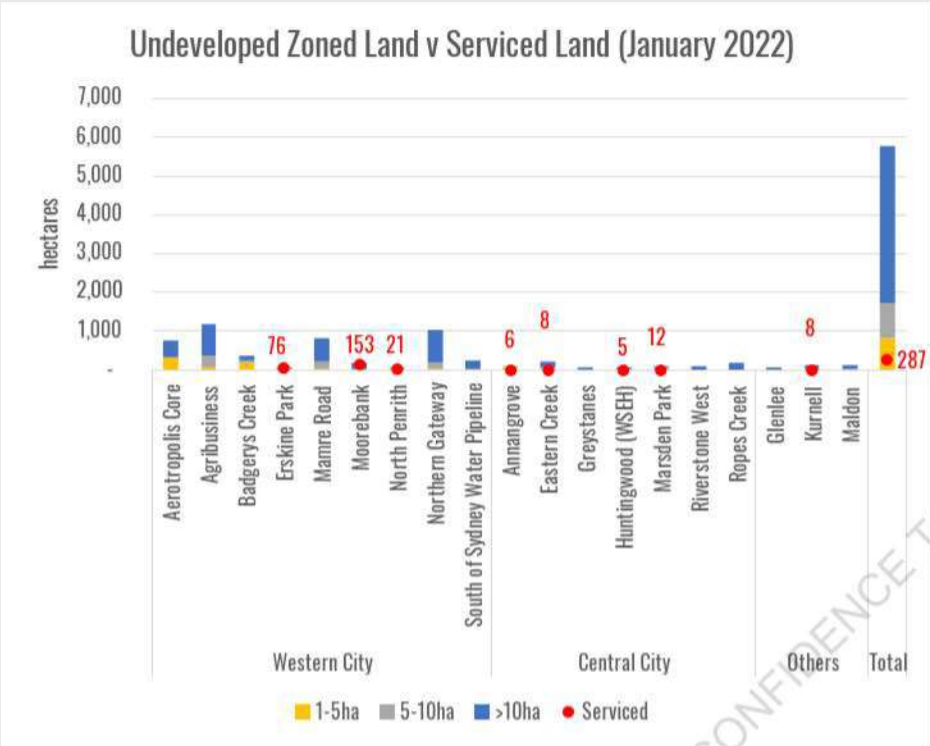
These simple land supply metrics do not provide the whole picture. To be desirable from a market and industry perspective, the land needs to be appropriately located and possess size and site attributes that make development viable. For many years industrial site size requirements have been becoming larger to keep up with demand. The following recent projects demonstrate:

- Techtronic Industries (75,000sqm).
- Toll (68,000sqm).
- Woolworths Distribution Centre (76,000sqm at Wetherill Park, 35,000 at Kemps Creek).
- Australia Post Distribution Centre (36,000sqm).
- Mainfreight Distribution Centre (55,800sqm).

Of the precincts listed in the ELDM as having serviced land, only four have land size greater than 20ha. At the time of writing, Atlas is aware of two sites that accommodate warehouses >30,000sqm, with one of those sites requiring tenants to have connection to the Moorebank Intermodal Terminal.

Atlas undertook an exercise of identifying undeveloped zoned and serviced land greater than 1ha, shown in **Figure 3-6**.

Figure 3-6: Undeveloped Zoned Land and Serviced Land by Size, >1ha (January 2022)



Source: DPE (2022)

The analysis reveals that 287ha of land in Greater Sydney is sized >1ha (compared to the overall 588ha of serviced land available). Furthermore, the data is at January 2022 and does not account for take-up of land in 2022 and 2023.

At an annual take-up rate of 300ha (the likely take-up in 2022 and similar to demand levels in Melbourne), Sydney has less than one year of remaining industrial land supply.

<u>Sydney v Melbourne and Brisbane</u>

The analysis above shows that Greater Sydney has less than one year of remaining industrial land supply.

In Melbourne, as at 2021, there was 7,856ha of vacant zoned industrial land, of which 4,557ha (58%) is within State Significant Industrial Precincts (SSIPs). Victoria's precinct structure planning process coordinates land rezoning and infrastructure servicing. At an annual absorption rate of 300ha, the land supply in the SSIPs is equivalent to 15 years supply.

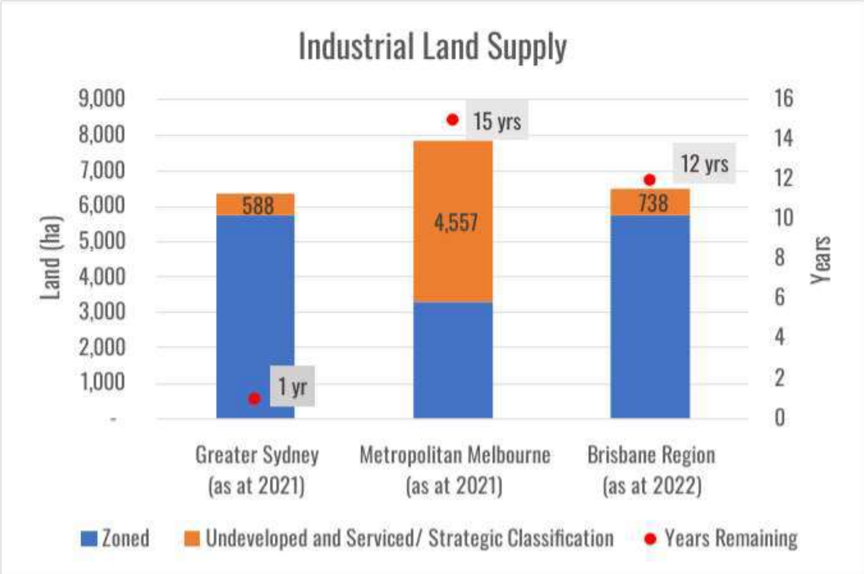
In the Brisbane region, as at September 2022 there was more than 700ha of serviced vacant land. At an annual absorption rate of 60ha, the serviced land supply is equivalent to 12 years supply.

Both State Governments in Victoria and Queensland have supply buffer policies that require 15 years of forward land supply.

Figure 3-7 compares Sydney's remaining industrial land supply with Metropolitan Melbourne and the Brisbane region.

Atlas ECONOMICS

Figure 3-7: Industrial Land Supply - Sydney, Melbourne and Brisbane



Source: Atlas

3.4 Implications for Greater Sydney's Competitiveness

The lack of serviced industrial land has evidently constrained Sydney's take-up of land. Over the 2017-2021 period, Sydney has averaged 135ha per annum whereas Melbourne and SEQ have averaged 290ha and 190ha per annum respectively.

For the largest capital city in Australia with both the largest population base and largest industrial sector, demand for land would be expected to be at least more than just 135ha per annum.

The analysis of data from the ELDM and Atlas' analysis of ABS data affirms that a constrained land supply situation has 'held back' investment and growth of the Industrial sector, with employment growth in Greater Sydney averaging 0.5% per annum over the 2016-2021 period compared to Melbourne's annual average of 1.2% and Brisbane's annual average of 1.1% over the same 2016-2021 period.

With less than one year of serviced supply remaining (compared to 15 years in Melbourne and 12 years in Brisbane), there is no room for business investment, business growth and further employment opportunities.

In 2019 when progressing the rezoning of the Mamre Road Precinct, DPE identified 4-5 years of land remaining. Since then, there has been no large scale servicing of land and structural changes following the COVID-19 pandemic have turbo-charged land demand. The low stock levels have now been depleted. This has been met with near zero vacancy and skyrocketing rents. This has severely affected Sydney's national competitiveness and added to the cost of living.

The Mamre Road Precinct is therefore an important part of the solution to easing Sydney's chronic capacity issue.

The Industrial sector is important to the regional and State economies, providing a growing number of jobs in Sydney.

The Industrial sector is not just important in its own right in terms of its economic contribution, but the fact that the industrial sector in general (and logistics sector specifically) supports many other industries across the economy, so constraints in the industrial sector will impact other parts of the economy as well.

The shortage of serviced, industrial land in Sydney has reached a critical point. The incredibly low vacancy rate and spiking prices demonstrate the severity of the issue and remaining serviced, industrial land stocks are almost exhausted.

The Mamre Road Precinct is important to not only solve the shortage of industrial land, but to allow the Sydney economy to grow, triggering business investment, generating new jobs and supporting the rest of the economy to grow as well.

4. Feasibility Analysis of Development

4.1 Methodology

Generic feasibility testing is carried out to ascertain the tolerance of development in the Precinct to the proposed water infrastructure charges. The Hypothetical Development or Residual Land Value (RLV) approach is adopted for the purposes of feasibility testing.

The RLV approach involves assessing the value of hypothetical development, considering total potential revenue and development costs, and making a further deduction for the profit and risk that a developer would require to take on the project.

The RLV can be defined as the maximum price a developer would be prepared to pay for a site in exchange for the opportunity to develop the site based on proposed (or existing) planning controls, whilst achieving target hurdle rates for profit and project return.

<u>Key Assumptions</u>

Feasibility modelling is premised on a notional development scheme - development yields assumed are the product of numeric application of site cover ratio (or FSR) to an assumed gross site area and net developable area (NDA) metrics.

Cost and revenue assumptions are generic and do not have regard to site-specific characteristics (e.g. topography, environmental factors, etc.) that a detailed site feasibility analysis/market valuation would typically have.

Revenue assumptions adopted are informed by a property market appraisal and consultation with marketing agents active in Western Sydney. Cost assumptions adopted are derived from standard industry publications and past experience.

The cash rate was kept at record lows for the last five years, with that and financing costs returning to long-term trend. Since their lowest position in mid-2022, average yields have softened by 95bps (Knight Frank, 2023). A minor softening of market yields by 25bps can extinguish any margins and render a project not feasible.

The set of revenue and cost assumptions adopted in feasibility testing are provided in SCHEDULE 1.

<u>Hurdle Rates</u>

In assessing the tolerance of development to contributing to the proposed water infrastructure charges, the key performance indicators and metrics relied upon are development margin[2] and project IRR[3].

The objective of feasibility testing is to assess if, after contribution to the water charges, development margin and project IRR are within acceptable range. Where development is found to result in either development margin or project IRR falling below the acceptance range, it is concluded that there is no tolerance to the proposed water charges.

Benchmark hurdle rates and their 'feasible' ranges for each development typology are indicated in **Table 4.1**.

Table 4.1: Benchmark Hurdle Rates

Hurdle Rates	Feasible	Marginal to Feasible	Not Feasible
Return on Cost (Development Margin)	>18%	16%-18%	<16%
Project IRR	>18%	16%-18%	<16%

Source: Atlas

Target hurdle rates depend on the perceived risk associated with a project. Risks generally include planning, market, financial and construction risk. The greater the risk the higher the hurdle rates required for investment. The Precinct has been rezoned, with precinct plans and development control plans in place to guide future development applications. Servicing and road infrastructure are however uncertain.

The adopted benchmark hurdle rates align with industry/ market expectations and are consistent with Atlas' previous work.

[2] Development Margin is profit divided by total costs (including selling costs)
[3] Project IRR is the project return on investment, where the discount rate where the cash inflows and cash outflows are equal

4.2 Review of Development Feasibility

The feasibility testing utilises the Hypothetical Development method or Residual Land Value (RLV) method. If the residual land value is the same as (or exceeds) the assumed cost of land while achieving the target hurdle rates (identified in **Table 4.1**), the development is considered feasible.

Tested Development and Scenarios

The section develops a notional development reflecting a 'likely' development in the Precinct. The development is then tested for impact of the proposed water infrastructure. The feasibility testing is shown in several steps:

1. Development (with s7.11 contributions only)
2. Development (with s7.11 contributions and SIC)
3. Development (with s7.11 contributions, SIC and proposed water charges)
    - Proposed DSP charges (drinking water and wastewater) at $50,000/ha NDA
    - Proposed stormwater and recycled water at $1,300,000/ha NDA (also a reduced charge or $1,150,000/ha NDA for stormwater only)

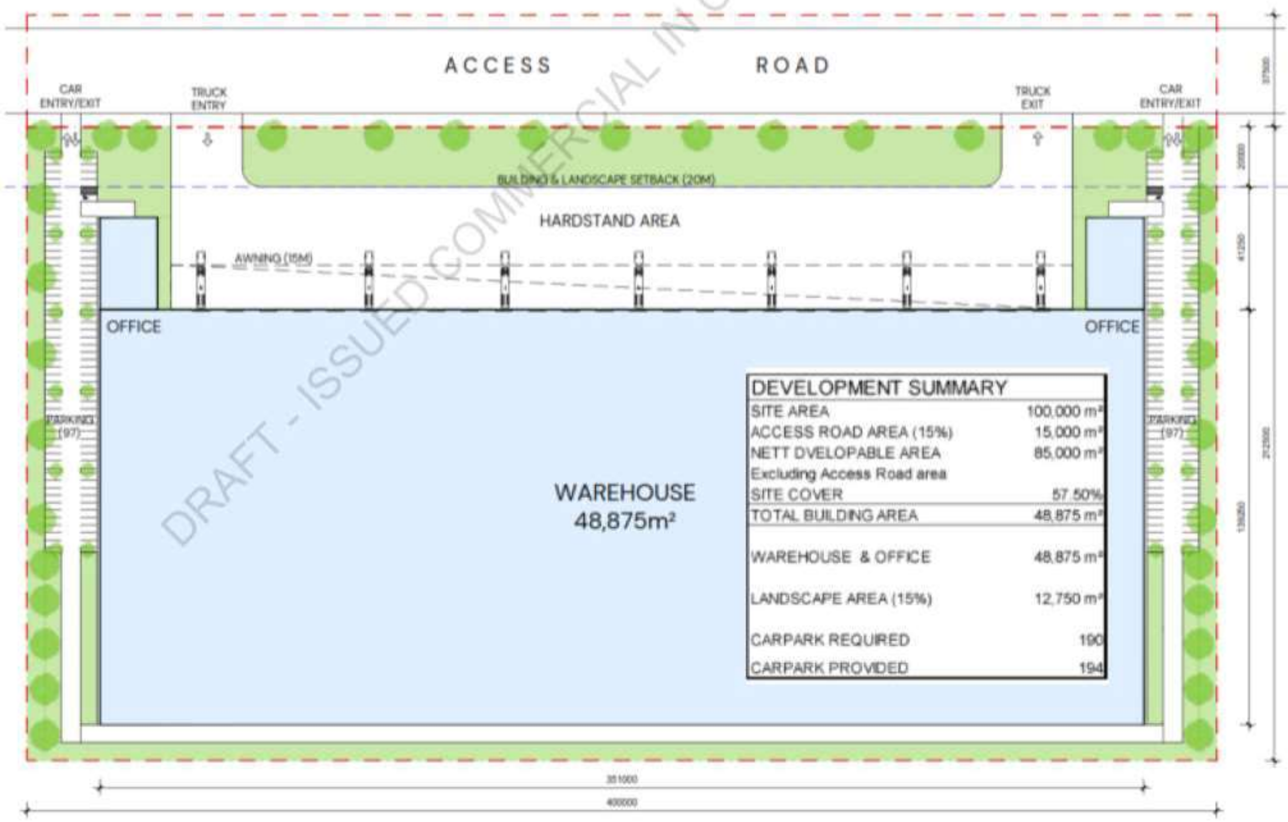
Table 4-2 provides a numerical overview of the assumed development parameters and **Figure 4-1** shows an indicative site plan of the assumed development parameters for the purposes of feasibility testing.

Table 4-2: Notional Development Parameters

Gross Site Area (sqm)	NDA (sqm)	Site Cover	GLA/GFA (sqm)*	Parking
100,000	85,000 (85%)	57.5%	48,875	At-grade

*Gross Lettable Area and Gross Floor Area are assumed similar for the analysis
Source: Atlas

Figure 4-1: Indicative Site Plan of Assumed Development Parameters



Source: ESR

Table 4-3 outlines the assumed rates for the fees and charges. Other statutory fees including DA fees, CC fees, long service levy, etc. are also included.

Table 4-3: Assumed Fees and Charges

Fees and Charges	$/ha NDA	$/sqm NDA
s7.11 contributions (as at March 2023)	$669,000	$66.9
SIC (as at 1 July 2022)	$210,763	$21.1
Proposed DSP charges (drinking water and wastewater)	$50,000	$5.0
Proposed stormwater and recycled water charges	$1,300,000	$130
Proposed reduced charge (stormwater only)	$1,150,000	$115

Source: Atlas

The RLV method requires cost and revenue assumptions which are detailed in SCHEDULE 1.

Modelling Results

Table 4-4 summarises the results and compares the feasibility indicators (with and without the proposed water charges).

Table 4-4: Feasibility Testing Results

Item	s7.11 only	s7.11, SIC	s7.11, SIC, water (DSP at $50k/ha, stormwater at $1.3m/ha)	s7.11, SIC, water (DSP at $50k/ha, stormwater at $1.15m/ha)
Gross Site Area (sqm)	100,000	100,000	100,000	100,000
Net Developable Area (sqm)	85,000	85,000	85,000	85,000
Gross Floor Area (sqm)	48,875	48,875	48,875	48,875
Assumed Fees and Charges ($/sqm)				
s7.11 contributions	$66.9	$66.9	$66.9	$66.9
Special Infrastructure Contributions (SIC)		$21.1	$21.1	$21.1
DSP charges (drinking water, wastewater)			$5.0	$5.0
Stormwater/ recycled water charges			$130.0	$115.0
Revenue				
Gross Sales Revenue*	$194,101,709	$194,101,709	$194,101,709	$194,101,709
Less: Selling Costs	$3,882,034	$3,882,034	$3,882,034	$3,882,034
Net Sales Revenue	$190,219,675	$190,219,675	$190,219,675	$190,219,675
Total Revenue	**$190,219,675**	**$190,219,675**	**$190,219,675**	**$190,219,675**
Costs				
Land Purchase Cost	**$57,500,000**	**$57,500,000**	**$57,500,000**	**$57,500,000**
Transaction Costs	$3,434,200	$3,434,200	$3,434,200	$3,434,200
Construction Costs (incl. Contingency)	$59,016,562	$59,016,562	$59,016,562	$59,016,562
Professional Fees	$5,016,408	$5,016,408	$5,016,408	$5,016,408
Statutory Fees (incl. s7.11)	$4,974,571	$4,974,571	$4,974,571	$4,974,571
Estate Servicing	$20,000,000	$20,000,000	$20,000,000	$20,000,000
Special Infrastructure Contributions	-	$1,791,486	$1,791,486	$1,791,486
Water Infrastructure Charges	-	-	$11,475,000	$10,200,000
Land Holding Costs	$2,463,272	$2,463,272	$2,463,272	$2,463,272
Finance Charges	$350,000	$350,000	$350,000	$350,000
Interest Expense	$5,499,752	$5,689,358	$6,903,843	$6,768,900
Total Costs	**$158,254,765**	**$160,235,857**	**$172,925,342**	**$171,515,399**
Performance Indicators				
Return on Cost	19.7%	18.3%	9.8%	10.7%
Residual Land Value	**$59,695,360**	**$57,852,841**	**$46,005,935**	**$47,321,535**
Feasible?	Yes	Yes	No	No

*Based on current net market rents of $185/sqm and capitalisation rate of 4.75%

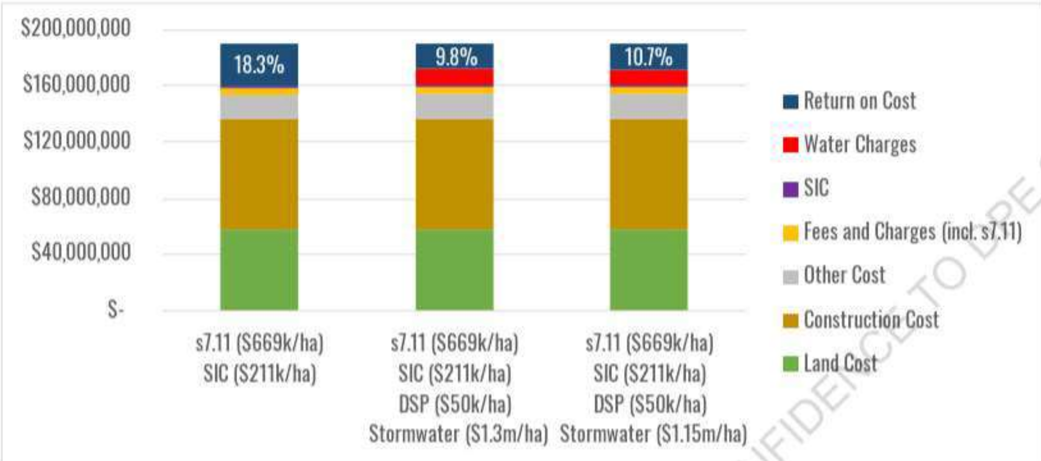
The assumed cost of land is $575/sqm site area, which aligns with the assumed cost of land (as at 2021) in the Mamre Road Precinct Development Contributions Plan. Atlas acknowledges that the assumed cost of $575/sqm is a conservative assumption, which is below current market transactions.

The modelling results indicate:

- Development which includes s7.11 contributions and SIC is just feasible - return on cost is 18.3%.
- After inclusion of the proposed DSP and stormwater charges ($1.35m/ha NDA), development feasibility is severely affected. The return on cost is at 9.8%, which is well below the target of 18%.
- At a reduced stormwater charge of $1.15m/ha NDA, the return on cost is 10.7%, also well below the target of 18%.

Figure 4-2 illustrates the impact of inclusion of the proposed water infrastructure charges on return on cost.

Figure 4-2: Comparison of Feasibility Modelling Results



Source: Atlas

The feasibility modelling shows the proposed water charges are significantly more than what is tolerated by development.

4.3 Scope for Water Infrastructure Charges

After the proposed DSP and stormwater charges, feasibility is adversely and significantly affected. At current assumptions, development has no capacity to pay for water charges at the proposed rates (even if reduced to $1,150,000/ha NDA).

Atlas understands that NSW Government published a report in 2022 named *Review of Water-sensitive Urban Design Strategies for Wianamatta - South Creek* (**the 2022 report**), which provided estimates of stormwater costs and indicative levies. The report concluded a $191,000/ha (infrastructure works) and $96,000/ha (land acquisition costs) to facilitate delivery of a regional stormwater system. This totals $287,000/ha ($29/sqm) for stormwater levies.

Given that development feasibility is marginal even before any water infrastructure charges, a cost of $287,000/ha would require higher rents to be charged. Current net rents average $185/sqm in the Precinct, which are 50% more than three years ago. A 5% increase would increase net rents to $195/sqm, which would put even more cost pressure on businesses.

The feasibility modelling in section 4.2 assumed net rents of $185/sqm and capitalisation rate of 4.75% to arrive at a building capital value of $3,900/sqm. A net rent of $195/sqm capitalised at 4.75% would arrive at $4,105/sqm building capital value.

Capitalisation rates have been at historic lows and the assumed 4.75% rate is not sustainable in the longer term.

Table 4-5 tests the sensitivity of building capital values to assumed net rents and softer capitalisation rates (5.0% and 5.25%). A softening to 5% reduces value from $4,105/sqm to $3,900/sqm, extinguishing any increase in value from the higher rent.

Table 4-5: Sensitivity of Building Capital Values to Rents and Capitalisation Rates

Net Rent capitalised at	4.75%	5.0%	5.25%
$185/sqm	$3,895	$3,700	$3,524
$195/sqm	$4,105	$3,900	$3,714

Table 4-6 applies the capital values derived in **Table 4-5** under different rents and capitalisation rates assuming:

- Cost of $287,000/ha for stormwater charges.
- Construction costs increased by $50/sqm to $1,200/sqm (as is indicated by current construction contracts).

Table 4-6: Feasibility Testing Results assuming Stormwater at $287,000/ha NDA

Item	s7.11, SIC, water (DSP at $50k/ha, stormwater at $1.15m/ha)	s7.11, SIC, water (DSP at $50k/ha, stormwater at $287k/ha)	s7.11, SIC, water (DSP at $50k/ha, stormwater at $287k/ha)	s7.11, SIC, water (DSP at $50k/ha, stormwater at $287k/ha)
Gross Site Area (sqm)	100,000	100,000	100,000	100,000
Net Developable Area (sqm)	85,000	85,000	85,000	85,000
Gross Floor Area (sqm)	48,875	48,875	48,875	48,875
Revenue Assumptions				
Net rent ($/sqm)	$185	$195	$195	$195
Capitalisation rate	4.75%	4.75%	5.00%	5.25%
Building capital value ($/sqm)	$3,895	$4,105	$3,900	$3,714
Cost Assumptions				
Build cost ($/sqm)	$1,150	$1,200	$1,200	$1,200
Assumed Fees and Charges ($/sqm)				
s7.11 contributions	$66.9	$66.9	$66.9	$66.9
Special Infrastructure Contributions (SIC)	$21.1	$21.1	$21.1	$21.1
DSP charges (drinking water, wastewater)	$5.0	$5.0	$5.0	$5.0
Stormwater/ recycled water charges	$115.0	$28.7	$28.7	$28.7
Revenue				
Gross Sales Revenue	$194,101,709	$204,593,693	$194,364,008	$185,108,579
Less: Selling Costs	$3,882,034	$4,091,874	$3,887,280	$3,702,172
Net Sales Revenue	$190,219,675	$200,501,819	$190,476,728	$181,406,408
Total Revenue	**$190,219,675**	**$200,501,819**	**$190,476,728**	**$181,406,408**
Costs				
Land Purchase Cost	**$57,500,000**	**$57,500,000**	**$57,500,000**	**$57,500,000**
Transaction Costs	$3,434,200	$3,434,200	$3,434,200	$3,434,200
Construction Costs (incl. Contingency)	$59,016,562	$61,582,500	$61,582,500	$61,582,500
Professional Fees	$5,016,408	$5,234,513	$5,234,513	$5,234,513
Statutory Fees (incl. s7.11)	$4,974,571	$4,986,648	$4,986,648	$4,986,648
Estate Servicing	$20,000,000	$20,000,000	$20,000,000	$20,000,000
Special Infrastructure Contributions	$1,791,486	$1,791,486	$1,791,486	$1,791,486
Water Infrastructure Charges	$10,200,000	$2,864,500	$2,864,500	$2,864,500
Land Holding Costs	$2,463,272	$2,463,272	$2,463,272	$2,463,272
Finance Charges	$350,000	$350,000	$350,000	$350,000
Interest Expense	$6,768,900	$6,095,999	$6,095,999	$6,095,999
Total Costs	**$171,515,399**	**$166,303,117**	**$166,303,117**	**$166,303,117**
Performance Indicators				
Return on Cost	10.7%	20.1%	14.2%	8.9%
Residual Land Value	**$47,321,535**	**$60,285,323**	**$52,383,645**	**$45,234,917**
Feasible?	No	Yes	No	No

The feasibility modelling shows how sensitive building capital values are to the capitalisation rate. Even if rents were able to be increased to $195/sqm, a softening of 25bps to 5.0% effectively extinguishes any increase in building capital value from the higher rent.

The modelling finds there is provisional capacity to pay a $287,000/ha charge if rents were increased to $195/sqm (from $185/sqm), however this is subject to:

- Tenants agreeing to a higher net rent of $195/sqm.
- Market yields (and capitalisation rate) softening by no more than 25bps.
- Construction cost at no more than $1,200/sqm.
- No other water infrastructure costs (e.g. interim on-site infrastructure and/ or loss of developable area).
- All infrastructure required to deliver the Precinct (not just utilities infrastructure but road and other infrastructure) in a timely manner is certain.

The cost of construction has been under significant upward pressure in the last 24 months. Some industry commentators expect cost rate escalations to return to trend from 2025. This does not mean construction cost prices will return to their previous levels, merely that annual cost rises will be circa 3%-4%. It is unknown whether construction costs will continue to face sustained upward pressure and the extent of cost inflation likely to be witnessed over the medium term.

A net rent of $195/sqm does not reflect rents agreed with the already committed tenants in the Precinct. This rent increase is untested with the market. Due to the severely constrained supply in Greater Sydney, businesses are already paying 50% more rent than they were three years ago. This has placed significant cost pressure on businesses. Businesses may well decide to remain in their existing, smaller premises if higher rents are not viable for their business operating model.

Financing costs and market yields have been at historic lows for the last few years. The softening of hurdle rates is inevitable and especially given the increase in financing costs and increasing global uncertainty. Indeed, average yields are noted to have softened by 95bps since their lowest position in mid-2022 (Knight Frank, 2023). As **Table 4-5** has shown, softening of the adopted 4.75% capitalisation rate by 25bps to 5.0% extinguishes the revenue gains from the higher $195/sqm rents.

Implications for the Precinct

The modelling shows that if the recommendations of the 2022 report were adopted and a stormwater charge of $287,000/ha were required, there would only be capacity for development to pay but an increase in rent to at least $195/sqm would be required. Rents at this level are not tested with the market.

New tenants (other than those already committed) ***may*** be willing to pay $195/sqm if they can be assured of the delivery of warehouse premises in the time required, i.e. that all infrastructure required (road and utilities infrastructure) was certain to be delivered in a timely manner.

Rents in the Precinct currently average $185/sqm which are 50% more than they were three years ago. This is 55% more than average Melbourne rents ($120/sqm) and 37% more than average Brisbane rents ($135/sqm). Accordingly, there is little capacity for business tenants to pay much higher rents as they grapple with the rising cost of fuel and energy and reduction in demand for non-essential goods.

Any increase in rents in the Precinct will either be met with resistance (i.e. tenants will remain in current, smaller premises or pursue development opportunities in other states) or if accepted, the higher rent is expected to be passed onto their customers.

5. Economic Impacts of Mamre Road Precinct

This chapter examines the economic activity and impacts that could result through delivery of the Mamre Road Precinct (**the Proposal**) during construction works and through ongoing activity upon completion.

5.1 Overview and Approach

Economic impacts are considered against a Base Case of no Government intervention where development is not feasible. Some committed developments can progress, however, the vast majority of development is no longer feasible to deliver and will not proceed.

The Landowners' Group controls 550ha zoned land (equivalent to approximately 466ha NDA). More than 200ha of the developable land has been committed to (referred to as **Stage 1**), with the remaining 263ha for future development (referred to as **Stage 2**).

Methodology

Atlas reviewed details of more than 20 businesses who have committed to the Precinct (who have signed heads of agreement) to build a profile understanding of:

- Floorspace and land committed in the Precinct.
- Industry sector and sub-sector (by ANZSIC).
- Whether the occupier was a new entrant to Sydney or if premises at Mamre Road represented an expansion of their current business operations.

Table 5-1 develops a profile of business activity that could occur in the Precinct (in Stage 1) should development proceed as planned. For the purposes of modelling the economic impacts, the profile of business activity in Stage 1 is assumed to be replicated in Stage 2.

Table 5-1: Profile of Businesses Committed to the Precinct

Industry	Land Committed (ha)	%	Floorspace Committed (sqm)	%
Basic Chemical Manufacturing	5.3	2.6%	24,785	2.4%
Wholesale Trade	45.1	22.1%	234,289	22.5%
Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals	23.5	11.5%	164,288	15.8%
Motor Vehicles and Parts, Other Transport Equipment Manufacturing	3.4	1.7%	8,640	0.8%
Human Pharmaceutical and Medicinal Product Manufacturing	5.0	2.5%	28,955	2.8%
Road Transport	115.8	56.8%	550,607	52.9%
Other Fabricated Metal Product Manufacturing	2.8	1.4%	14,000	1.3%
Plaster and Concrete Product Manufacturing	3.0	1.5%	15,000	1.4%
Total	**203.8**	**100.0%**	**1,040,564**	**100.0%**

Source: Landowners' Group, Atlas

The committed floorspace (1,040,564sqm) is equivalent to approximately FSR 0.5:1, which is consistent with on-the-ground observations in other estates.

Atlas undertook a process in collaboration with the leasing agents responsible for placing the businesses at the Precinct of identifying whether the premises would be an expansion/ consolidation of current premises elsewhere in Sydney or if the premises represent a net addition. In the case of the former, the economic impacts associated with the expanded floorspace (net new floorspace) was considered for modelling. As such, the economic impact considered only *net new economic activity* and excludes any existing economy activity already taking place in the Sydney region by the businesses committed to the Precinct.

After building the likely occupier/ business activity profile, Atlas assessed the economic impacts of the activity at the Greater Sydney level. An Input-Output model (including the development of specific regional Input-Output transaction tables) was developed to reflect the economic structure of Greater Sydney (see SCHEDULE 2 for further detail).

Input-Output modelling considers economic activity through examining four types of impacts as described in **Table 5-2**.

Table 5-2: Economic Indicators

Indicator	Description
Output	The gross value of goods and services transacted, including the cost of goods and services used in the development and provision of the final product. Care should be taken when using output as an indicator of economic activity as it counts all goods and services used in one stage of production as an input to later stages of production, thus overstating economic activity.
Gross Value Added	The value of output after deducting the cost of goods and services inputs in the production process (less the impact of net taxes on final production). Gross Value Added (GVA) defines a net contribution to economic activity.
Incomes	The wages and salaries paid to employees as a result of the Project either directly or indirectly.
Employment	Employment positions generated by the Project or Proposal (either full time or part time, directly or indirectly). Employment is reported in terms of Full-time Equivalent (FTE) positions or person-years.

Source: Atlas

Input-Output modelling estimates show the impacts of direct spending in a particular industry as well as from Production-induced impacts (Type I) or Consumption-induced impacts (Type II).

- **Production-induced impacts (Type I)** show the effects of industrial support effects of additional activities undertaken by supply chain industries increasing their production in response to direct and subsequent rounds of spending.
- **Consumption-induced impacts (Type II)** estimate the re-circulation of labour income earned as a result of the initial spending, through other industry impacts, and impacts from increased household consumption.

The estimates of economic impacts consider production and consumption-induced flow-on impacts. Type II impacts are commonly considered to overstate economic activity and therefore the types of flow-on impacts are reported separately.

Drivers of Economic Activity

To understand the economic impacts likely to result from the Proposal, it is necessary to distinguish economic impacts during the construction phase and those economic impacts that will be more permanent in nature following construction completion and operations commencement and stabilisation to long-run averages.

- **Construction Phase:** Construction activity will draw resources from and thereby generate economic activity in Greater Sydney. Modelling assumes the construction phase is serviced by labour and businesses within the Greater Sydney area.
- **Operational Phase:** Estimated ongoing economic activity from industrial businesses locating into the Precinct.

Economic activity through the construction and operational phases has been divided into:

- **Stage 1 Committed Development (Net Additional Activity):** Activity generated through committed developments within the Precinct. Economic activity from these occupiers has been reported net of:
  - Existing regional employment space (elsewhere in Sydney) that will be vacated to relocate into Mamre Road.
  - Developments that are likely to go ahead elsewhere or within the Precinct regardless of proposed water infrastructure charges.
- **Stage 2 Future Development Activity:** Activity on parcels of land within the Precinct that have not yet been committed to by a specific operator but will be available for future development. Assumptions have been made by Atlas regarding the types of businesses that will likely occupy this space in the future given the mix of committed developments. Estimates of future activity have been reported without allowance for relocation from existing employment space within Greater Sydney.

Refer to SCHEDULE 2 for a description of the drivers and assumptions that underpin the assessed economic impacts.

5.2 Economic Activity and Impacts

Economic impacts arising in the construction phase are estimated separately to the operational phase. Construction impacts are expected to be short-term in nature (occurring as individual sites are developed) and will conclude when development activity is completed.

Construction Phase

Through construction works the Proposal is projected to generate significant economic impacts for Greater Sydney, including:

- **Stage 1** - currently committed developments are estimated to generate:
  - $3.3 billion in output (including $1.5 billion in direct activity).
  - $1.3 billion contribution to GVA (including $472.8 million in direct activity).
  - $671.6 million in incomes and salaries paid to households (including $233.9 million in direct income). Based on NSW current payroll tax rate of 4.45% this would result in up to $36.6 million in payroll tax depending on the share of wages paid above the payroll tax threshold.
  - 6,679 FTE jobs (including 2,501 FTE directly employed in construction activity).
- **Stage 2** - future development activity has the potential to generate even greater activity over the longer term:
  - $7.0 billion in output (including $3.3 billion in direct activity).
  - $2.8 billion contribution to GVA (including $924.6 million in direct activity).
  - $1.5 billion in incomes and salaries paid to households (including $505.6 million in direct income) and up to $79.1 million in payroll tax contribution.
  - 14,435 FTE jobs (including 5,405 FTE directly employed in construction activity).

Economic impacts during construction are summarised in **Table 5-3**.

Atlas highlights that construction impacts are reported ***in total*** for the construction phase over the life of the development, and do not represent an average annual estimate.

Table 5-3: The Proposal Construction Impacts, Greater Sydney

Indicator	Output ($M)	GVA ($M)	Incomes ($M)	Employment (FTE)
Committed Development (Stage 1)				
Direct	$1,541.1	$427.8	$233.9	2,501
Flow-on Type I	$928.6	$419.6	$246.8	2,204
Flow-on Type II	$784.3	$441.4	$190.9	1,974
Total	**$3,254.0**	**$1,288.7**	**$671.6**	**6,679**
Future Development Activity (Stage 2)				
Direct	$3,330.7	$924.6	$505.6	5,405
Flow-on Type I	$2,006.9	$906.9	$533.3	4,764
Flow-on Type II	$1,695.1	$953.9	$412.7	4,266
Total	**$7,032.7**	**$2,785.3**	**$1,451.6**	**14,435**
Total Economic Activity				
Direct	$4,871.7	$1,352.6	$739.6	7,906
Flow-on Type I	$2,935.9	$1,326.9	$780.3	6,968
Flow-on Type II	$2,479.1	$1,394.9	$603.7	6,240
Total	**$10,286.7**	**$4,074.4**	**$2,123.6**	**21,114**

Note: Totals may not sum due to rounding
Source: Atlas

The Proposal is estimated to result in significant construction activity over the life of the development (Stage 1 and 2):

- $10.3 billion additional in output (including $4.9 billion in direct activity).
- $4.1 billion additional in contribution to GVA (including $1.4 billion in direct activity).
- $2.1 billion additional in incomes and salaries paid to households (including $739.6 million directly).
- Up to $115.7 million payroll tax contribution.
- 21,114 additional FTE jobs (including 7,906 additional FTE jobs directly).

Operational Phase

Following the completion of construction, the Proposal is estimated to support the following annual economic activity through direct and indirect (flow-on) impacts associated with operations in the Precinct:

- **Stage 1** Committed Developments (Net Additional Activity):
    - $3.0 billion in output (including $1.3 billion in direct activity).
    - $1.5 billion contribution to GVA (including $615.9 million in direct activity).
    - $781.3 million in incomes and salaries paid to households (including $360.3 million in direct income).
    - Up to $42.6 million payroll tax contribution.
    - 7,433 ongoing FTE jobs (including 3,333 FTE directly related to activity in the Precinct).
- **Stage 2** Future Developments (once fully developed and occupied):
    - $9.1 billion in output (including $4.2 billion in direct activity).
    - $4.5 billion contribution to GVA (including $1.9 billion in direct activity).
    - $2.3 billion in incomes and salaries paid to households (including $2.3 million in direct income).
    - Up to $126.5 million payroll tax contribution.
    - 21,015 ongoing FTE jobs (including 8,811 FTE directly related to activity in the Precinct).

Table 5-4 summarises the estimated economic impacts during the operational phase supported by Stage 1.

Table 5-4: Stage 1 Operational Impacts, Greater Sydney

Indicator	Output ($M)	GVA ($M)	Incomes ($M)	Employment (FTE)
Committed Development (Net Additional Activity)				
Direct	$1,340.6	$615.9	$360.3	3,333
Flow-on Type I	$782.1	$374.5	$215.1	1,972
Flow-on Type II	$845.6	$475.8	$205.8	2,128
Total	**$2,968.3**	**$1,466.2**	**$781.3**	**7,433**
Future Development Activity				
Direct	$4,175.3	$1,917.3	$1,056.1	8,811
Flow-on Type I	$2,453.6	$1,164.6	$654.0	5,880
Flow-on Type II	$2,512.7	$1,414.0	$611.7	6,324
Total	**$9,141.7**	**$4,496.0**	**$2,321.8**	**21,015**
Total Economic Activity				
Direct	$5,515.9	$2,533.2	$1,416.4	12,144
Flow-on Type I	$3,235.7	$1,539.1	$869.1	7,852
Flow-on Type II	$3,358.3	$1,889.8	$817.5	8,452
Total	**$12,110.0**	**$5,962.2**	**$3,103.1**	**28,448**

Note: Totals may not sum due to rounding.
Source: Atlas

The Proposal facilitates a significantly intensified use of the Precinct, accommodating more businesses and employment activity, resulting in greater levels of output and contribution to the Greater Sydney economy.

The Proposal (Stage 1 and Stage 2) is estimated to result in a total increase in economic activity (including committed and future developments once fully developed and occupied) through direct and indirect (flow-on) annually at:

- $12.1 billion additional in output (including $5.5 billion in direct activity).
- $6.0 billion additional in contribution to GVA (including $2.5 billion in direct activity).
- $3.1 billion additional in incomes and salaries paid to households (including $1.4 billion directly) and up to $169.1 million payroll tax contribution.
- 28,448 additional FTE jobs (including 12.144 additional FTE jobs directly related to activity in the Precinct).

The economic impacts estimated in this section demonstrates the Proposal has economic merit, having the ability to contribute significantly to the Greater Sydney economy.

5.3 Implications for Greater Sydney's Economy

Given the lack of serviced supply of industrial land in Greater Sydney, businesses that are committed to premises in the Precinct are not expected to be able to locate elsewhere. This means that the economic activity that is foregone in the Precinct will represent a ***net loss*** to the Greater Sydney economy.

The economic impacts to Greater Sydney's economy should development of the Precinct not occur would result in foregone business investment, employment opportunities and economic output.

There are more than 20 businesses who have already committed to the Precinct (approx. 204ha of land) and are ready to invest and create jobs. There are many more enquiries, but the uncertainty of delivery is deterring tenant commitment. Immediate development would facilitate the following annual economic activity through direct and indirect (flow-on) impacts associated with operations in the Precinct:

- $3.0 billion in output (including $1.3 billion in direct activity).
- $1.5 billion contribution to GVA (including $615.9 million in direct activity).
- $781.3 million in incomes and salaries paid to households (including $360.3 million in direct income).
- 7,433 ongoing FTE jobs (including 3,333 FTE directly related to activity in the Precinct).

Without available industrial land, Sydney's competitive position is at significant risk of losing these immediate opportunities and the 7,400 employment opportunities for Western Sydney. More broadly, without additional available and serviced industrial land, Greater Sydney has no room for more investment and will miss out on additional jobs.

The unlocking of development in the Precinct will add 3 years to Sydney's industrial land supply. While not solving the broader issue of land supply, it will provide temporary/ short-term relief. Government intervention to enable development in the Precinct is critical.

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Schedules

SCHEDULE 1

Development Feasibility Testing Assumptions

Feasibility modelling is undertaken to examine the tolerance of development to the proposed water infrastructure charges.

Development Typology

Based on proposed land uses in the Precinct, a typical development is numerically constructed for feasibility testing.

Table S1-1: Notional Development Parameters

Gross Site Area (sqm)	NDA (sqm)	Site Cover	GLA/GFA (sqm)*	Parking
100,000	85,000 (85%)	57.5%	48,875	At-grade

*Gross Lettable Area and Gross Floor Area are assumed similar for the analysis
Source: Atlas

Timing Assumptions

The following assumptions are made to reflect construction programme of the notional development.

Table S1-2: Timing of Development

Construction Program	Month Start	Month Span
Land purchase/ design	0	6
Development approvals	6	12
Infrastructure/ Estate servicing	18	8
Building works	26	14
Completion	40	1

Source: Atlas

Revenue Assumptions

Revenue assumptions for the completed industrial floorspace assume:

- Net market rent of $185/sqm lettable area.
- Capitalisation rate of 4.75% thereby resulting in a $3,900/sqm capital building value.

Other revenue assumptions:

- GST is excluded.
- Marketing and legal costs are each assumed at 0.25% of gross sales revenue.
- Sales commission on sales included at 1.5% of gross sales revenue.

Cost Assumptions

The cost of land assumed at $575/sqm of gross site area.

- Legal and due diligence costs assumed at 0.5% of land cost and is assumed to be paid on exchange in Month 1.
- The site is assumed to be appropriately zoned with design and development planning occurring immediately upon settlement.

Construction cost assumptions are generic in nature and based on experience and industry cost publications.

- Construction build cost at $1,150/sqm GFA.
- Estate servicing at $200/sqm of gross site area.

Other cost assumptions:

- Professional fees at 8.5% of construction cost expensed as follows:
  - 5.5% pre-construction (during design and DA documentation).
  - 3.0% pro-rated with construction.
- Construction contingency of 5% of construction cost.
- Statutory fees and charges:
  - DA, CC and long service levy at statutory rates.
  - Section 7.11 contributions at $668,893/ha NDA (assuming 20% can be offset against works-in-kind), as at March 2023.
  - SIC at $210,763/ha NDA (assuming no state roads), as at 1 July 2022.
- Holding costs including land tax, Council and water rates.

Other cost assumptions:

- Developer equity used for land purchase cost with remaining costs debt funded with interest capitalised monthly (nominal 5.5% per annum).
- Finance establishment cost of 0.35% of peak debt.

Hurdle Rates and Performance Indicators

Target hurdle rates are subject to perceived risk of a project (planning, market, financial and construction risk). The higher the project risk, the higher the hurdle rate. The following performance indicators are relied upon:

- Development Margin is profit divided by total development costs (including selling costs).
- Discount rate refers to the project internal rate of return (IRR) where net present values of an investment is zero.
- Residual Land Value is arrived at by assessing the maximum land value a developer is willing to pay based on both hurdles of development margin and discount rate being met.

The following benchmark hurdle rates are assumed.

Table S1-3: Benchmark Hurdle Rates

Hurdle Rates	Feasible	Marginal to Feasible	Not Feasible
Return on Cost (Development Margin)	>18%	16%-18%	<16%
Project IRR	>18%	16%-18%	<16%

Source: Atlas

Atlas ECONOMICS

SCHEDULE 2

Input-Output Modelling Methodology

Input-Output models are a method to describe and analyse forward and backward economic linkages between industries based on a matrix of monetary transactions. The model estimates how products sold (outputs) from one industry are purchased (inputs) in the production process by other industries.

The analysis of these industry linkages enables estimation of the overall economic impact within a catchment area due to a change in demand levels within a specific sector or sectors.

Impacts are traced through the economy via:

- **Direct impacts**, which are the first round of effects from direct operational expenditure on goods and services.
- **Flow-on impacts** (indirect impacts), which comprise the second and subsequent round effects of increased purchases by suppliers in response to increased sales. Flow-on impacts can be disaggregated to:
    - **Industry Support Effects (Type I)** derived from open Input-Output models. Type I impacts represent the production induced support activity as a result of additional expenditure by the industry experiencing the stimulus on goods and services, and subsequent round effects of increased purchases by suppliers in response to increased sales.
    - **Household Consumption Effects (Type II)** derived from closed Input-Output Models. Type II impacts represent the consumption induced activity from additional household expenditure on goods and services resulting from additional wages and salaries being paid within the catchment economy.

Economic analysis considers the following four types of impacts.

Table S2-1: Economic Activity Indicators

Indicator	Description
Output	The gross value of goods and services transacted, including the cost of goods and services used in the development and provision of the final product. Care should be taken when using output as an indicator of economic activity as it counts all goods and services used in one stage of production as an input to later stages of production, thus overstating economic activity.
Gross Value Added	The value of output after deducting the cost of goods and services inputs in the production process (less the impact of net taxes on final production). Gross Value Added (GVA) defines a net contribution to economic activity.
Incomes	The wages and salaries paid to employees as a result of the Project or Proposal either directly or indirectly.
Employment	Employment positions generated by the Project or Proposal (either full time or part time, directly or indirectly). Employment is reported in terms of Full-time Equivalent (FTE) positions or person-years.

Source: Atlas

Regional Model Development

Multipliers used in this assessment have been created using a regionalised Input-Output model derived from the 2020-2021 Australian transaction table (ABS, 2023a).

Estimates of gross industry production in the catchment area were developed based on the share of employment (by place of work) of the catchment area within the Australian economy (ABS, 2022) using the Flegg Location Quotient and Cross Hauling Adjusted Regionalisation Method (CHARM). See Norbert (2015) and Kronenberg (2009) for further details. Where required, values were indexed to current dollar values using CPI (ABS, 2023b).

Modelling Limitations and Assumptions

Input-Output modelling is subject to a number of key assumptions and limitations (ABS, 2023a):

- **Lack of supply–side constraints:** The most significant limitation of economic impact analysis using multipliers is the implicit assumption that the economy has no supply–side constraints. That is, it is assumed that extra output can be produced in one area without taking resources away from other activities, thus overstating economic impacts. The actual impact is likely to be dependent on the extent to which the economy is operating at or near capacity.
- **Fixed prices:** Constraints on the availability of inputs, such as skilled labour, require prices to act as a rationing device. In assessments using multipliers, where factors of production are assumed to be limitless, this rationing response is assumed not to occur. Prices are assumed to be unaffected by policy and any crowding out effects are not captured.
- **Fixed ratios for intermediate inputs and production:** Economic impact analysis using multipliers implicitly assumes that there is a fixed input structure in each industry and fixed ratios for production. As such, impact analysis using multipliers can be seen to describe average effects, not marginal effects. For example, increased demand for a product is assumed to imply an equal increase in production for that product. In reality, however, it may be more efficient to increase imports or divert some exports to local consumption rather than increasing local production by the full amount.
- **No allowance for purchasers' marginal responses to change:** Economic impact analysis using multipliers assumes that households consume goods and services in exact proportions to their initial budget shares. For example, the household budget share of some goods might increase as household income increases. This equally applies to industrial consumption of intermediate inputs and factors of production.
- **Absence of budget constraints:** Assessments of economic impacts using multipliers that consider consumption induced effects (type two multipliers) implicitly assume that household and government consumption is not subject to budget constraints.

Despite these notable limitations, Input-Output techniques provide a solid approach for assessing the direct and flow-on economic impacts of a project or policy that does not result in a significant change in the overall economic structure.

Drivers of Economic Impact

In order to understand the economic impacts likely to result from the Proposal, it is necessary to distinguish economic impacts during the construction phase and those economic impacts that will be more permanent following construction completion.

- **Construction Phase:** Construction activity will draw resources from and thereby generate economic activity in the Greater Sydney economy as well as from outside Greater Sydney

  Assumptions are made on the proportion sourced from within and from outside Greater Sydney.

- **Operational Phase:** Estimated ongoing economic activity from industrial businesses locating onto the Site has been divided into:
  - **Stage 1 Committed Development (Net Additional Activity):** Activity generated through committed developments within the Precinct. Economic activity from these occupiers has been reported net of existing employment space and developments that are likely to go ahead elsewhere in the absence of the Proposal or within the Precinct regardless of water infrastructure charge impacts.
  - **Stage 2 Future Development Activity:** Activity on parcels within Mamre Road Precinct that have not yet been committed to by a specific operator but will be available for future development.

<u>Construction Phase</u>

For modelling purposes, construction costs (including contingency) for the Proposal were broken down into their respective Australia and New Zealand Standard Industrial Classification (ANZSIC) industries.

The breakdowns were developed based on the following assumptions by Atlas regarding the most appropriate ANZSIC industries for each activity and estimated average square metre construction costs for occupying businesses.

Activity has been split into committed developments (sites with a committed proponent for development, likely to undergo construction in the near term of the Proposal proceeds) and future development activity (sites which are yet to be purchased for development).

Construction costs have been estimated based on industry benchmarks from sources such as RLB as well as from Atlas industry knowledge. Estimated construction costs were affirmed by the Landowner's Group to accurately reflect the projects being considered for development.

Table S2-2: Construction Cost Allocation (including Contingency)

Work Type	($M)	ANZSIC
Committed Developments		
Buildings	$1,201.9	Non-Residential Building Construction
Site Works	$218.5	Heavy and Civil Engineering Construction
Professional Services Costs	$120.7	Professional, Scientific and Technical Services
Total	**$1,541.1**	
Future Development Activity		
Buildings	$2,597.5	Non-Residential Building Construction
Site Works	$472.3	Heavy and Civil Engineering Construction
Professional Services Costs	$260.9	Professional, Scientific and Technical Services
Total	**$3,330.7**	

Note: Totals may not sum due to rounding.
Source: Atlas

For modelling purposes, it is assumed that construction and professional services activity will be sourced from within the Greater Sydney catchment area.

Operational Phase

In order to model the economic impacts, operational employment levels for the economic activity occurring in the Proposal were categorised into the ANZSIC industries. Employment was estimated through converting the floorspace proposed to be developed within the Site based on employment density assumptions by Atlas.

For illustrative purposes, operational activity was divided into:

- **Stage 1 Committed Activity (Net Additional Activity):** Employment estimates for these spaces have based on committed developments within Mamre Road net of any:
    - Existing local employment space held by the occupier.
    - Developments likely to proceed elsewhere (or continue on the site regardless of the water charges).

  The above assumptions have been developed based on market intelligence from leasing agents working on the Precinct. Proposed occupiers have been allocated to the most relevant ANZSIC sectors based on assumptions by Atlas.

  Information for individual occupiers has not been disclosed to maintain commercial confidentiality and occupancy has been summed based on groupings of ANZSIC categories.

Table S2-3: Committed Developments Net Additional Activity Esitmates

ANZSIC	Occupier Notes	Land Committed (sqm)	Floorspace Committed (sqm)	Net Floorspace Increase[1]	Job Density (sqm/FTE)	Employment Impact (FTE)
Basic Chemical Manufacturing	Limited alternative sites, occupier will stay in current location without the Proposal	52,530	24,785	18,750	150	125
Wholesale Trade	Multiple occupiers, mix of new market entrants and expansion projects	450,731	234,289	190,500	200	953

ANZSIC	Occupier Notes	Land Committed (sqm)	Floorspace Committed (sqm)	Net Floorspace Increase[1]	Job Density (sqm/FTE)	Employment Impact (FTE)
Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing	New facilities, majority of activity will likely proceed regardless of infrastructure charges	234,697	164,288	-	1,000	0
Motor Vehicles and Parts; Other Transport Equipment manufacturing	Relocation/ expansion, occupier will stay in current location without the Proposal	33,833	8,640	1,400	150	9
Human Pharmaceutical and Medicinal Product Manufacturing	Consolidation of operations into a single site which is unlikely to occur elsewhere without the Proposal	50,014	28,955	24,250	150	162
Road Transport	Multiple occupiers, mix of relocation and new facilities. Existing operators will stay in current location without the Proposal	1,157,835	550,607	494,000	250	1976
Other Fabricated Metal Product Manufacturing	Single occupier expansion project, proponent will maintain current facilities	28,000	14,000	14,000	250	56
Plaster and Concrete Product Manufacturing	Relocation of existing facilitates with significantly expanded footprint.	30,000	15,000	13,000	250	52
Total	**-**	**2,037,640**	**1,040,564**	**755,900**	**227**	**3,333**

Notes: [1] Estimates adjusted for relocation from existing space and/or development that will occur regardless of infrastructure charges. Totals may not sum due to rounding.
Source: Atlas

- **Stage 2 Future Development Activity:** Based on available employment lands to be developed within the Precinct which have yet to be committed to by a specific occupier (approximately 204ha committed out of 635.5ha developable area). Activities within these spaces has been based on ANZSIC sectors likely to take up space within the Site over time given the profile of committed developments.

  No allowance has been made for the transfer of existing employment to these sites, though given the supply/demand balance for industrial land in Greater Sydney, it is likely that future development will support a net increase in employment and economic activity.

Table S2-4: Future Development Economic Activity Esitmates

ANZSIC	Land Area (sqm)	GFA (sqm)	Employment Density (sqm/FTE)	Future Employment (No.)
Basic Chemical Manufacturing	111,301	52,515	150	350
Wholesale Trade	955,011	507,366	200	2,537
Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing	497,277	348,094	1,000	348
Motor Vehicles and Parts; Other Transport Equipment manufacturing	71,685	18,306	150	122
Human Pharmaceutical and Medicinal Product Manufacturing	105,970	61,350	150	409
Road Transport	2,453,226	1,199,805	250	4,799
Other Fabricated Metal Product Manufacturing	59,327	29,663	250	119
Plaster and Concrete Product Manufacturing	63,564	31,782	250	127
Total	**4,317,360**	**2,248,881**	**227**	**8,811**

Note: Totals may not sum due to rounding.
Source: Atlas

Employment by industry estimates for committed and future developments were converted to a direct output value using a multiplier based on the national transaction table (ABS, 2023a). The resultant estimates of output were modelled as the direct activity associated with the Proposal.

Table S2-5: Operational FTE Allocation of Floorspace

ANZSIC	Employment (FTE)	Direct Output ($M)
Committed Development (Net Additional Activity)		
Basic Chemical Manufacturing	125	$155.8
Wholesale Trade	953	$466.7
Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing	0	$0.0
Motor Vehicles and Parts; Other Transport Equipment manufacturing	9	$3.5
Human Pharmaceutical and Medicinal Product Manufacturing	162	$95.0
Road Transport	1,976	$553.5
Other Fabricated Metal Product Manufacturing	56	$29.1
Plaster and Concrete Product Manufacturing	52	$36.9
Total	**3,333**	**$1,340.6**
Future Development Activity		
Basic Chemical Manufacturing	350	$436.3
Wholesale Trade	2,537	$1,243.1
Internet Service Providers, Internet Publishing and Broadcasting, Websearch Portals and Data Processing	348	$713.0
Motor Vehicles and Parts; Other Transport Equipment manufacturing	122	$46.3
Human Pharmaceutical and Medicinal Product Manufacturing	409	$240.4
Road Transport	4,799	$1,344.2
Other Fabricated Metal Product Manufacturing	119	$61.6
Plaster and Concrete Product Manufacturing	127	$90.3
Total	**8,811**	**$4,175.3**

Notes: Totals may not sum due to rounding.
Source: Atlas

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Appendix D

Atlas Economics

The Housing Crisis and the Industrial Sector

The Housing Crisis and the Industrial Sector

Sydney's Capacity to Respond

Mamre Road Landowners' Group

May 2024

Atlas ECONOMICS
ANALYSIS. INSIGHTS. OUTCOMES.

Executive Summary

THE HOUSING CRISIS

The housing crisis in NSW has been well documented and is well known. Currently, housing affordability and availability are at their lowest levels in decades. Homelessness NSW estimates that there is a shortfall of more than 200,000 social and affordable homes in the state, with almost 60,000 households waiting for social housing.

The National Housing Accord is an agreement between the Commonwealth, states and territories to deliver 1.2 million homes from 2024 to 2029. The NSW share is 357,700 dwellings (equivalent to an average of 75,000 dwellings annually) and for Greater Sydney, the target is equivalent to 50,000 annually over the five-year period.

Greater Sydney averaged 30,700 homes annually over the last two decades. The highest level of dwelling completions was 42,000 per annum in 2017/18 and 2018/19. **To meet the National Housing Accord targets, dwelling delivery in Greater Sydney needs to rise 60% from the historical average**, which is a significant, step-change increase.

Atlas Economics (**Atlas**) has been engaged by the Mamre Road Landowners Group to investigate the role of the industrial sector and specifically serviced industrial land in alleviating the Greater Sydney housing crisis (**the Study**).

This Study estimates the quantum of additional industrial land which will be required to deliver the Housing Accord targets. In particular, the Study considers the capacity of construction supply chains in Greater Sydney to deliver the housing targets and achieve the Government's objective of improving housing affordability.

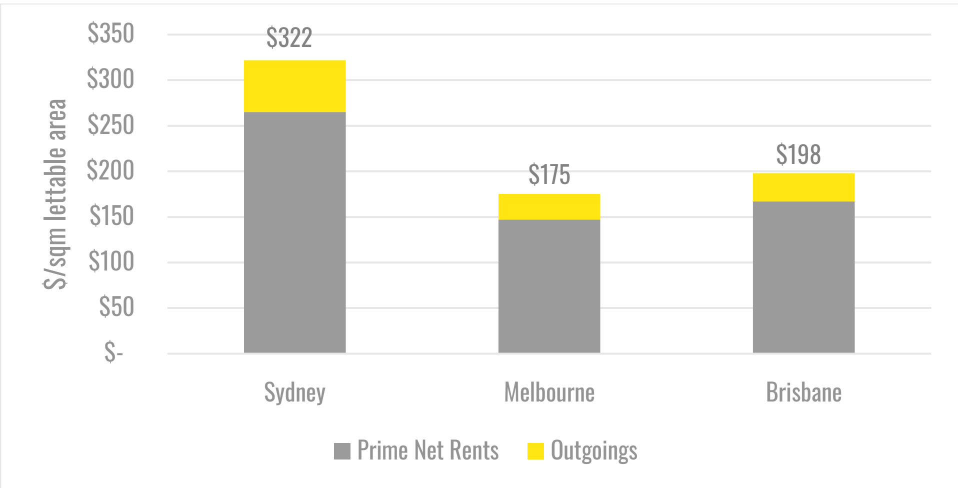
THE CURRENT STATE OF PLAY

Sydney has a housing crisis. Sydney also has an industrial lands crisis. Previous Atlas research found that Greater Sydney has approximately one year of serviced industrial land supply remaining and has the lowest industrial vacancy rate nationally. This acute shortage of industrial supply has serious consequences for the cost of doing business, the cost-of-living and Sydney's ability to be competitive and provide for employment opportunities.

Rents, Land Values and Building Capital Values

Figure ES-1 shows that in 2024, businesses in Sydney are paying rents that are 85% higher than Melbourne's and 65% higher than Brisbane's. This poses an acute affordability problem for businesses.

Figure ES-1: Prime Net Rents and Outgoings - Sydney, Melbourne, Brisbane (2024)

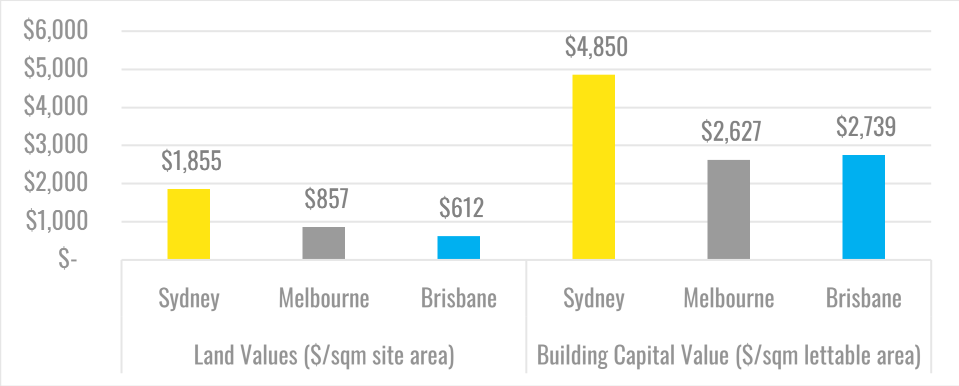


Source: Cushman and Wakefield (2024)

Land values in Sydney are more than double Melbourne's and more than treble Brisbane's. This means much higher economic rents must be charged for development to be feasible.

Figure ES-2 shows a comparison of land values and building capital values between Sydney, Melbourne and Brisbane. The significant gap between the prices of Sydney and peer capital cities highlights a supply and affordability crisis in Sydney.

Figure ES-2: Land Values and Building Capital Values - Sydney Melbourne and Brisbane (2024)



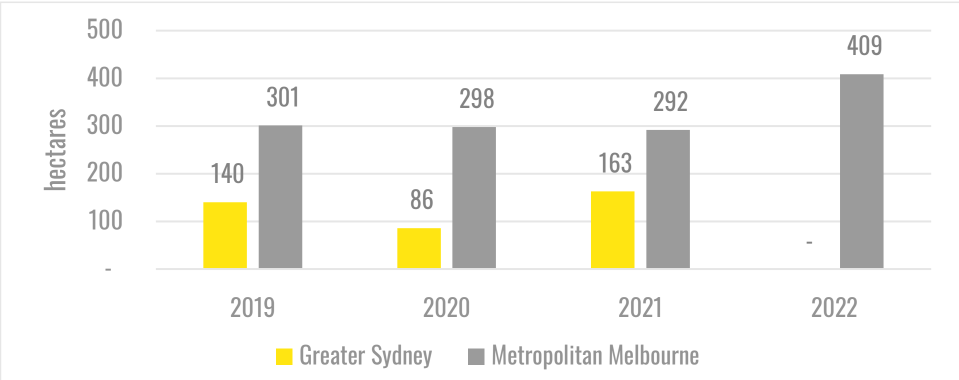
Source: Cushman and Wakefield (2024)

Take-up and Remaining Supply of Industrial Land

The take-up (development of land) is a reflection of market demand. For Australia's largest capital city, demand for land in Sydney would be expected to be at least on par with Melbourne's.

Instead, and as shown in **Figure ES-3**, the annual take-up of industrial land in Sydney has been only 30%-60% of Melbourne's. This is symptomatic of a supply constrained market. The anaemic rate of take-up has been for over more than a decade, and assuming a similar take-up to Melbourne's, the lack of supply has resulted in a cumulative deficit of 1,700 hectares.

Figure ES-3: Annual Take-up of Industrial Land, Sydney v Melbourne (2019-2022)

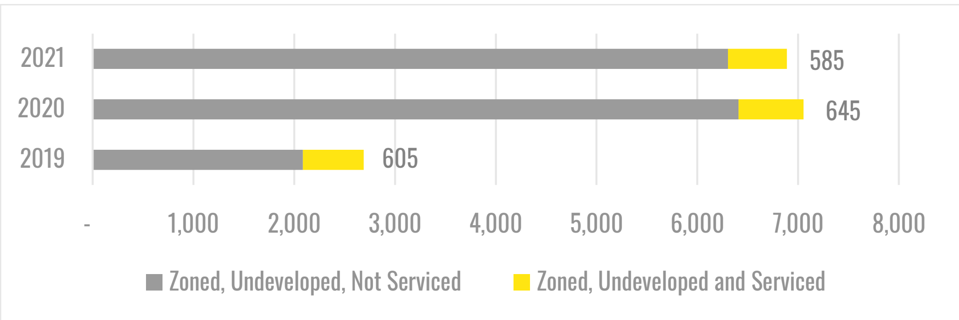


Source: DPHI (2022), DTP (2023), Atlas

Sydney has about 1.5 years of ***theoretical*** supply remaining. However, analysis shows much of that supply is either too small or not available to the general market. Greater Sydney has at best, **about one year of remaining industrial land supply**.

Figure ES-4 illustrates the supply of undeveloped land in Greater Sydney (serviced and not serviced) as at January 2022. There is almost 7,000ha of undeveloped zoned land, but >90% is not serviced (having a lack of roads and utility services).

Figure ES-4: Undeveloped Zoned Land and Serviced Land, Greater Sydney (January 2022)



Source: DPHI (2022)

In stark contrast, Melbourne has about **11.5 years** of theoretical supply and South East Queensland (SEQ) about **13.5 years**. Governments in VIC and QLD have strategic land supply policies that require 15 years of forward land supply.

No Room to Grow

With one year of supply remaining, there is no room for business investment, growth and further employment. With near zero vacancy there is no space available, businesses are forced to pay prices much higher than Melbourne and Brisbane.

Demand from residential construction to meet the Housing Accord targets will place additional demands on industrial land that is constrained and result in even greater upward pressure on rents and prices.

Business Perspectives

The Study interviewed some of the largest businesses within the building and construction supply chain. These businesses manufacture and/or supply a range of critical building materials including steel, cement, timber, wall panels, etc.

The shortage of industrial land in Sydney is well-known in the industry and the Greater Sydney region has long been seen as too expensive to allow for local expansion, even though this would be their preference. Engagement confirmed that the construction industry is running at utilisation levels (85%-90%). Some businesses' Sydney facilities are at full capacity.

The shortage of industrial land in Sydney has forced these businesses to find alternative solutions. Many have expanded to regional areas, while others simply supply the Sydney market from interstate. These strategies have cost implications - the added transport trips increase the price of materials for the construction industry and increase carbon emissions.

CONSTRUCTION DEMAND FOR INDUSTRIAL LAND

Additional Demand

Master Builders Australia (MBA) produces a five-year industry forecast across residential and non-residential construction and heavy and civil engineering (i.e. infrastructure). For NSW, these forecasts show how industry activity can ramp-up to meet the National Housing Accord targets. The forecasts are used to identify the associated demand for industrial land.

The current circumstances do not enable the construction sector to ramp-up to much needed capacity to meet the Housing Accord housing targets. Delivery of 50,000 dwellings (avg. 2 bedroom) requires 50,000 kitchens, 100,000 toilets, 150,000 sinks and taps, etc. per annum. Building materials such as timber, steel, bricks, tiles and sanitary ware will be procured from a mix of offshore and local sources, requiring the supply chain to expand its capacity to source, store and distribute.

No Capacity

Since 2010, Sydney has lagged Melbourne's ability to respond to market demand, resulting in a cumulative deficit of 1,700 hectares. Currently, there is at best, one year of serviced industrial land remaining. Existing serviced stocks in Sydney are all but exhausted. In contrast, Melbourne and SEQ can both draw on stocks of more than 10 years supply of industrial land.

Even if the construction supply chain expanded capacity (at regional and Victorian sites), it would lead to higher costs and longer lead-times. This perversely thwarts the Government's objective of housing supply to improve housing affordability.

Flood of Supply Needed

Using the MBA forecasts, the increased delivery of housing would require about 280-380 hectares of serviced industrial land (the lower of the range required if there was surplus capacity available across existing supply chain facilities in Sydney). In reality though, even if 280-380 hectares of serviced industrial land were to become available, high prices for land would likely remain, making procurement of new facilities not viable for the construction sector (and much of its supply chain). A much greater amount of land is therefore required to not only provide capacity but to ***re-set prices***.

The release of 2,000 hectares of serviced land is needed to act as a pressure valve release for demand that has not been satisfied - a situation that has resulted in runaway rents and prices. That would provide the headroom capacity for broader industries, as well as ~300 hectares to support residential construction (aligned to the National Housing Accord targets). This level of a supply would provide for a re-setting of the current high prices and enable take-up by the construction sector (and others) at affordable prices.

Sydney's strategic location on the East Coast of Australia positions it well as a servicing base for the three most populous states of NSW, Victoria and Queensland. The availability of land that is developable and affordable has ramifications not just for the Housing Accord targets but has broader consequences for Sydney's economic prosperity.

INTERVENTIONS NEEDED

As at January 2022, Sydney had 6,900 hectares of zoned industrial land. Only 8% of that land was serviced, with much of that land is either too small (<5ha) or not available to the general market. There is a concentration of large lots (>5ha) in precincts that are zoned, but not serviced. These are Mamre Road (775ha) precinct and the Northern Gateway (1,000ha), Agribusiness (870ha), Aerotropolis Core (465ha) and Badgerys Creek (180ha) which are in the Western Sydney Aerotropolis.

The Mamre Road Precinct was rezoned in 2020. It is the only zoned precinct that has significant institutional investment and tenant interest and where development planning is well advanced.

Mamre Road Precinct

In 2023, Atlas undertook a feasibility analysis of the Mamre Road Precinct following release of Sydney Water DSP charges at >$1,000,000/ha NDA. The work found that the entire Mamre Road Precinct was not feasible to develop.

The work found that there was provisional capacity to pay up to $287,000/ha NDA for DSP charges subject to a number of factors, including *inter alia*, if rents were increased by 5%, if there was no interim abortive costs or land sterilisation associated with meeting waterway health controls ahead of a regional scheme and if funding and if delivery of the required road infrastructure was forthcoming in a timely manner.

Despite this, the DSP charges submitted by Sydney Water to IPART for finalisation are $800,000/ha NDA and the NSW Government requires interim waterway measures that would sterilise approximately 60% of site area.

The cumulative impact of the loss of developable area ***and*** additional cost associated with the interim solution results in development that is not feasible.

As the Government scrambles to ease the housing crisis and greatly increase the supply of housing in NSW, any increase in housing supply should be supported by an urgent increase in serviced industrial land.

Immediate Steps

There are immediate interventions that can unlock development in the Mamre Road Precinct. Focusing on this precinct makes sense due to development planning that is advanced and the weight of investment capital and tenant interest in play.

- **Administrative amendment of SIC allocation to biodiversity (currently 72%)** - this would enable SIC payments from first mover developers to deliver enabling infrastructure. Once the enabling infrastructure is delivered, the allocation from future SIC payments to biodiversity conservation can be re-adjusted as needed. At present, only 28% from SIC contributions can be offset against works-in-kind (e.g. delivery of roads), with 72% to be paid in cash for biodiversity.
- **Fast track delivery of critical roads Mamre Road and Southern Link Road** - funding accompanied by fast-track delivery.
- **Economic evaluation of new (step-change) water targets** - consider DSP charges in an economic appraisal (including a cost benefit analysis). Atlas is not aware of any cost benefit analysis (**CBA**) completed to weigh up the costs and benefits of the desired stormwater target outcomes. If there is an economic case (i.e. the benefits exceed the costs), the CBA must also consider the distributional impacts of the benefits and the costs.

  A feasibility analysis (by Atlas which was peer reviewed by DPHI) confirms the disproportionate cost burden of the DSP charges and the loss of developable land (60% of site area). The adverse impact on the feasibility of development was found to be severe, not capable of remedy even when construction cost escalations 'settle'.

  The implementation of public policy must have regard to how cost and benefit is distributed. In the case of the desired stormwater targets, the issue is 'who should pay for the targeted benefits?' If development cannot afford to bear the cost and if broader societal net benefits are targeted, it would be appropriate for that cost to be borne by Government. If Government does not have the capacity or appetite to bear the cost, alternate stormwater targets should be developed - targets that are affordable, and which are capable of being delivered.
- Unlock the backlog of planning applications and enable greater flexibility in planning controls.
- Provide an urgent, immediate coordination role to streamline infrastructure delivery and development.

Once implemented, the above interventions would set the scene for delivery of lands in the Western Sydney Aerotropolis.

Integration of Land Use and Infrastructure Planning

It is imperative for Sydney that land use planning is integrated with infrastructure planning. There is little point in rezoning land if that land has no reasonable prospect of being serviced by road and utility infrastructure.

The Victorian PSP (precinct structure plan) process recognises this - it embeds a collaborative process between key stakeholders (developers, referral authorities and decision makers) to resolve key planning challenges early. The Victorian Planning Authority (VPA) leads the preparation of the PSP in close partnership with the associated council and relevant agencies. Land is not rezoned unless it is developable and infrastructure funding arrangements are in place.

The effectiveness of the integration of land use and infrastructure planning and the Victorian PSP process can be observed in the relative pricing of dwellings in greenfield areas. In Sydney, a typical house and land package in a greenfield area is $1,000,000 while in Melbourne, a typical house and land package in a similar greenfield area is $650,000.

The coordinated and orderly release of land in Victoria has meant that land value movements have been more tempered. In contrast, Sydney's land value movements have experienced increases of epic proportions.

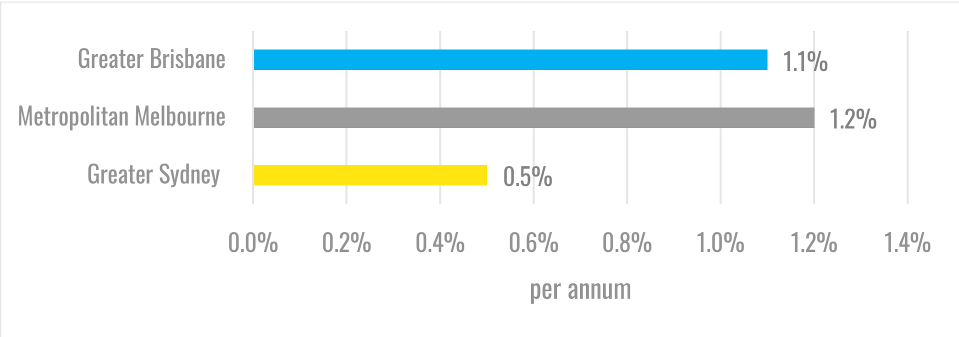
Strategic Land Supply Policy

Victoria and Queensland both have strategic land supply policies that are given statutory weight. Both state planning frameworks require 15 years of land supply that is zoned and serviced, or capable of being serviced.

NSW would benefit from implementing a strategic land supply policy for all land uses. This would ensure a healthy and viable supply of land. This is essential to temper land value movements - which occurred at runaway proportions in Sydney.

The industrial sector is valuable. During 2020-21, the industrial sector contributed an estimated $70 billion (18%) to the Greater Sydney economy. Despite this, Sydney's constrained land supply situation has 'held back' investment and growth of the industrial sector. **Figure ES-5** shows the comparatively low employment growth compared to Melbourne and Brisbane.

Figure ES-5: Industrial Employment Growth, Sydney v Melbourne v Brisbane (2016-2021)



Source: ABS (2022)

The Cost of Do Nothing

Without large-scale unlocking of serviced industrial land, the twin objectives of housing supply and housing affordability of the Housing Accord will not be met. The construction supply chain will be serviced from outside Sydney, leading to higher construction costs. These costs will be passed on and the cost of housing will be even less affordable.

If allowed to continue, the industrial lands crisis in Sydney will continue to:

- Stymie employment growth in the industrial sector.
- Drive up land values and rents, and cumulatively impact the cost of doing business and cost-of-living.
- Stymie business growth and shift investment away from Sydney.
- Increase the environmental cost through greater trucking movements from regional and interstate locations.

Sydney has no capacity to respond to the Housing Accord targets in a timely or cost-effective manner. Immediate interventions are needed at the Mamre Road Precinct to urgently unlock zoned land as longer-term strategies are also pursued but that take time to bear dividend.

Terms and Abbreviations

Terms

Take-up of land	Development of land
Theoretical capacity	Refers to the physical and legal ability of land to be developed. It takes into account permissibility under the planning framework. It is a commercial reality that not all sites will be developed to their theoretical capacity even though permissible. This could be due to various reasons including lack of market demand, ownership and lot fragmentation and high property values.
Market capacity	Refers to the realisable capacity of theoretical capacity. There will be market capacity where there is market demand and development is feasible to undertake.

Abbreviations

ABS	Australian Bureau of Statistics
CBA	Cost Benefit Analysis
DPHI	NSW Department of Planning, Housing and Infrastructure
DSP	Development Servicing Plan
DTP	VIC Department of Transport and Planning
DSDMIP	QLD Department of State Development, Infrastructure, Local Government and Planning
IPART	Independent Pricing and Regulatory Tribunal
NDA	Net developable area
PSP	Precinct structure plan
SEQ	South East Queensland
SIC	Special infrastructure contribution
VPA	Victorian Planning Authority

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1. Introduction

1.1 Background

Greater Sydney currently faces one of the most acute housing crises in the world. The city is ranked as the 2nd least affordable city in the world (behind only Hong Kong), and acute issues including rental/ mortgage stress and homelessness have reached crisis proportions. There is general consensus across the community and all levels of government that additional housing supply is the key means to alleviate the housing crisis.

The Federal Government's Housing Accord aims to lift national housing supply significantly beyond the business-as-usual. However, delivering the required housing stock will require significant expansion of industrial supply chains including direct construction, product manufacturing, and warehousing/ transport functions which are critical in new housing construction.

The construction sector faces significant headwinds from the sharp rise in construction input costs, compounded by shortages of labour and materials which has eroded profit margins on existing fixed-price contracts. Contagion presents serious risk where subcontractors do not have a diversified revenue stream and are directly affected by builder insolvency. The construction sector was reported to have the highest number of insolvencies (28%), follows by the accommodation and food services industry (15%) in the 12 months to 30 June 2023 (ASIC, 2023).

The industrial sector is also facing significant headwinds, including rising input costs, labour and skills competition (including from a generational infrastructure construction pipeline). More particularly in Greater Sydney, the industrial sector additionally faces a shortage of serviced land and a shortage of available floorspace.

Atlas' previous research found that Greater Sydney has approximately one year of serviced industrial land supply remaining and has the lowest industrial vacancy rate nationally. The impacts of the acute shortage of industrial supply opportunities is demonstrated in pricing levels:

- Industrial rents in Greater Sydney are 80% higher than Melbourne's and 60% higher than Brisbane's.
- Industrial land values in Greater Sydney are 200% Melbourne's and 300% Brisbane's.

This acute shortage of industrial supply opportunities has serious consequences for the cost of doing business and the cost of living, with broader ramifications for Sydney's competitiveness.

National Housing Accord

In August 2023, the National Cabinet agreed to a national target to build 1.2 million homes over five years from 2024. National Cabinet also endorsed the Commonwealth providing $3.5 billion in payments to state, territory and local governments to support the delivery of new homes towards this target. The Housing Accord is one component of the government's broader housing agenda which also includes significant funding for social and affordable housing and additional support for renters and homebuyers.

As part of the accord, the NSW has a share of the overall delivery target of 375,000 dwellings (75,000 dwellings pa over five years) of which an estimated 245,000 dwellings (49,106 dwellings pa) would be allocated within Greater Sydney based on share of population and identified need.

Figure 1-1: National Housing Accord Targets (2024/25 to 2029/30)

Geography	Share of Population	Dwelling Target (2024/25 to 29/30)	Annual Dwelling Target
Australia	100.0%	1,200,000	240,000
NSW	31.3%	375,665	75,133
Greater Sydney	20.5%	245,532	49,106

Source: Commonwealth Treasury (2024), Atlas

NSW will need to build 375,000 homes (or 75,000 each year), over this period to contribute to the national target. This volume of housing production has never been achieved in NSW, with the highest level in a five-year period achieved over 2016-2021, where ~298,000 dwellings were delivered (equivalent to ~59,000 pa).

Supply Chain Capacity for Expansion

Whilst much has been discussed on what steps the residential construction sector needs to take to meet this housing target, little has been mentioned of the role of industrial lands and businesses in supporting the target.

The residential construction sector is a large user of industrial lands, as is their upstream supply chain. The capacity of the sector to grow and scale at the level needed to meet the NSW housing target is intrinsically tied to the availability of industrial land, particularly in Greater Sydney where the bulk of new housing is planned for delivery.

The construction industry is a notable contributor to the demand for industrial land. Leasing data suggests that demand for industrial land from the construction sector is 5%-7%, which would equate to 600-800 hectares in Greater Sydney.

The Importance of Industrial Lands

Atlas Economics (**Atlas**) has been engaged by the Mamre Road Landowners Group to investigate the role of the industrial sector and specifically serviced industrial land in alleviating the Greater Sydney housing crisis (**the Study**).

This Study investigates the historical links between industrial activity and new housing delivery and estimates the quantum of additional industrial land which will be required to deliver the Housing Accord targets. In particular, the Study considers the capacity of construction supply chains in Greater Sydney to deliver the housing targets and achieve the Government's objective of improving housing affordability.

The twin issues of the affordability of land (and premises) and the cost of doing business are inextricably linked to the ability of the construction sector to deliver more housing, affordably.

1.2 Study Objectives and Approach

The Study focuses primarily on the industrial land requirement to meet the housing targets under the National Housing Accord. Other construction demands (e.g. by non-residential construction and infrastructure delivery) placed on industrial land are also considered in the interest of providing context to the overall demand for industrial land as well as the relationship between new households, new jobs and the infrastructure to support the two.

Optimisation of the Construction Supply Chain

The construction supply chain's requirements depend on whether it is infrastructure (road/ rail) or building construction. Infrastructure construction has greater relative demand for steel and concrete which are more weighted to 'make to order' manufacturing less reliant on warehouse storage. Building construction has greater demand for warehousing as it relies more on 'make to stock' products (e.g. plumbing, electrical, bricks, tiles, etc.), many of which are imported.

One nuance in quantifying the additional demand for land and floorspace is the issue of utilisation and productivity. The demand for land/ floorspace is not linear. If there is a need for more space, suppliers will naturally explore opportunities to utilise their existing facilities more efficiently. This could include interventions such as:

- Putting on more shifts.
- Utilising more automation and investing in technology.
- Reducing their stock of inventory held, therefore increasing the velocity of stock through their warehouse and ultimately the capacity of their facilities.

It is necessary to understand the potential for existing premises to have higher utilisation rates. Industrial facilities could already be operating at high utilisation levels and older premises could be challenging to retrofit with automation and technology to increase utilisation and output.

The ability of supply chains to improve productivity/ capacity depends on a number of factors including transport infrastructure, workforce availability, investment in warehouse layout changes, etc. The assessment of additional land/ floorspace requirement is therefore a complex question.

Atlas worked with Infosys Portland to carry out interviews of select businesses in the construction supply chain. The interviews sought to obtain business perspectives on their likely supply chain response (in particular the need for more land) to an uptick in residential construction activity.

Structure of the Study

The remainder of this Study is structured as follows:

- Chapter 2 analyses historical new home construction data and the links to uptake of industrial lands. This provides historical context and basis for future need.
- Chapter 3 reviews the broader supply and demand dynamics for the Greater Sydney industrial market, providing context for the supply situation that the Housing Accord demand will be driving demand into.
- Chapter 4 considers the capacity of supply chains to increase productivity, capacity and velocity within existing premises and the outlook for Greater Sydney's industrial market from an industry perspective.

  Interviews with businesses who manufacture and/ or supply to the construction sector identify the factors that influence supply chain capabilities and growth prospects. The business perspectives provide insight into the growth expectations of the construction sector.
- Chapter 5 applies transaction table relationships (utilising Input-Output multipliers) to estimate the industrial land needs across the supply chain to deliver additional housing as well as respond to ongoing growth arising from non-residential and infrastructure projects. More particularly, the assessment is cognisant of:
  - The gap between the historical delivery in Greater Sydney and the housing target of 50,000 dwellings per annum.
  - The need to service growth arising from the non-residential and civil construction sectors.
- Chapter 6 reviews the findings of the Study and considers the implications of increased construction sector activity on the need for serviced industrial land in Greater Sydney.

  The chapter examines the state of play of industrial markets in Greater Sydney and the interventions needed to meet the Government's objectives of increasing housing supply and improving housing affordability.

1.3 Assumptions and Limitations

This Study relies on a number of key assumptions and is subject to the following limitations:

- **Volatility and cyclical nature of the construction sector:** The construction sector is currently subject to significant volatility due largely to rapidly rising costs/ higher interest rates and supply chain disruptions. Furthermore, the nature of the construction sector and demand for industrial land are cyclical and will vary considerably at the high and low points of the cycle.

  The aim of the Study is to consider the specific lands needed to deliver Housing Accord targets in the context of the current supply and demand dynamic.
- **Limitations of Input-Output multipliers:** Input-Output multipliers are subject to a number of key assumptions and associated limitations. To the extent possible, estimates of need are adjusted based on industry consultation, specifically the potential to expand production on the current industrial footprint.
- **Limited to the Greater Sydney catchment**: Impacts from outside of the Greater Syndey economy (e.g. industrial expansion elsewhere, increased housing demand in other regions which may be serviced by the Greater Sydney supply chain) are not incorporated into the demand modelling.
- **Changing nature of construction delivery:** Estimates of demand are based on the most recent transaction table relationships and projected future growth across sectors. Changing delivery practices and technologies such as 3D printing and on-site manufacturing may notably change the relationship between demand for industrial land and new housing delivery over time.

Despite the limitations, this Study aims to provide a robust understanding of the relationship between new housing delivery, industrial land and the supply needed to facilitate future housing delivery within Greater Sydney.

2. Industrial Activity and Residential Construction

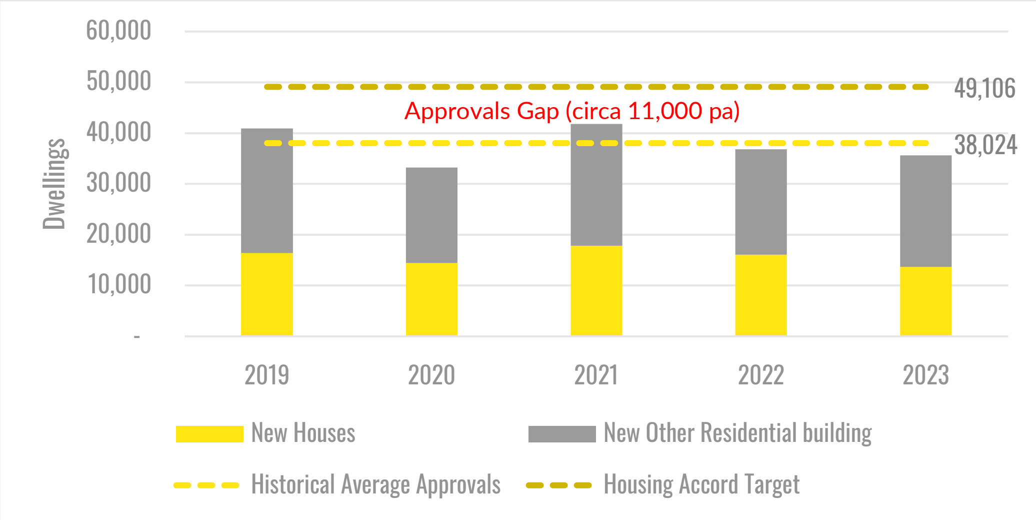
2.1 Housing Construction Activity

Greater Sydney has historically approved between 30,000, and 40,000 dwellings annually going back to 2019. Activity is volatile from year to year, with swings of -19% and +25% over the COVID-impacted years of 2020 and 2021.

Notably, there is no discernible growth trend within the five-year data, with industry cost pressures and higher interest rates leading to weaker activity (just under 36,000 dwelling approvals) over 2023 compared to the five-year average of 38,000. To meet the goals of the Housing Accord, Greater Sydney would need to sustain delivery approximately 50,000 dwellings annually over a five-year period.

The mix of dwellings approved is weighted toward higher density (circa 55% of total approvals) with detached houses still representing a significant share of total new housing delivery.

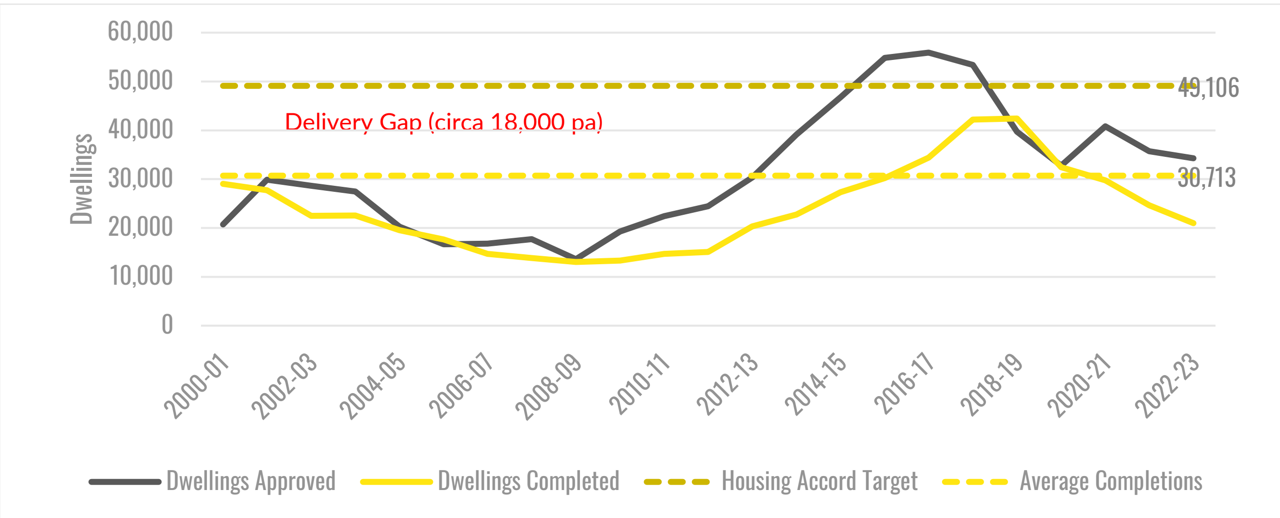
Figure 2-1: Historical Dwelling Approvals, Greater Sydney (2019-2023)



Source: ABS (2024a)

The actual completion of dwellings has increasingly lagged approvals (by up to 21,000 dwellings annually). In the most recent year of data, dwelling completions lagged approvals by 15,000 dwellings. Over the last two decades, Greater Sydney has averaged just 30,700 dwelling completions per year. Completions peaked in 2017/18 and 2018/19 at just over 42,000 dwellings per year. Historical completions are well below the Housing Accord target share of 50,000 dwellings per year.

Figure 2-2: Approvals v Dwelling Completions, Greater Sydney (FY2001 to FY2023)

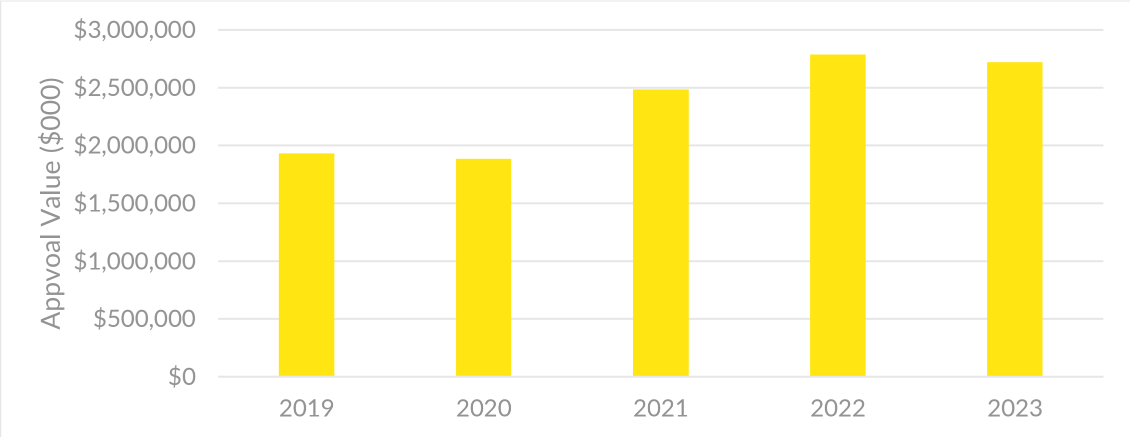


Source: ABS (2024a, DPHI, 2024)

The annual value of residential construction has averaged between $15 billion and $20 billion pa over the past five years, with the total value of approvals also volatile from year to year (see **Figure 2-3**).

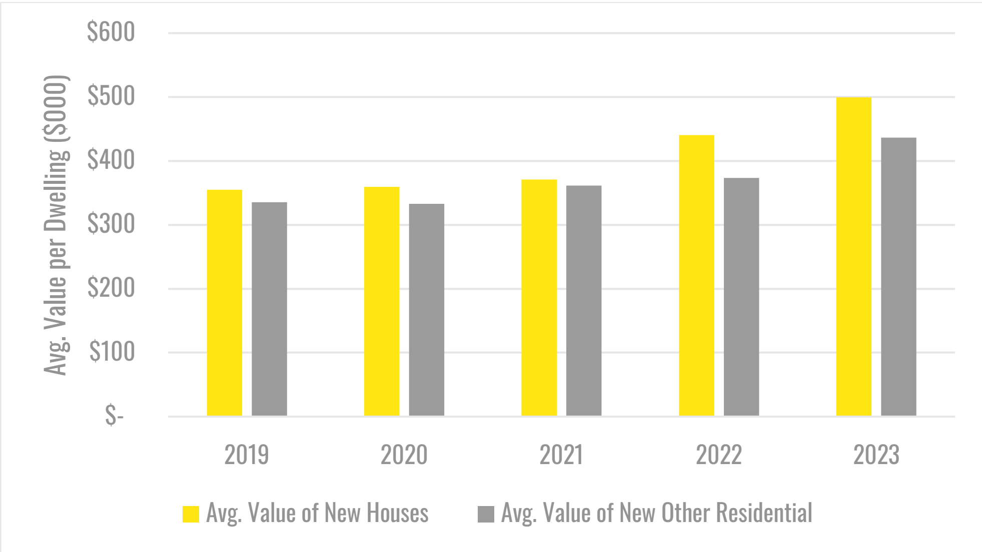
The average cost of new dwellings has risen rapidly from $355,000 to $499,000 for detached houses (+8.9% annual increase) and $335,000 to $436,000 for higher density dwellings (+6.8% annual increase) over the analysis period (see **Figure 2-4**).

Figure 2-3: Value of Residential Building Approvals, Greater Sydney (2019-2023)



Source: ABS (2024a)

Figure 2-4: Avg. Approval Value Per Dwelling, Greater Sydney (2019-2023)



Source: ABS (2024a)

<u>**Future Construction Activity**</u>

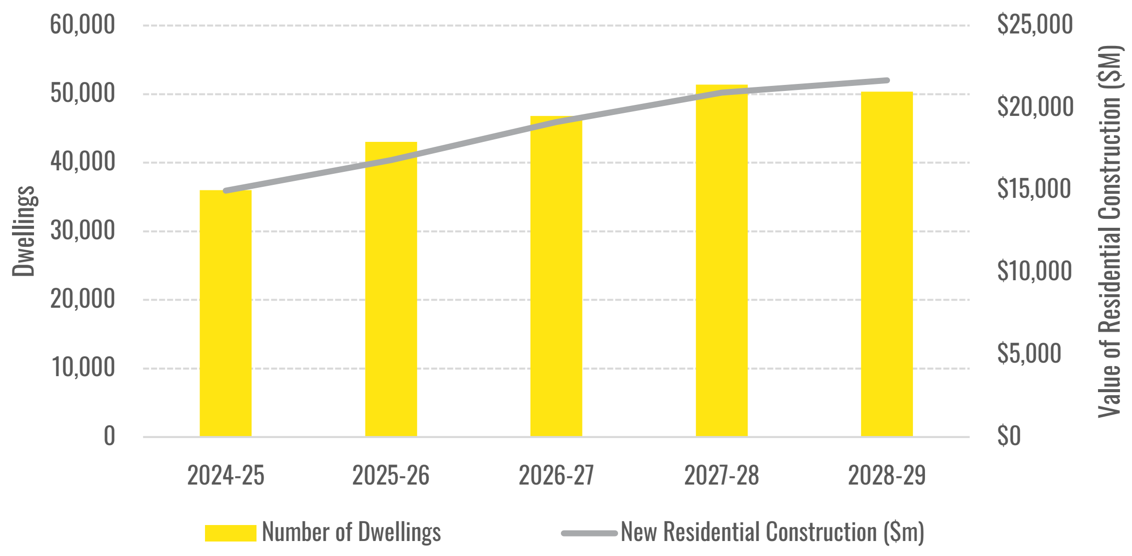
Master Builders Australia (**MBA**) is the only industry body representing the three sectors that comprise the building and construction industry - residential, non-residential and civil construction.

MBA recently released forecasts (April 2024) for NSW that demonstrate how the industry can meet the National Housing Accord annual target of 75,000 homes. The projections also provide a forecast for future building activity in the non-residential and civil construction sectors. These forecasts have been made at the State level.

To identify residential forecasts at the Greater Sydney regional level, a population weighting based on future population projections from the NSW Department of Planning Housing and Infrastructure (**DPHI**) has been used. Historical economic activity has been used to identify the Greater Sydney portion of the future forecasts.

Based on MBA forecasts, Greater Sydney will reach 50,000 new residential dwellings by 2027-28 at a value in excess of $20 billion. The forecasts represent a significant ramping-up of industry production, well above the historical average of 30,700 new dwellings per year.

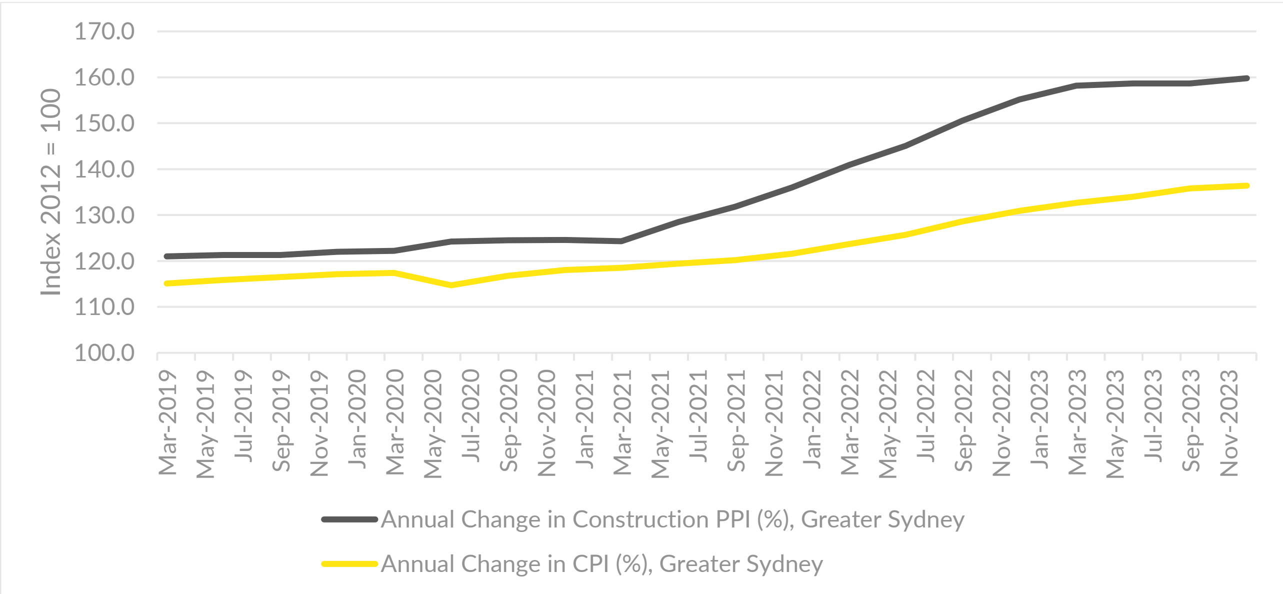
Figure 2-5: Residential Construction Forecast, Greater Sydney (FY2025 to FY2029)



Source: MBA (2024), Atlas

Construction costs for housing have escalated significantly in real terms, with key inputs including steel, lumber and labour all rising well ahead of inflation. Since 2019 the construction sector Producer Price Index (PPI) has outpaced the Consumer Price Index (CPI).

Figure 2-6: Consumer Price Index (CPI) v Construction Producer Price Index (PPI) Housing (2019-2023)



Source: ABS (2024)

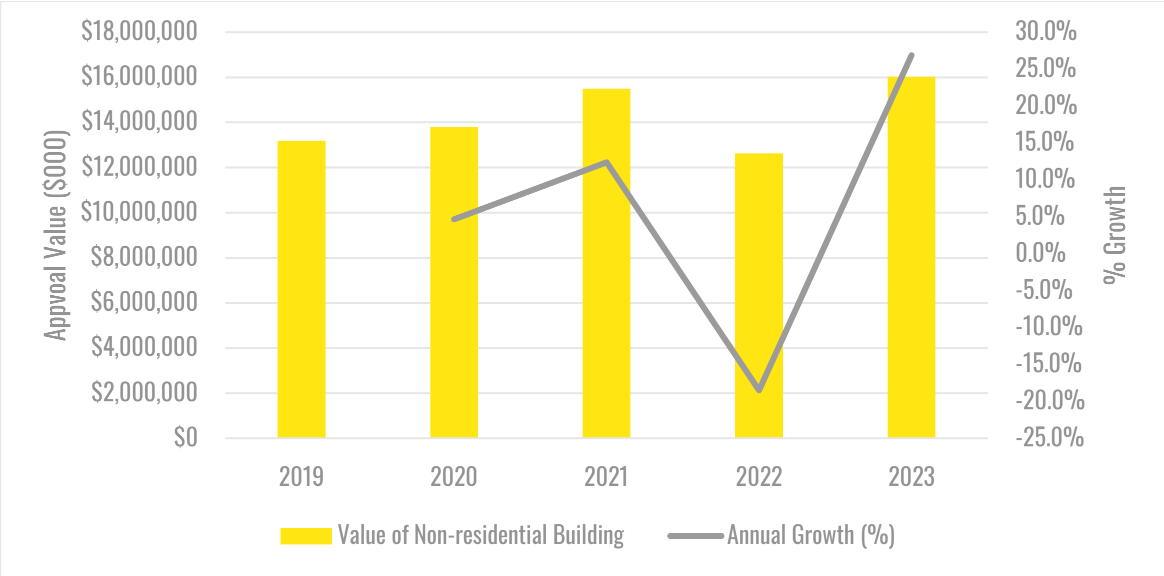
2.2 Other Construction Activity

Non-Residential Construction

Greater Sydney has historically approved between $12 billion and $16 billion in non-residential building construction (commercial, retail, industrial building) activity. Approvals recovered strongly (+26.9% growth) over 2023 after very weak performance in 2022.

Aside from the weakness in 2022 there is a discernible growth trend in non-residential activity, having averaged 5.0% pa since 2019.

Figure 2-7: Non-Residential Building Construction Approvals, Greater Sydney (2019-2023)

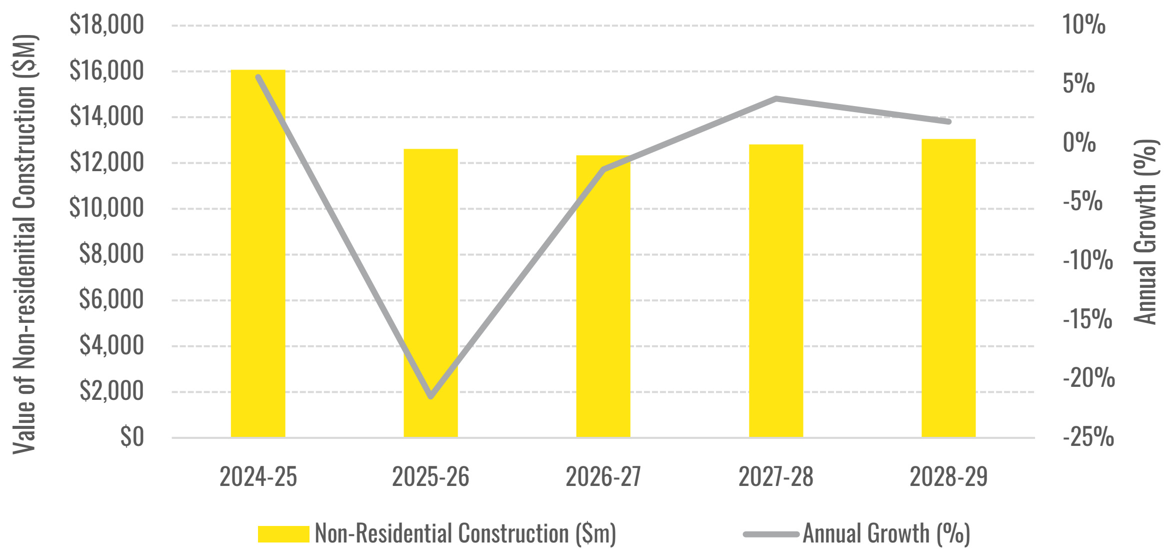


Source: ABS (2024a)

Using the forecasts by Master Builders Australia, non-residential construction is expected to peak in 2024/ 25 at just over $16 billion, a slight increase from the previous year. After this period, non-residential construction is expected to reduce to a more typical level between $12 billion and $14 billion.

The current high level of activity has been influenced by significant projects, such as the construction of the Western Sydney International Airport (Nancy-Bird Walton) which is expected to be completed in 2026.

Figure 2-8: Non-Residential Construction Forecast, Greater Sydney (FY2025 to FY2029)

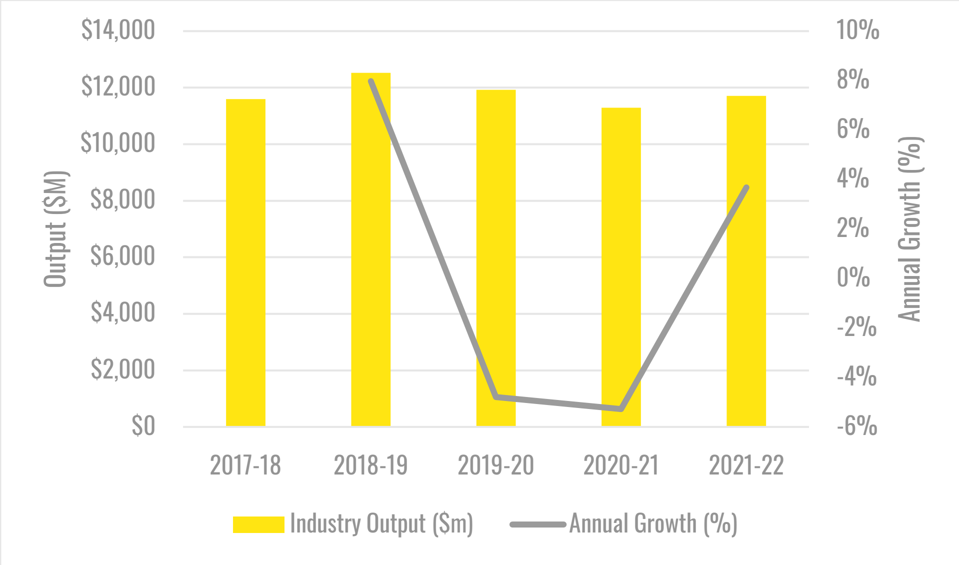


Source: Master Builders (2024)

Infrastructure Construction

The Greater Sydney heavy and civil engineering construction sector delivers circa $11 billion to $12 billion annually in output, with robust growth of 3.7% over the most recent year of available data (2021-22). Output and growth in the sector have generally been less volatile than the (residential and non-residential) building construction sectors.

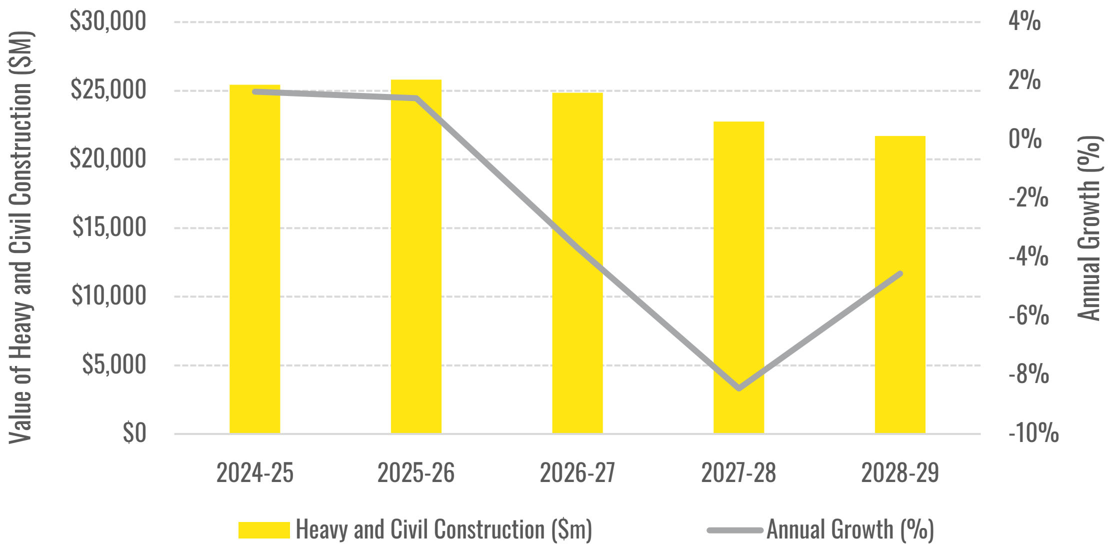
Figure 2-9: Heavy and Civil Engineering Construction Industry Output, Greater Sydney (FY2018 to FY2022)



Source: .id (2024)

The MBA forecasts show a very high level of infrastructure construction over the next two years - in excess of $25 billion in the Greater Sydney region. After this period, infrastructure construction is expected to decline, however, it will remain elevated relative to historical levels, which demonstrates the strong existing pipeline of major infrastructure works.

Figure 2-10: Heavy and Civil Engineering Construction Forecast, Greater Sydney (FY2025 to FY2029)



Source: MBA (2024), Atlas

NSW has a generational infrastructure pipeline, with Infrastructure Partnerships Australia (2024) identifying 169 projects in the pipeline with a total project value of >$160 billion. The NSW Budget 2024 allocated $85.6 billing general government funding over the four years to FY2027.

2.3 Construction Outlook

The construction industry has experienced significant headwinds in recent years with key factors including:

- **Supply chain disruption and acute labour shortages during and post the COVID-19 pandemic**, including:
  - Sudden temporary bans on most forms of construction, renovation and repair work in Greater Sydney in 2021.
  - Restrictions on international travel, removing access to a key pool of industry skilled labour.
- **Ongoing labour shortages:** Infrastructure Australia estimated a shortage of 229,000 full-time infrastructure workers (as at October 2023) with shortages expected in all occupational groups (Infrastructure Australia, 2023). A backlog of projects and fierce competition for labour means the industry shortfall is challenging to fill.

  Jobs and Skills Australia (2023) projects that national industry employment in the construction sector will grow by >120,000 positions (nearly 10%) by 2033, which highlights likely additional pressure on existing shortages.
- **Rapidly rising input costs:** Impacts from the pandemic, war in the Ukraine and ongoing disruption of key Chinese supply have all contributed to rapidly rising input costs for construction which have risen well ahead of inflation (shown in **Figure 2-6**). While broader supply chain impacts have eased, prices for a number of key inputs continue to rise. Escalating inflation, material costs and labour shortages have created a tense environment, exerting sustained pressure on fixed-price contracts and profit margin targets (BCI, 2024).
- **Greater regulatory burden:** changes to Building Code of Australia requirements, changes to environmental standards and more onerous development control requirements cumulative add to lead-times and compliance cost.
- **Higher and uncertain future borrowing costs:** 13 cash rate rises by the Reserve Bank of Australia (**RBA**) was met with interest rate rises which created uncertainty for borrowers. While inflation appears to have peaked (at nearly 8% pa in 2022), the future timing and scope for potential rate reduction remains highly uncertain.
- **A rise in project deferrals**: Due to the ongoing cost and macro uncertainty there has been a rise in project deferrals (BCI, 2024). While there is a noted trend in project deferrals, overall abandonment rates remain low and the outlook for activity over the coming 12 months remains strong.

While there are significant challenges in the construction industry, there remains a significant pipeline of construction work across Greater Sydney and indeed most Australian states. The commitment to the National Housing Accord will further drive demand for construction (on top of existing strong levels) and the need for associated industrial space across the supply chain.

2.4 Implications for Demand for Industrial Land

The implementation of the National Housing Accord will add significant demand for industrial lands within Greater Sydney.

Key factors include:

- Housing delivery will need to increase by >20,000 annually above historical averages (around a 67% increase). The target sits almost 8,000 dwellings above the all-time annual record of 42,414 dwellings delivered in 2018-19.
- The target has been committed to during a time of significant challenges for the construction sector and broader supply chain. Rising costs, labour shortages, greater regulatory burden and borrowing cost uncertainty are all contributing to an uncertain macro-economic environment which makes investment in expansion challenging. Many construction companies have experienced an insolvency event due to the current economic environment.
- Strong short-term growth in the non-residential and civil construction sectors is also forecast, which will further drive competition for industrial lands within greater Sydney and more broadly.

All of the available indicators point to increased demand for industrial lands within the short-term arising from the residential and broader construction sector supply chains.

3. Demand and Supply of Industrial Lands

3.1 Industrial Demand and Typologies

Economic Trends and Drivers

Demand for industrial floorspace is influenced by a broad set of macro-economic factors - at the global and domestic level. Population and economic growth, infrastructure investment, changing consumer patterns and technological advancements are some of the core drivers which guide businesses' floorspace requirements and how floorspace is utilised.

Sydney's industrial market had been growing for a number of years in the lead up to the initial outbreak of COVID-19 in March 2020. The outbreak of COVID-19 amplified these demand drivers with a convergence of tailwinds driving some of the strongest market conditions in the industrial sector on record. Looking forward, industrial market conditions in Sydney's industrial sector are expected to remain strong due to the following key drivers:

- Large scale transport infrastructure projects and residential development underway and in the pipeline stimulating industrial activity, particularly in Western Sydney.
- Continued development of manufacturing sectors particularly advanced manufacturing.
- Continued uptake of e-commerce platforms, driving significant demand for freight and logistics floorspace.
- Population growth driving demand in the food and beverage and urban services sector (e.g. waste recycling, automotive services, utilities, small scale manufacturing).
- Further growth in internet usage driving demand for data storage in large, purpose-built facilities (i.e. data centres).

These strong tailwinds have resulted in significant investment interest into industrial assets across Greater Sydney in recent years, in response to market demand. This investment focus is expected to continue and strengthen moving forward.

Demand for Different Typologies

The nature of industrial demand is not homogenous. There are different development typologies that respond to demand.

It is useful to consider industrial development typologies in three categories:

- Transport-based industrial (servicing the transport and logistics sector).
- General industrial (which could accommodate a range of activities including manufacturing and assembly, product servicing, wholesaling and storage, as well as functions such as marketing, administration, payroll, etc.); and
- Light industrial/ urban services.

While there would be exceptions to the above categories, they are a useful categorisation for types of industrial demand.

Large Format Warehousing (Transport and Logistics)

Transport-based industrial uses are commonly referred to as the 'transport and logistics' or 'freight and logistics' sector. These industrial uses typically occupy large format warehouse typologies - examples of these large format facilities can be observed at Eastern Creek, Erskine Park and other locations directly accessible off the orbital road network.

Direct road access off arterial roads and the ability to operate in a conflict-free environment are important site selection factors to these large industrial formats. Access for large, articulated vehicles (e.g. B-doubles, semi-trailers) is critical. These typologies also require the ability to operate 24/7 to ensure logistics fulfilment is time effective.

General Industrial

General industrial uses (e.g. food production, assembly and distribution of electrical parts) service regional catchments and require proximity and direct access to their customer base and suppliers. They occupy a range of building sizes (generally smaller than transport-based industrial uses) but still require adequate vehicle access for loading, storage and parking.

General industrial uses at present comprise the largest proportion of industrial activity, with the volume of industrial zoned land reflecting this. Some of these uses can be noisy, emit odours and be subject to frequent visits by large vehicles. They can often be regarded as non-conducive to residential living and therefore are at risk of land use conflicts if sufficient buffers with sensitive land uses are not in place.

General industrial areas comprise the highest proportion of industrial activity with precincts like Auburn, Lidcombe, Silverwater, South Penrith and St Marys North examples.

Light Industrial/ Urban Services

Demand for light industrial uses/ urban services (e.g. automotive servicing, household appliance repairs) is directly driven by population growth. Their relationship with population growth is comparable to other uses such as local retail services.

Similar to general industrial uses, light industrial uses also service local catchments and choose locations that allow them to be accessible by their customer base and suppliers. These industrial development typologies are generally smaller in scale and serviced by smaller vehicles (rigid trucks and vans).

Light industrial land in proximity to established centres, highways/ and arterial roads that have the potential for commercial uses can achieve higher sale rates. Light industrial areas comprise a smaller proportion of precincts and include precincts like Marrickville, Penrith and Artarmon.

The Study highlights that the development typologies accommodated within industrial precincts are not mutually exclusive. It is common for precincts to accommodate more than one development typology.

The Study is primarily concerned with the demand for large format warehousing and general industrial facilities.

3.2 Demand and Take-up of Industrial Land

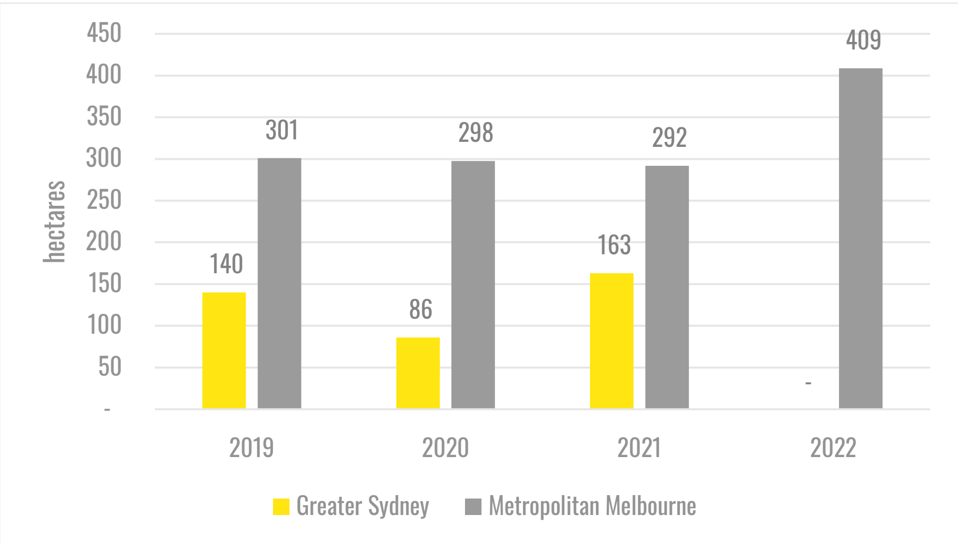
The take-up of land is a useful indicator of demand for land. ‘Take-up’ refers to the development of vacant industrial land.

Market Response to Demand

The strong tailwinds can be seen in the take-up of industrial land in Melbourne, where the annual take-up was sustained (at 300 hectares) in 2020/ 2021 despite the COVID-19 pandemic and thereafter reaching a record of 409 hectares in 2022.

In contrast, the annual take-up of land in Sydney (80ha-160ha) has generally been 30%-60% of Melbourne’s.

Figure 3-1: Annual Take-up of Industrial Land, Sydney v Melbourne (2019-2022)



Source: DPHI (2022), DTP (2023), Atlas

Since 2019, Melbourne averaged annual take-up of 325 hectares, whereas Sydney only averaged 130 hectares. With a population base larger than Melbourne’s and comparable port throughput volumes, the low annual take-up of industrial land in Sydney is symptomatic of a supply constrained market. The rest of the section explores this issue in greater detail.

Sydney v Melbourne v South East Queensland (SEQ)

Annual take-up of industrial land in Greater Sydney has averaged 130 hectares in the 2019-2021 period. In contrast, Southeast QLD (SEQ)'s averaged 195 hectares over the same period.

There is one additional year of data for Melbourne - its take-up of industrial land over the 2019-2022 period averaged 325 hectares. In 2022 the take-up of land in Melbourne reached a record of almost 410 hectares.

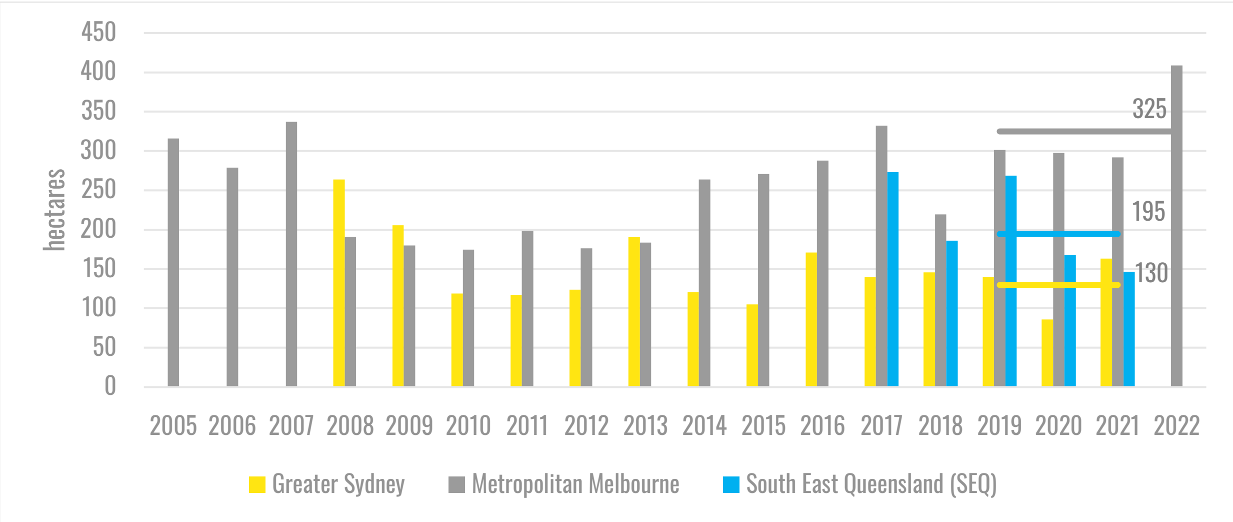
Table 3-1 and **Figure 3-2** compare the relative sizes of the capital city markets against their annual take-up of land.

Table 3-1: Annual Take-up of Industrial Land - Sydney, Melbourne, Brisbane and SEQ (2019-2021)

Region	Value of Industrial Sector (IVA)	Population (2021)	Annual Land Take-up (ha)				
			2019	2020	2021	2022	Avg. (2019-2021/22)
Greater Sydney	$70.0 billion	5.3 million	140	86	163		130
Metropolitan Melbourne	$62.7 billion	5.0 million	301	298	292	409	325
Southeast QLD (SEQ)		3.6 million	269	168	147		195

Source: DPHI (2022), DTP (2023), DSDMIP (2022), Atlas

Figure 3-2: Annual Take-up of Industrial Land (2005-2022)



Source: DPE (2022), DTP (2023), DSDMIP (2022), Atlas

Sydney has the largest population base (5.3 million residents) compared to Melbourne (5.0 million residents) and SEQ (3.6 million residents). Furthermore, container throughput in Sydney is similar to Melbourne and much greater than Brisbane. Despite these factors, Sydney's average annual take-up of 130 hectares has been significantly lower than Melbourne's 325 hectares per annum and SEQ's 195 hectares per annum (a region that is less than 70% the size of Sydney).

The analysis highlights that a lack of serviced land supply in Sydney has constrained its ability to respond to demand. Since 2010, Sydney has trailed Melbourne's market response to demand by a cumulative amount of approximately 1,700 hectares. The impact of this cumulative deficit on market indicators (rents and values) is examined in the next section.

The Study cautions that the above data is dated. Data for industrial land take-up for 2022 and 2023 is not available.

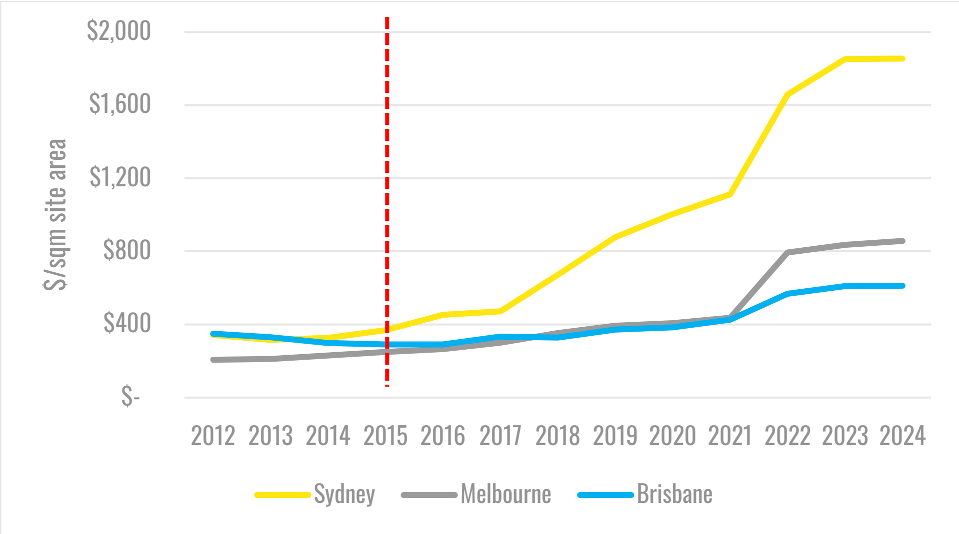
3.3 Rents and Values of Industrial Property

The sufficiency of land to meet demand can be observed through market signals. Market indicators such as rising prices, falling incentives, falling vacancy rates, etc. signal a market that is undersupplied.

Land Values and Building Capital Values

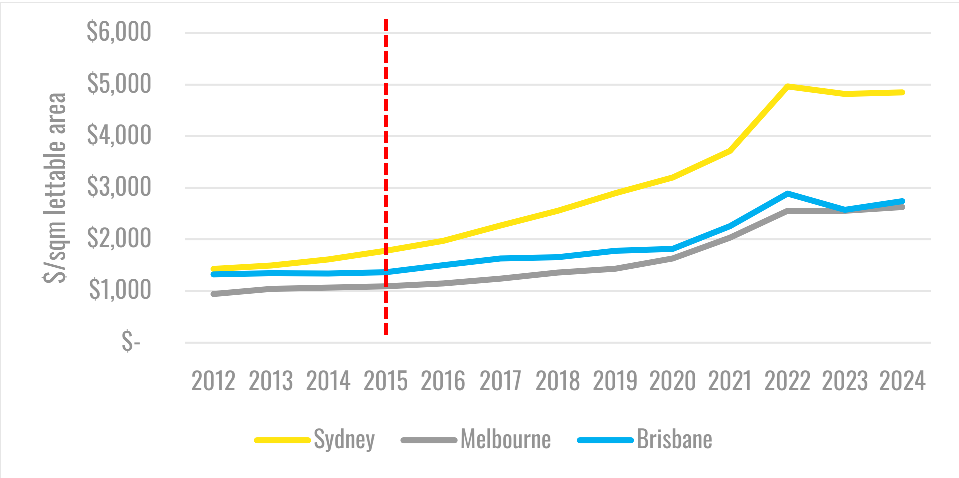
Figure 3-3 and **Figure 3-4** show that land values and building capital values in Sydney were already higher than peer capital cities Melbourne and Brisbane in 2012. From approximately 2015, land values and building capital values in Sydney dramatically outstripped those in Melbourne and Brisbane.

Figure 3-3: Land Value Movements - Sydney, Melbourne, Brisbane (2012-2024)



Source: Cushman and Wakefield (2024)

Figure 3-4: Building Capital Value Movements - Sydney, Melbourne, Brisbane (2012-2024)

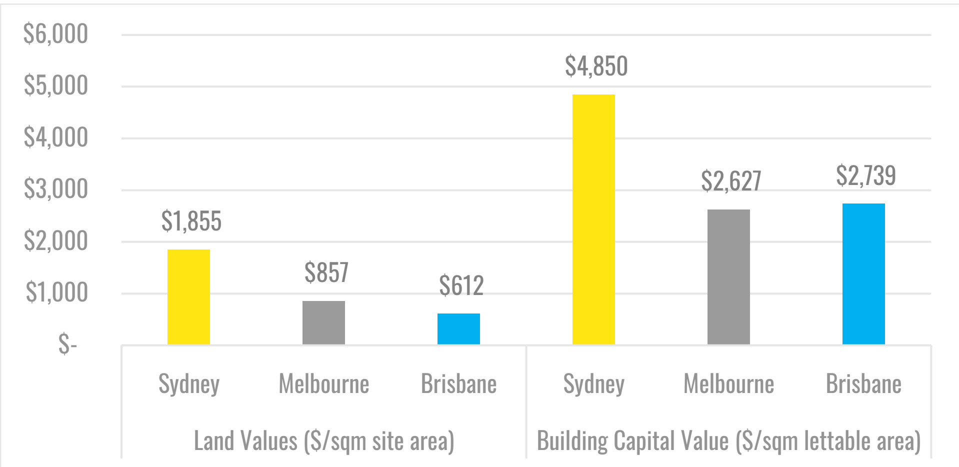


Source: Cushman and Wakefield (2024)

Figure 3-5 shows a comparison of land values and building capital values between Sydney, Melbourne and Brisbane (as at 2024). Industrial land values are 200% and 300% compared to Melbourne and Brisbane.

The significant gap between the prices of Sydney and peer capital cities highlights a supply and affordability crisis in Sydney.

Figure 3-5: Land Values and Building Capital Values - Sydney, Melbourne, Brisbane (2024)



Source: Cushman and Wakefield (2024)

Rents and Outgoings

This section illustrates the rent, outgoings and vacancy movements in Sydney compared to peer capital cities of Melbourne and Brisbane. In 2024, Sydney's gross rents ($322/sqm) are >80% higher than Melbourne's and >60% higher than Brisbane's. Sydney also has the lowest vacancy rates nationally.

Figure 3-6: Prime Net Rents - Sydney, Melbourne, Brisbane (2012-2024)

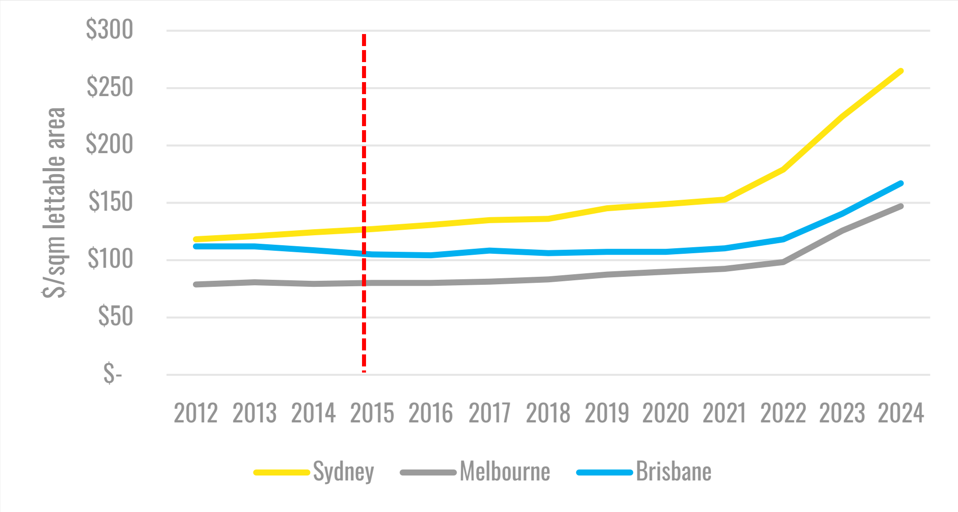


Figure 3-7: Prime Net Rents and Outgoings - Sydney, Melbourne, Brisbane (2024)

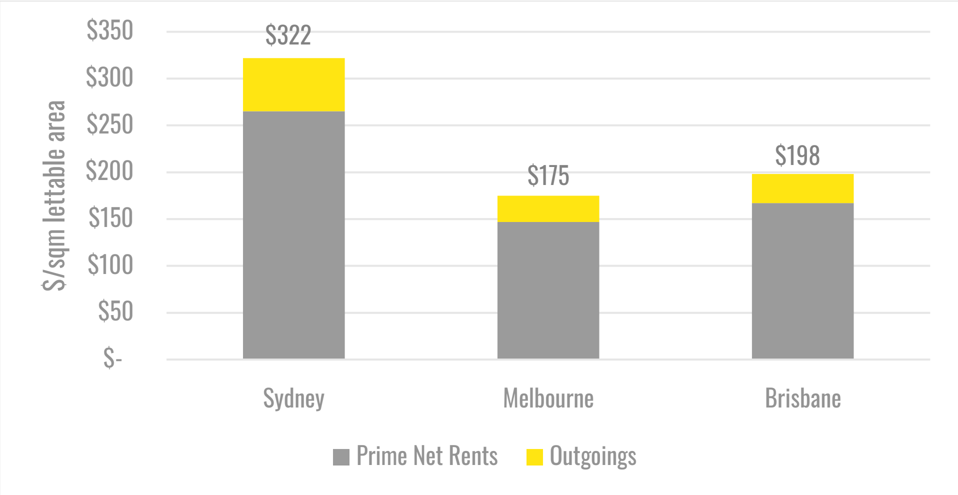
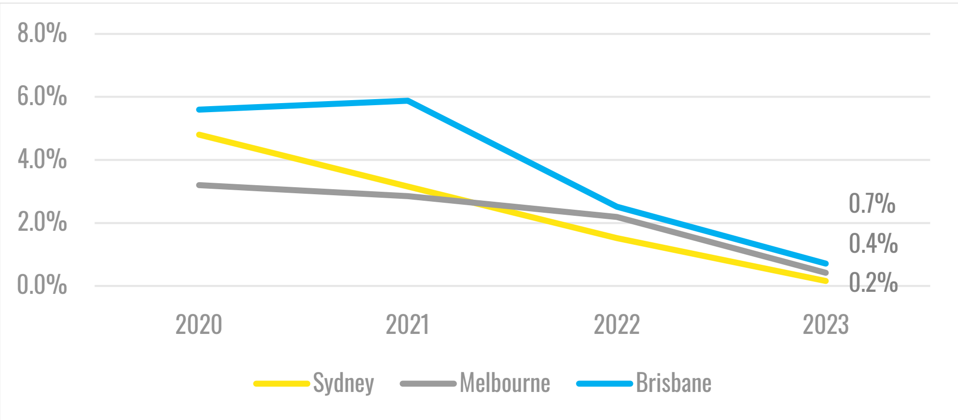


Figure 3-8: Vacancy Rates - Sydney, Melbourne, Brisbane (2020-2023)



Source: Cushman and Wakefield (2024)

All market indicators point to a severely undersupplied industrial market in Sydney - one that has insufficient supply of land *and* floorspace to respond to market demand. This poses a serious affordability and business certainty problem.

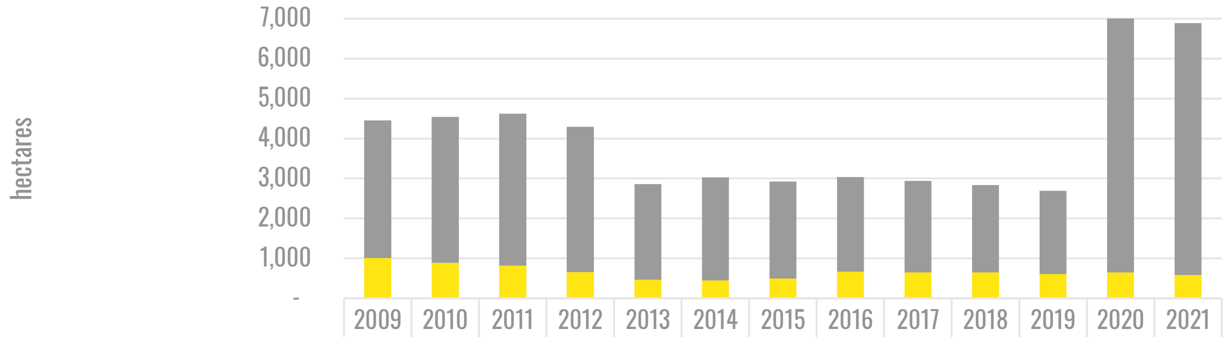
3.4 Remaining Supply of Industrial Lands

Theoretical Land Supply (Serviced)

As at January 2022, the DPHI's Employment Land Development Monitor (ELDM) showed the supply of undeveloped zoned and serviced land in Greater Sydney was 585 hectares (only 8% of total undeveloped zoned land).

Figure 3-9 illustrates the supply of undeveloped land in Greater Sydney (serviced and not serviced) as at January 2022. There is almost 7,000ha of undeveloped zoned land, but >90% is not serviced (having a lack of roads and utility services).

Figure 3-9: Undeveloped Zoned Land and Serviced Land, Greater Sydney (January 2022)



	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Total Zoned and Undeveloped	4,457	4,543	4,620	4,290	2,859	3,030	2,928	3,032	2,937	2,838	2,691	7,055	6,889
Zoned, Undeveloped, Not Serviced	3,445	3,651	3,803	3,634	2,396	2,580	2,431	2,369	2,291	2,193	2,085	6,410	6,304
Zoned, Undeveloped and Serviced	1,012	892	817	656	463	450	497	663	646	645	605	645	585

Source: DPHI (2022)

Research by Mecone (2024) identifies there could potentially be 879 hectares of zoned industrial land that is serviced - assuming land within precincts that are partially serviced is capable of being serviced.

However, environmental constraints (e.g. flood prone land, riparian land and watercourses) and land reserved for infrastructure restrict the development capacity of land. Mecone estimates that at best, there is around 597 hectares of land zoned, vacant and unconstrained land in serviced precincts suitable for large format industrial development. This is similar in quantum to the supply of undeveloped zoned and serviced land estimated by DPHI at January 2022.

Market Requirements

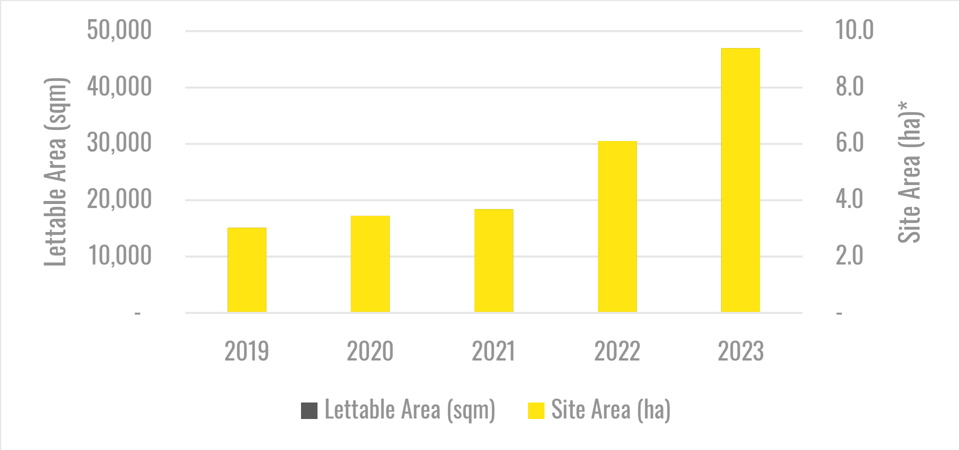
The simple land supply metrics do not provide the whole picture. To be viable from a market perspective, the land needs to be appropriately located with suitable size and site attributes. The following recent projects demonstrate size requirements:

- Techtronic Industries (75,000sqm).
- Toll (68,000sqm).
- Woolworths Distribution Centre (76,000sqm at Wetherill Park, 35,000 at Kemps Creek).
- Australia Post Distribution Centre (36,000sqm).
- Mainfreight Distribution Centre (55,800sqm).

National average pre-lease data shows size requirements have been increasing.

Figure 3-10 shows that in 2023, the average pre-lease tenancy size was 47,000sqm lettable area. At a site cover ratio of 50%, this implies a site of 9.4 hectares is required.

Figure 3-10: National Average Pre-lease Size (sqm) (2019-2023)



*Site area (ha) requirements estimated assuming site cover of 50%

Source: Cushman and Wakefield

<u>Theoretical Capacity v Market Requirements</u>

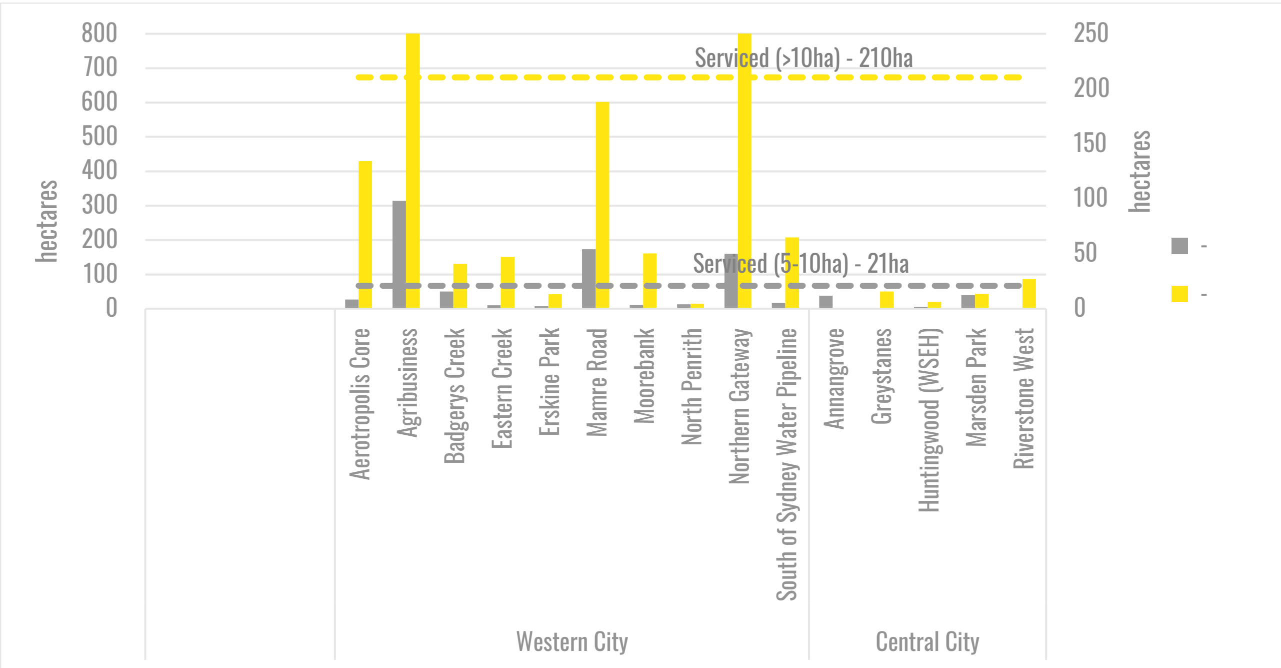
Land that is zoned (and serviced) may have the theoretical capacity for development, but only land that meets market requirements (in the right location and with suitable size and site attributes) will be developed.

This section identifies undeveloped zoned and serviced land that is greater than 5 hectares. The analysis shows that:

- Less than 40% of 585 hectares of serviced undeveloped zoned land is greater than 5 hectares in size (231 hectares out of 585 hectares).
- Of the 231 hectares of land larger than 5 hectares in size, more than 150 hectares is at Moorebank. Accommodation at the Moorebank Intermodal Terminal is generally only available to tenants who utilise the intermodal rail facilities.
- Less than 80ha of serviced undeveloped zoned land (> 5ha in size) is available to the general market.

The analysis shows that while there is theoretical capacity of 585 hectares, less than 80 hectares is larger than 5 hectares in size and available to the general market. At an annual take-up rate of 400 hectares (similar to recent demand levels in Melbourne), Sydney has at best, one year of industrial land supply remaining.

Figure 3-11: Undeveloped Zoned Land by Size, >5ha (January 2022)



Source: DPHI (2022)

The analysis shows a concentration of large lots (>5ha) within precincts that are not serviced. These precincts are the Mamre Road precinct (775ha) and the precincts of Northern Gateway (1,000ha), Agribusiness (870ha), Aerotropolis Core (465ha) and Badgerys Creek (180ha) which are located in the Western Sydney Aerotropolis (**WSA**).

The Mamre Road Precinct is the only precinct with large landholdings, institutional investment and committed tenant interest and with development planning that is well advanced.

Even if they were to be serviced, the WSA precincts are constrained in their ability to be developed (Mecone, 2024):

- The Agribusiness precinct is designed to support a specific and narrow type of activity, preventing more general large format industrial development from occurring.
- Large parts of the Badgerys Creek and Aerotropolis Core precincts are highly fragmented, creating challenges for site amalgamation and the development of large >10 ha sites.
- A range of environmental constraints (such as the blue-green grid) that limit site developability. The distribution of these constraints cut through lots, creating environmentally fragmented sites.

The cumulative impact of these constraints is that industrial land in the WSA risks being sterilised for decades.

Development Feasibility at Mamre Road Precinct

In 2023, Atlas undertook a feasibility analysis of the Mamre Road Precinct following release of Sydney Water DSP charges. The work found that when added to the other statutory fees and charges (local and state contributions), the entire Mamre Road Precinct was not feasible to develop.

The work found that there was provisional capacity to pay up to $287,000/ha NDA for DSP charges subject to a number of factors, including *inter alia*, if rents were increased by 5%, if there was no interim abortive costs or land sterilisation associated with meeting waterway health controls ahead of a regional scheme and if funding and delivery of the required road infrastructure was forthcoming in a timely manner.

Despite this, the DSP charges submitted by Sydney Water to IPART for finalisation are $800,000/ha NDA and the NSW Government requires interim waterway measures that would sterilise approximately 60% of site area.

The cumulative impact of the loss of developable area ***and*** additional cost associated with the interim solution results in development that is not feasible.

Sydney v Melbourne v South East Queensland (SEQ)

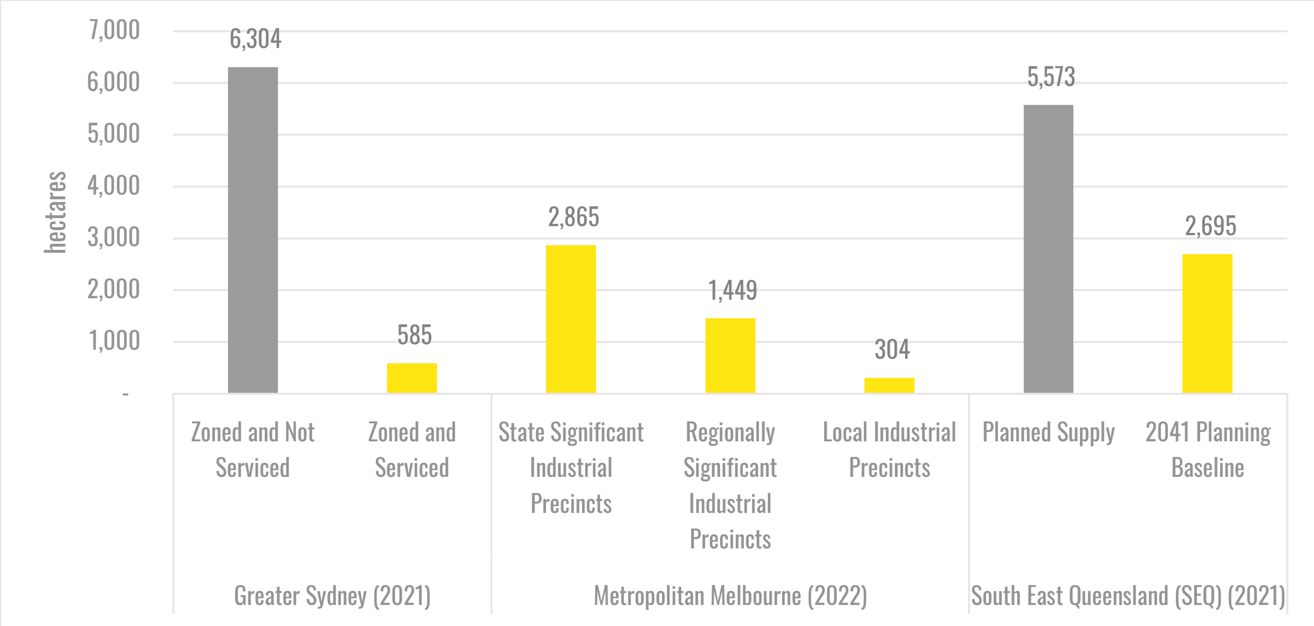
In Melbourne (as at 2022), there was 4,618 hectares of zoned and vacant industrial land, of which 2,900 hectares (>60%) is within State Significant Industrial Precincts (SSIPs). SSIPs are recognised to be critical to Melbourne's economy and are accorded 'special status' (Victoria Planning Provisions Clause 17.03-3S).

Victoria's precinct structure planning (PSP) process coordinates land rezoning and infrastructure servicing, wherein land is not rezoned unless it is capable of being serviced. At an annual absorption rate of 400 hectares, the land supply is equivalent to 11.5 years of theoretical supply.

In SEQ (as at 2021) there is an estimated 2,700 hectares available for what is referred to as "2041 Planning Baseline". At an annual absorption rate of 200 hectares, the serviced land supply is equivalent to 13.5 years of theoretical supply.

Figure 3-12 compares Sydney's zoned and serviced industrial land supply with Metropolitan Melbourne and the SEQ region.

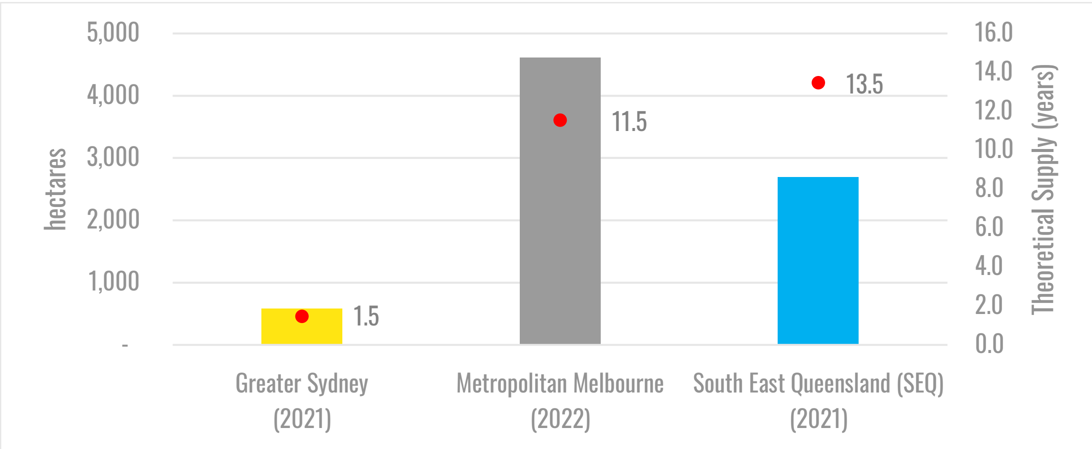
Figure 3-12: Industrial Land Supply - Sydney, Melbourne and South East Queensland (SEQ)



Source: DPE (2022), DTP (2023), DSDMIP (2022), Atlas

Figure 3-13 shows Sydney's remaining theoretical land supply compared to Melbourne and SEQ (with 11.5 years and 13.5 years respectively).

Figure 3-13: Years of Theoretical Industrial Land Supply - Sydney, Melbourne and South East Queensland (SEQ)



Source: Atlas

While Sydney has 1.5 years of ***theoretical*** supply remaining, the analysis in **Figure 3-11** shows much of that supply is either too small or not available to the general market. When taking into account size and site attributes, Greater Sydney has at best, about one year of remaining industrial land supply.

Both State Governments in Victoria and Queensland have strategic land supply policies that require 15 years of forward land supply. Atlas is not aware of a similar policy that exists in NSW.

3.5 Implications for Business Certainty, Affordability and Employment

The lack of serviced industrial land has evidently constrained Sydney's ability to respond to market demand. Over last three years (of available data), Sydney has averaged a take-up of 130 hectares per annum whereas Melbourne and SEQ have averaged 325 hectares and 195 hectares per annum respectively.

For the largest capital city in Australia with the largest population base and largest industrial sector, demand for land in Sydney would be expected to be at least on par with Melbourne's. The anaemic annual take-up of industrial land in Sydney is symptomatic of a supply constrained market. These constraints have evidently been in the making for more than a decade.

Furthermore, with vacancy rates the lowest nationally (and globally), there is also no floorspace availability for business to move between premises. Vacancy rates of 4%-6% are needed for a healthy and functioning market - it enables businesses to scale-up (when they grow) and relocate to other premises as their requirements change and evolve.

Leasing data from Cushman and Wakefield shows that in recent years, lease renewals has comprised >95% of leasing activity. This is driven by the near-zero vacancy levels which have not allowed businesses access to suitable premises. In previous years where vacancy rates were healthy and allowed occupier friction between premises, the ratio of lease renewals to new leases was observed to be closer to 70%.

Investment and Employment Elsewhere

The systemic supply shortfall of serviced industrial land (evident for more than a decade) is borne out in Sydney's employment numbers. ABS data shows that of industrial employment (2016-2021) was very much lower than peer capital cities of Melbourne and Brisbane:

- Greater Sydney averaged 0.5% per annum.
- Metropolitan Melbourne averaged 1.2% per annum.
- Greater Brisbane averaged 1.1% per annum.

The analysis affirms that a constrained land supply situation has 'held back' investment and growth of the industrial sector. With about one year of theoretical supply remaining (compared to 11.5 years in Melbourne and 13.5 years in SEQ), there is no room for business investment, business growth and further employment opportunities.

No Capacity for Business and Employment

The industrial sector is valuable. During 2020-21, the industrial sector contributed an estimated $70 billion (18%) to the Greater Sydney economy.

The shortage of serviced, industrial land in Sydney has reached a critical point. The record low vacancy rate and rapidly escalating prices demonstrate the severity of the issue as remaining serviced, industrial land stocks are almost exhausted.

The analysis shows that the industrial supply crisis has affected:

- Employment growth - ABS data shows that despite being the largest capital city, Sydney's industrial employment has been the lowest.
- Business certainty - leasing data shows businesses are staying in place despite their need for more space.
- Business cost and affordability - the cost of accommodation (rents) in Sydney is 85% more expensive than Melbourne and 65% more expensive than Brisbane. This has direct consequences for the cost of living in Sydney.
- Cost of land - with the supply of serviced land at critical lows in Sydney, land values are more than double Melbourne's and more than treble Brisbane's. This has direct consequences for the economic rents that must be charged for development to be feasible.
- Future development and new supply - higher economic rents must be charged for development to be feasible, putting further upward pressure on rents that are already significantly higher than the peer capital cities of Melbourne and Brisbane.

This chapter has demonstrated that industrial lands in Sydney are already severely constrained. There is little availability and businesses are forced to pay prices much higher than in Melbourne and Brisbane. The lack of supply opportunities is exacerbating the cost-of-living crisis and will undoubtedly shift investment out of Sydney.

Demand from residential construction to meet the Housing Accord targets will place further demands on industrial land that is constrained and result in even greater upward pressure on rents and prices.

The next chapter details business perspectives in the context of the acute industrial lands crisis.

4. Industry Engagement

This chapter summarises the industry engagement undertaken by Infosys Portland as part of this Study to help understand the need for industrial lands within Greater Sydney and the position of industry to deliver the housing accord in the region.

4.1 Engagement Process

Infosys Portland approached businesses who operate within, and supply to the construction sector. Most of businesses are ASX listed or on the Fortune 200 list. A selection of in-depth one-on-one interviews were undertaken with various senior executives from the businesses to discuss current market characteristics, supply chain and future potential growth.

Table 4-1 contains a general description of their business activity and the position held by the interviewed executive.

Table 4-1: Business and Personnel Interviewed

Business	Executive Interviewed	Nature of Business Activity
Business 1	General Manager, Supply Chain	Manufacturer of surface materials
Business 2	General Manager	Australian manufacturer of structural products
Business 3	Regional CEO	Global manufacturer and distributor
Business 4	General Manager, Supply Chain	Leading concrete supplier
Business 5	Property Executive	Global manufacturer of components for building and construction
Business 6	Supply Chain Executive	Timber supplier
Business 7	Head of Property	Building products manufacturer and distributor
Business 8	Supply Chain Executive	Bathroom and laundry products supplier

Source: InfoSys

Questions were posed to the businesses to understand:

- How well their construction supply chains are placed to increase productivity/ capacity/ velocity to meet Greater Sydney's growth demands.
- The factors affecting supply chains' capabilities to grow capacity to meet increased demand.
- The businesses' current approach to servicing the Greater Sydney market (including operating model, customer expectations, and key supply chain challenges) and how they are planning to meet growth expectations.

4.2 Engagement Feedback

The shortage and cost of industrial and logistics property is forcing construction sector suppliers to increasingly service the Greater Sydney market from locations outside Sydney.

- Suppliers are avoiding adding manufacturing and warehouse capacity in Greater Sydney.
- Additional supply chain costs from increased transport are passed on to the customer.
- Additional transport distances to service Graeter Sydney are resulting in increased emissions.
- There are expectations to move a greater JIT (just-in-time) delivery for construction sites and the major hardware retailers/ wholesalers are requesting shorter lead times.
- Opportunities for step-change in productivity/ throughput are limited. Any improvements will not be sufficient to avoid additional servicing from outside Sydney.

Most businesses are sceptical that the housing targets will be achieved in NSW.

Case Study

Business X is a leading manufacturer of structural components for the building/ construction industry. They are located at leased premises in Sydney's southwest. The landlord had developed a plan to redevelop the site which required Business X to evaluate options for relocation. The initial search in Sydney for alternate sites at a viable cost proved futile.

The company decided to relocate its manufacturing capability to Regional NSW with 2-3 hours travel time to markets in Greater Sydney. Despite proximity to market being an important part of the company's value proposition, with no viable alternative in Sydney, they elected to build a new manufacturing site in Regional NSW.

The increase in transport and logistics costs were passed on to their customers.

Table 4-2 summarises key themes that have emerged from the interviews.

Table 4-2: Feedback Themes

Question	
How well are your construction supply chains placed to increase productivity/ capacity/ velocity to meet Sydney's growth demands?	Businesses raised concerns about supply chain constraints other than industrial property in Greater Sydney which impact growth opportunities including: • Road congestion • Poor port access • Labour availability and costs • NSW Government's lack of capabilities in planning and infrastructure delivery. There is a general sentiment that SEQ and VIC are more attractive markets than NSW.
What factors impact your supply chain's capability to growth and meet forecast increased demand?	Businesses are exploring options such as increased automation to increase productivity and throughput to mitigate the need for expanded warehouse/ manufacturing capacity. The paybacks from increase automation are however often not attractive enough or are not feasible in 'legacy' facilities. Any improvements gained are likely insufficient to avoid servicing additional volumes from outside Sydney.
How are you servicing the Sydney market and how are you planning to meet growth expectations?	Most of the businesses interviewed are planning to avoid additional warehouse or manufacturing capacity in Sydney. They are planning to service Sydney market growth through one or a combination of the following: • increased use of existing regional NSW facilities. • Servicing more volumes from Melbourne or Brisbane facilities. • Building/ sourcing new capacity in regional NSW. Servicing Greater Sydney from facilities outside Sydney will result in additional transportation costs. The businesses plan to pass these costs on through freight recovery.

Source: Infosys

Table 4-3 highlights notable quotes from the interviews.

Table 4-3: Notable Quotes

Interviewee (Business Activity)	Quote
Head of Property (Large building products manufacturer and distributor)	We have put a line through Sydney as an option to expand manufacturing capacity.
	We have been evaluating new manufacturing capacity in Australia and cannot justify new manufacturing capacity in Sydney due to the property costs and the uncertainty.
	We looked at Regional NSW, we have a regional site already and Wollongong is land constrained. Other options we are looking at are Brisbane and Melbourne.

Interviewee (Business Activity)	Quote
Regional CEO (Global manufacturer and distributor)	The only thing that may change our view from servicing Sydney from Melbourne would be if there was an unusually large increase in transport costs which may be driven by a carbon tax or similar government intervention.
	We do not have plans to increase capacity in NSW. We see Melbourne has having significant advantages over Sydney for warehouse locations with better access to the port and lower costs. We will focus on leveraging our Victorian sites for any growth.
General Manager - Supply Chain (Manufacturer surface material)	Currently running two shifts in the NSW warehouse - could move to have a night shift however this would increase costs - about 30% additional labour cost.
Property Executive (Global manufacturer of components for building and construction)	We have been unable to expand due to the lack of industrial property available. We wanted a greenfield site but there were no suitable options and too expensive. We are at capacity and realistically we need at least 50% more capacity. This is constraining growth for our business.
General Manager (Australian manufacturer of structural products)	Our warehousing is operating at 85%-90%. Manufacturing is operating at about 100%. We would ideally like to stay where we are and use the existing network to meet demand in Sydney. We could move to comparable premises in Sydney to maintain our workforce but the problem is the property costs in Sydney do not make this feasible. We have been moving our capacity to our regional site. We have had to increase prices to offset the additional transport costs.

Source: Infosys

4.3 Implications for Greater Sydney's Capacity

There are common themes that have emerged, which are summarised as follows:

- Facilities within Greater Sydney are currently operating at near maximum capacity with most stakeholders reporting between 90% and 100% utilisation of their existing facilities in Greater Sydney.
- The shortage of serviced industrial lands in Greater Sydney is well acknowledged. A number of businesses are experiencing high demand and forecast future growth over the Housing Accord period. However, the lack of availability and high costs is prohibiting local activity and a number of processes are already underway, including:
  - Either an expansion of regional operations or servicing Greater Sydney from Melbourne or Brisbane are the preferred delivery options for stakeholders.
  - Typically customers are seen as more accepting of higher transport costs (e.g. to freight from Melbourne) being passed on rather than site development costs or industrial rents.
  - There are attractive back-loading rates into Greater Sydney.
  - There is ever increasing need on the speed/reliability of the supply chain which would favour development within Greater Sydney, however the cost and lack of suitable sites precludes expansion/development in many instances:
- There is general scepticism within industry regarding Greater Sydney's ability to meet the Housing Accord targets:
  - The capacity of the local industrial supply chain is a part of the issue, there is general consensus surplus demand would be delivered through regional centres (e.g. Newcastle) and interstate (Melbourne and Brisbane). This will further add to construction costs, which are already a major constraint to new housing delivery.

Broader issues including an acute industry labour shortage and macroeconomic uncertainty will further constrain industry's ability to deliver the Housing Accord targets.

5. Construction Supply Chain and Need for Land

The following sections estimate the associated demand for industrial land across the Greater Sydney supply chain to support achieving the National Housing Accord target within the context of broader construction industry, including:

- **Residential Housing:** Industrial lands required to meet National Housing Accord targets.
- **Non-Residential Building & Infrastructure Construction:** Industrial lands required to meet projected real growth.

5.1 Modelling Approach

Input-Output modelling has been used to develop future demand estimates for industrial land required to meet the National Housing Accord targets. A specific set of transaction tables were developed to reflect the structure of the Greater Sydney economy. Refer to SCHEDULE 1 for additional detail on the specific Input-Output modelling methodology applied.

Input-Output analysis produces four types of economic indicators (**Table 5-1**).

Table 5-1: Economic Activity Indicators

Indicator	Description
Output	The gross value of goods and services transacted, including the cost of goods and services used in the development and provision of the final product. Care should be taken when using output as an indicator of economic activity as it counts all goods and services used in one stage of production as an input to later stages of production, thus overstating economic activity.
Gross Value Added	The value of output after deducting the cost of goods and services inputs in the production process (less the impact of net taxes on final production). Gross Value Added (GVA) defines a net contribution to economic activity.
Incomes	The wages and salaries paid to employees as a result of the Project or Proposal either directly or indirectly.
Employment	Employment positions generated by the Project or Proposal (either full time or part time, directly or indirectly). Employment is reported in terms of Full-time Equivalent (FTE) positions or person-years.

Source: Atlas

Input-Output modelling considers direct economic impacts and indirect (flow-on) impacts. Indirect impacts are two types:

- **Production-induced impacts (Type I)** show the effects of industrial support effects of additional activities undertaken by supply chain industries increasing their production in response to direct and subsequent rounds of spending.
- **Consumption-induced impacts (Type II)** estimate the re-circulation of labour income earned as a result of the initial spending, through other industry impacts, and impacts from increased household consumption.

5.1.1 Construction Activity driving Demand for Land

The assessment uses the future anticipated value of construction as the key driver for future demand for industrial land. It considers the direct impact this future expenditure will have on the construction sector (and its demand for industrial land) as well as the supply chain that supports the construction sector including the industries of:

- Manufacturing.
- Wholesale Trade.
- Transport, Postal and Warehousing.
- Electricity, Gas, Water and Waste Services.

Only the Type 1 (production-induced) indirect impacts have been used and only the industries (highlighted above) that occupy industrial land have been included in the indirect activities for the demand assessment. Essentially, the modelling highlights the direct impact of future building activity on the construction industry, then includes the associated activity from the manufacturing, wholesale trade, transport, postal warehousing and utility sectors.

In other words, the modelling captures the direct activity of the construction sector (and its impact on demand for industrial land) as well as the associated supply chain (and subsequent impact on demand for industrial land).

The Input-Output analysis has been used to identify the future employment associated with meeting the National Housing Accord targets. The future employment is then used to determine the future amount of industrial land required, using DPHI data on employment land and ABS data on industrial employment for the Greater Sydney region.

In 2021 (most recent year of available data), there was approximately 11,455 hectares of zoned and developed (occupied) employment land in the Greater Sydney region. Employment data (NIEIER, 2023) shows industrial employment in the region at approximately 370,000 jobs, yielding an average density of 32 workers per hectare. This if all industrial jobs are located on industrial lands. In reality, some industrial jobs could be accommodated on commercial lands. Equally, some non-industrial jobs (e.g. professional, scientific & technical services, public administration & safety) could be located on industrial lands.

Historically, 20% of construction employment has required separate premises with the majority of construction workers based on a building site. The 20% benchmark helps measure businesses engaged directly in construction that would operate out of a central depot (and therefore require land/ floorspace) where machinery, equipment and supplies would be stored.

5.1.2 Modelling Drivers

This section lists the assumptions used to model demand for industrial land arising through the construction supply chain.

Residential Building Construction

Additional industrial capacity required to deliver residential construction has been modelled based on the MBA forecasts (earlier described in Chapter 2). Two scenarios have been considered:

- A Base Case that measures the impact of activity above the historical average production of 30,712 dwellings per year.
- A second scenario that assumes that industry has up to 15% existing capacity to absorb increased future demand, thereby raising its production capacity to 35,320 dwellings per year.

Consultation with industry (detailed in Chapter 4) has indicated that existing facilities in the Greater Sydney region are currently operating at a relatively high rate of utilisation, some operating at 100% capacity, however, a simplified industry-wide assumption of 15% available capacity has been used.

Estimated industry activity above the thresholds from FY2025 to FY2029 were used as direct industry turnover modelled through the residential building construction sector as per the assumptions in **Table 5-2**.

Table 5-2: Projected Housing Construction Activity, Greater Sydney

Input	2024-25	2025-26	2026-27	2027-28	2028-29
New Dwelling Starts	36,001	43,046	46,833	51,398	50,376
Value of Construction Activity ($2023/24 M)	$14,968.2	$16,830.0	$19,139.9	$20,924.2	$21,672.9
Base Scenario					
Dwelling Growth Above Historical Production (30,713 pa)	5,288	12,333	16,120	20,685	19,663
Value of Additional Building Work Modelled ($2023/24 M)	$2,198.7	$4,821.9	$6,588.0	$8,421.0	$8,459.5
Existing Capacity Scenario					
Dwelling Growth Above Existing 15% Capacity (35,320 pa)	681	7,726	11,513	16,078	15,056
Value of Additional Building Work Modelled ($2023/24 M)	$283.3	$3,020.7	$4,705.2	$6,545.5	$6,477.5

Source: Master Builders (2024), Atlas

Non-Residential Building Construction

Non-residential building requirements have been modelled based on the MBA forecasts for industry activity which is projected to peak in FY2025.

In NSW state-wide and across all sub-sectors (retail and commercial, industrial building, social/ cultural and recreational building) non-residential construction work is projected to increase by approximately $1.2 billion (5.6%) over FY2025.

Over the past 10 years Greater Sydney has consistently been responsible for approximately 75% of NSW non-residential building construction (ABS, 2024), with only moderate variation between 70% and 78%. As such future growth has been proportionally scaled by 25% to produce a Greater Sydney growth share estimate of approximately $860 million.

This growth was conservatively scaled down by 15% to allow for capacity within the current supply chain, with the remaining annual $728.6 million modelled through the non-residential building construction sector.

Modelling assumptions for growth in the non-residential building construction sector are summarised in **Table 5-3**.

Table 5-3: Non-Residential Building Construction Modelling Assumptions (Real $2023-24)

Factor	Input
NSW Industry Turnover FY 2024 ($M)	$21,901.3
NSW Projected Industry Turnover 2025 ($M)	$23,134.8
NSW Projected Growth FY2025 ($M)	$1,233.5
% of growth applied to Greater Sydney	75%
Greater Sydney Industry Growth FY2025 ($M)	$857.1
Assumed Capacity within the Current Supply Chain	15%
Direct Industry Turnover Modelled ($M)	$728.6

Source: Master Builders (2024), Atlas

Heavy and Civil Engineering Construction

Heavy and civil engineering construction requirements have also been modelled based on the MBA forecasts for industry activity, with significant growth projected over FY2025 and FY2026. In NSW state-wide and across all sub-sectors (transport, utilities, resources, and recreation & other engineering) heavy and civil engineering construction work is projected to increase by approximately $613 million (1.6% growth) during FY2025 and a further $541 million (1.4% growth) during FY2026 before easing back toward the end of the Housing Accord forecast period.

As of the 2021 census, Greater Sydney accommodated two-thirds of total NSW heavy and civil construction employment (by Place of Work), having increased from circa 60% in 2016[1]. As such, future growth has been scaled by one-third to produce a Greater Sydney growth estimate of $409 million over FY2025 (and a further $360.6 million over FY2026).

As per residential and non-residential construction, FY2025 growth was conservatively scaled down by 15% to allow for potential capacity within the current supply chain, with the remaining annual $347.6 million modelled through the heavy and civil engineering construction sector.

Modelling assumptions for growth in heavy and civil engineering construction are summarised in **Table 5-4**.

Table 5-4: Heavy and Civil Engineering Construction Modelling Assumptions

Factor	Input
NSW Industry Turnover FY 2024 ($M)	$37,543.9
NSW Projected Industry Turnover 2025 ($M)	$38,157.4
NSW Projected Growth FY2025 ($M)	$613.4
% of growth applied to Greater Sydney	66.6%
Greater Sydney Industry Growth FY2025 ($M)	$408.9
Assumed Capacity within the Current Supply Chain	15%
Direct Industry Turnover Modelled ($M)	$347.6

Source: Master Builders (2024), Atlas

Land and Floorspace Requirements

The lack of supply in Greater Sydney has resulted in businesses (out of necessity) utilising their premises more intensely, e.g. producing more output per square metre of floorspace and having more employees per square metre of floorspace.

A review of employment densities in a selection of industrial precincts shows that employment densities (workers per hectare) has been trending upwards over 2011-2021 period. The modelling assumes land utilisation at an average employment density of 40 workers per hectare.

[1] Excludes migratory workers and those with no fixed address.

5.2 Modelled Demand for Industrial Land

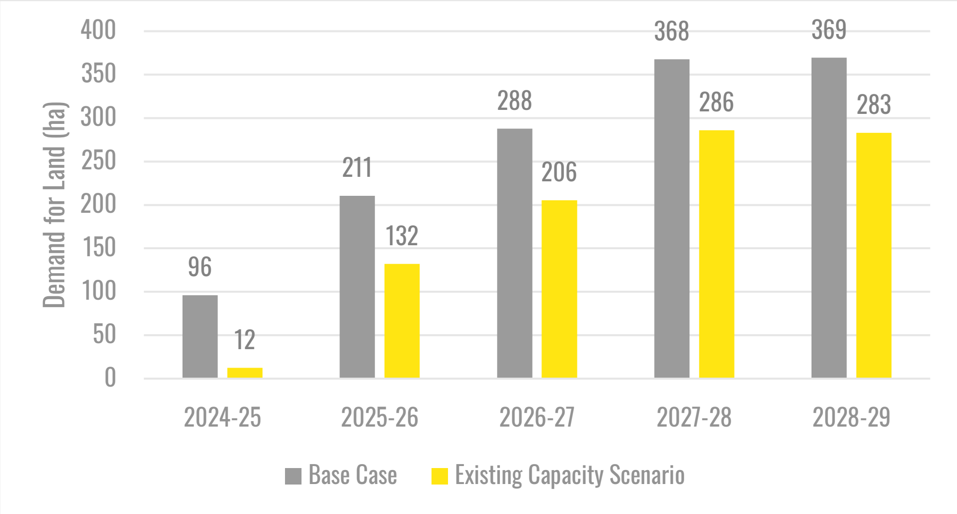
Modelling estimates the demand for additional industrial land for the (significant) growth in residential construction capacity. The modelling conservatively assumes inherent capacity of 15% before new facilities are needed. The modelling considers separately the demand for industrial land to support residential, non-residential and heavy & civil construction activity.

Residential Building Construction

To meet projected industry demand and Housing Accord targets, Greater Sydney is estimated to require up to 369 hectares of serviced industrial land by FY2028. If the industry had 15% existing capacity, the demand would be less - 283 hectares. The strong demand for land (in either scenario) is directly associated with the dramatic increase in dwelling production, moving from a historical average of 30,700 dwellings to around 50,000 dwellings per year (an increase of over 60%).

A simple demand metric can be extracted - 1 hectare land for every 50 additional dwellings of annual capacity. this assumes a mostly linear production function, perfect substitution and limited economies of scale between resources. This however, does not allow for land needed to alleviate the price pressure of the cumulative deficit that has been allowed to build.

Figure 5-1: Demand for Industrial Land, Residential Construction (FY2025 to 2029)



Source: Atlas

The Impact of Price and Market Dynamics

The modelling suggests 280-380 hectares of serviced industrial land is required to meet the housing targets. However, 280-380 hectares of serviced industrial land *alone* is not likely to enable the desired building and construction outcomes.

The construction sector accounts for a small fraction of total demand for industrial land (estimated at 5%-7%). For many years, the transport, logistics and distribution sectors have driven the majority of demand for industrial land, estimated to be close to 50% of total demand in 2023. Additionally, the retail industry, spurred on by the growth of e-commerce has also contributed significantly to the demand for industrial land, contributing 15% in 2023 (Cushman and Wakefield).

Given demand from other sectors, the chronic shortage of industrial land in Sydney means there would be significant competition for any increase in serviced industrial land. Further, the construction industry has a much lower gross profit margin (9%) compared to the transport industry (20%) (ABS, 2024c) - which means lower capacity to pay for facilities.

In reality, even if 280-380 hectares of serviced industrial land were to become available, high prices for land would likely remain, making procurement of new facilities not viable for the construction sector (and much of its supply chain). The land would be taken-up to support new industrial facilities for industries with the highest capacity to pay.

To re-set land values from current record highs, a much more significant increase in serviced industrial land is needed.

Since 2010, Sydney has lagged Melbourne's ability to respond to market demand, resulting in a cumulative deficit of 1,700 hectares. At a minimum, an increase of that order of magnitude is needed to act as a pressure valve release for demand that has not been satisfied - one that has resulted in runaway rents and prices.

The release of 2,000 hectares of serviced land would provide the headroom for broader industries, as well as 300 hectares to support residential construction (aligned to the Housing Accord targets). This level of a supply would provide for a re-setting of the current high prices and enable take-up by the construction sector (and others) at affordable prices.

Based on industry engagement, it appears that industry plans to service any increased demand in Sydney from locations outside Sydney including regional areas such as Newcastle as well as from interstate (i.e. Melbourne and Brisbane).

Businesses interviewed note that movements through the Melbourne and Brisbane ports was more efficient than through the Port of Botany. Additionally, stakeholders cited that customers were more agreeable to a cost increase to pay for increased transport, rather than cost increases to pay for local facility costs. As such, a greatly increased level of housing production in Greater Sydney without an increase in industrial land would be possible, however, it would be at a much higher cost and put additional upward pressure on inflation.

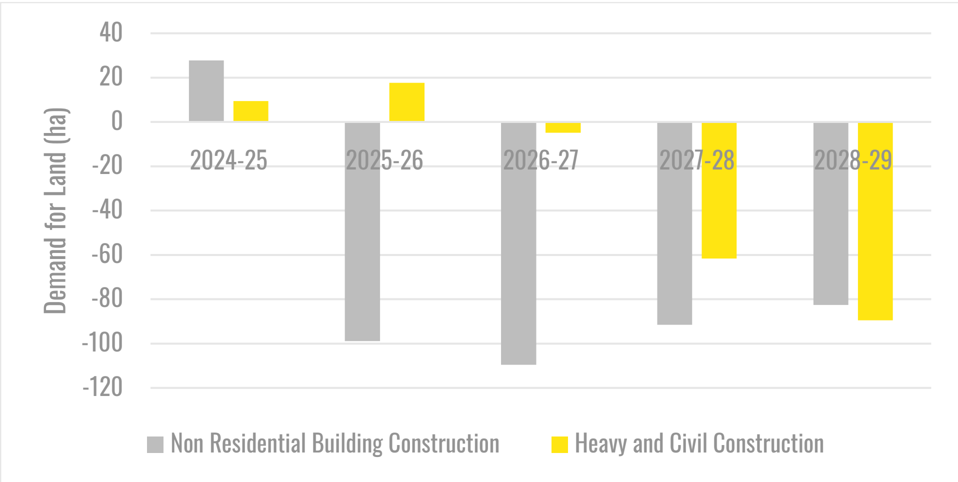
Perversely, this would make the cost of construction more than it would otherwise be. Given the other cost pressures in the residential building construction industry (i.e. labour, supplies, etc.), the cost increase associated with greater transport costs would be inflationary.

Non-Residential and Heavy & Civil Construction Supply Chains

Projected short-term growth within the non-residential and heavy & civil construction supply chains is estimated to add further demand for serviced industrial lands in Greater Sydney. The industry growth is projected to generate need (from indirect and flow-on demand) for 37 additional hectares over FY2025.

Demand arising from growth in these sectors is forecast to be short-term in nature, with activity easing towards the back end of the Housing Accord period.

Figure 5-2: Demand for Industrial Land, Non-Residential and Infrastructure Construction (FY2025 to 2029)



Source: Atlas

Based on the modelling, additional demand for industrial land from non-residential and infrastructure construction will be over the short-term, with the expected expenditure in these sectors to fall over the forecast period. At its peak in FY2025, there would be demand for a total of 37 hectares of industrial land to support these sectors.

Demand for Land from Non-residential and Infrastructure Construction Activity

The high level of demand from non-residential and infrastructure construction is expected to be short-term in nature. The Study expects that industry will make short-term adjustments to their supply chains, thereby negating the need for more industrial land that the market would otherwise require. This is consistent with feedback from businesses.

In fact, it is likely that these short-term adjustments (such as servicing Greater Sydney from other markets) have already been made. The measures to transport goods from markets outside of Greater Sydney has likely contributed to increasing the costs of major projects over the last three years.

5.3 Implications for Greater Sydney's Capacity

This chapter finds than an additional 280-380 hectares of land is needed to enable scaling-up of the construction sector to respond to the Housing Accord. Furthermore, the Study finds that at current pricing levels (land values more than double Melbourne's and more than treble Brisbane's), 280-380 hectares of land alone is insufficient to enable the construction sector (and its supply chain) to respond. A small release of 280-380 hectares will be taken-up at premium prices by businesses with the capacity to pay.

For development to be viable and economic rents to be at levels businesses can afford, much more land is needed to reverse runaway price movements that have prevailed for more than a decade.

The release of 2,000 hectares of serviced land would provide room for broader industries as well as 300 hectares to support residential construction (aligned to the National Housing Accord targets). This level of a supply would provide for a re-setting of the current high prices and enable take-up by the construction sector (and others) at affordable prices.

The re-setting of price levels is expected to occur over time. Business and investment decisions (e.g. those to regional sites or Victorian sites) will not be reversed overnight. The additional availability of serviced land will provide the headroom and opportunity for new decisions to be made.

Sydney's strategic location on the East Coast of Australia positions it well as a servicing base for the three most populous states of NSW, Victoria and Queensland. The availability of land that is developable and affordable has ramifications not just for the Housing Accord targets but has broader consequences for Sydney's economic prosperity.

6. Study Findings and Interventions Needed

6.1 Step Change in Residential Construction Activity

The housing crisis in Greater Sydney is acute. Delivering the Housing Accord targets will require a significant and sustained commitment from both government and industry. Ongoing population growth and the existing housing shortfall both point to greatly expanded supply as the only realistic option to alleviate the housing crisis.

For Greater Sydney, this means delivery of almost 50,000 dwellings annually, representing a circa 60% increase in capacity above the historical average of 30,700 completions per annum.

Consultation with businesses indicates that the industry and supply chain are already operating at high rates of utilisation and capacity, and that any significant increase above current throughput would require more industrial space.

The Current State of Play

The shortage of serviced, industrial land in Sydney has reached a critical point. The record low vacancy rate and rapidly escalating prices demonstrate the severity of the issue as remaining serviced, industrial land stocks are almost exhausted.

The Study has shown that the industrial supply crisis has affected:

- **Business risk of 'homelessness'** - leasing data shows businesses are mitigating the risk of being displaced by remaining in place even though they may need more space or the premises are no longer suitable.
- **Businesses' willingness to invest** - many of the businesses consulted do not consider Sydney as a candidate for increasing capacity, choosing to focus on their Victorian sites and regional sites instead. This is due to affordability (Sydney's costs are not viable) and availability (land or facilities are simply not available).
- **Business cost** - with rents in Sydney 85% more expensive than Melbourne and 65% more expensive than Brisbane, businesses have passed the cost on to their customers. Additional transport costs (from Melbourne and regional NSW) are also passed on to the customer. This has direct consequences for the cost of living in Sydney.
- **Cost of land and development feasibility** - with the supply of serviced land at critical lows in Sydney, land values are more than double Melbourne's and more than treble Brisbane's. This means even higher economic rents must be charged for development to be feasible.
- **New charges and future development** - with developer contributions and rents already significantly higher than Melbourne and Brisbane, even higher rents will exacerbate the cost-of-living crisis and shift investment out of Sydney.

Industrial lands in Sydney are severely constrained and already under significant pressure from demand that is struggling to be met. There is little availability of space and businesses are forced to pay prices much higher than in Melbourne and Brisbane. The higher cost of doing businesses is being passed to the consumer, exacerbating the cost-of-living crisis. Higher emissions are generated from businesses trucking to and from regional and Victorian sites.

Meeting the Housing Targets

Demand from residential construction to meet the Housing Accord targets will place additional demands on industrial land that is already constrained and result in even greater upward pressure on rents and prices.

The supply chain modelling undertaken indicates that increased housing production would lead to additional demand for 280-380 hectares of industrial land by FY2028. This is even before accounting for the acute unmet need from industry growth for more than 10 years. The lack of serviced industrial land has led to a lack of viable sites for expansion and pushed rents and land values to unaffordable and uncompetitive levels.

Even if 280-380 hectares of serviced industrial land were available today, there would still be upward pressure on prices/ rents because the demand for industrial land (from all sectors) has overwhelmingly not been met for more than a decade.

In reality, the need for serviced industrial land supply is closer to 2,000 hectares to ensure an appropriately functioning market into the medium-term (five-year Housing Accord forecast period). This is necessary to comprehensively re-set land values and rents to levels that are affordable and viable for businesses to take space.

The construction industry has already began making adjustments because there is no land in Sydney and development has become cost-prohibitive. Developing in regional markets as well as servicing Sydney from Melbourne and Brisbane are seen as more viable options. Servicing from outside the region will not only lead to increased transport costs and higher construction costs but also to environmental impacts (increased carbon emissions).

Under a scenario where the construction industry services the construction activity from outside of Greater Sydney (to meet the housing targets), it will be done at a significant price premium. The cost to construct a dwelling will be higher given the additional transport costs and logistics time-to-market involved, which will flow through to overall build costs. In turn, these cost impacts will keep upward pressure on inflation and interest rates.

For Greater Sydney to realistically meet the Housing Accord targets and alleviate its critical housing shortage, a key step will be to significantly unlock the availability of serviced industrial land in Sydney to support the expansion of the housing construction supply chain. This is concurrently needed to alleviate the cost-of-living pressures that arise from elevated business costs due to a lack of serviced industrial land.

6.2 Business Affordability and Housing Affordability

There is an urgent need for NSW Government to enable industrial land already rezoned to be serviced for development. The Study has demonstrated that a lack of serviced industrial land has led to unaffordable rents and land values, and in turn:

- Businesses no longer consider Sydney for additional manufacturing or warehousing capacity.
- Businesses service Sydney from regional NSW and Victoria, resulting in higher carbon emissions and transport costs.
- Higher business costs which are passed on to the customer, resulting in higher price of goods and services.

The current circumstances do not enable the construction sector to ramp-up to much needed capacity to meet the Housing Accord housing targets. Delivery of 50,000 dwellings (avg. 2 bedroom) requires 50,000 kitchens, 100,000 toilets, 150,000 sinks and taps, etc. per annum. Building materials such as timber, steel, bricks, tiles and sanitary ware will be procured from a mix of offshore and local sources, requiring the supply chain to expand its capacity to source, store and distribute.

Currently, there is simply no supply of serviced industrial land. Existing serviced stocks in Sydney are all but exhausted. In contrast, Melbourne and SEQ can both draw on their stocks of industrial land (11.5 and 13.5 years supply respectively).

Even if the construction supply chain expanded its capacity (through regional and Victorian sites), it would lead to higher cost, longer lead-times and thwart the Government's objective of increasing housing supply to improve housing affordability.

Zoned Land Not Serviced

Chapter 3 showed that much of Sydney's supply of serviced industrial land is either too small or not available to the general market. When taking into account size and site attributes, Sydney has at best, one year of remaining industrial land supply.

The analysis also showed a concentration of large lots (>5ha) in precincts that are zoned, but not serviced. These are Mamre Road (775ha), Northern Gateway (1,000ha), Agribusiness (870ha), Aerotropolis Core (465ha) and Badgerys Creek (180ha).

The Mamre Road Precinct was rezoned in 2020. It is the only zoned precinct that has significant institutional investment and tenant interest with development planning already advanced. The Mamre Road Precinct is therefore an important part of the solution to easing Sydney's chronic capacity issue.

In 2019 when the Mamre Road Precinct was prepared for rezoning, DPHI identified 4-5 years of land remaining (DPHI, 2019). Since then, there has been no large-scale servicing of land and structural changes following the COVID-19 pandemic have turbo-charged land demand. The low stock levels have now been depleted. This has been met with near zero vacancy and skyrocketing rents. This has severely affected Sydney's national competitiveness and added to the cost of living.

Development in Mamre Road Precinct has not proceeded due to:

- Limited funding or timeframe for the delivery of critical infrastructure (roads, sewer, electrical).
- Development that is no longer feasible following the imposition of Sydney Water DSP charges.
- Land that must be sterilised for interim waterway measures until the Regional Stormwater Scheme is developed.
- Lack of flexibility in the implementation of planning controls and a backlog of planning applications.

The recently introduced DSP charges are to deliver water targets that represent a step-change in planning requirements. The capacity of the market to bear these charges at the Mamre Road Precinct had not been tested prior to their imposition.

6.3 Recommended Interventions

Immediate Steps

There are immediate interventions that can be made to unlock the developability of lands in the Mamre Road Precinct. Focusing on this precinct makes sense due to the advanced nature of development planning and the weight of investment capital and tenant interest already in play.

- **Administrative amendment of SIC allocation to biodiversity (currently 72%)** - this would enable SIC payments from first mover developers to deliver enabling infrastructure. Once the enabling infrastructure is delivered, the allocation from future SIC payments to biodiversity conservation can be re-adjusted as needed. At present, only 28% from SIC contributions can be offset against works-in-kind (e.g. delivery of roads), with 72% to be paid in cash for biodiversity.
- **Fast track delivery of critical roads Mamre Road and Southern Link Road** - funding accompanied by fast-track delivery. This is additional to the recent commitment by the Federal Government to fund the upgrades of Mamre Road at Kemps Creek ($50 million) and priority sections of Elizabeth Drive ($400 million).
- **Economic evaluation of new (step-change) water targets** - consider DSP charges in an economic appraisal (including a cost benefit analysis). Atlas is not aware of any cost benefit analysis (**CBA**) completed to weigh up the costs and benefits of the desired stormwater target outcomes. If there is an economic case (i.e. the benefits exceed the costs), the CBA must also consider the distributional impacts of the benefits and the costs.

  A feasibility analysis (by Atlas which was peer reviewed by DPHI) confirms the disproportionate cost burden of the DSP charges and the loss of developable land (60% of site area). The adverse impact on the feasibility of development was found to be severe, not capable of remedy even when construction cost escalations 'settle'.

  The implementation of public policy must have regard to how cost and benefit is distributed. In the case of the desired stormwater targets, the issue is 'who should pay for the targeted benefits?'

  If development cannot afford to bear the cost and if broader societal net benefits are targeted, it would be appropriate for that cost to be borne by Government. If Government does not have the capacity or appetite to bear the cost, alternate stormwater targets should be developed - targets that are affordable, and which are capable of being delivered.
- Unlock the backlog of planning applications with greater resource allocation.
- Allow greater flexibility in planning controls and agency response.
- Provide an urgent, immediate coordination role to streamline infrastructure delivery and development. Greater coordination between agencies is critically needed.

Once implemented, the above interventions would set the scene for delivery of lands in Western Sydney Aerotropolis.

Integration of Land Use and Infrastructure Planning

It is imperative for Sydney that land use planning is integrated with infrastructure planning. There is little point in rezoning land if that land has no reasonable prospect of being serviced by road and utility infrastructure.

The Victorian PSP (precinct structure plan) process recognises this - it embeds a collaborative process between key stakeholders (developers, referral authorities and decision makers) to resolve key planning challenges early. The Victorian Planning Authority (VPA) leads the preparation of the PSP in close partnership with the associated council and relevant agencies. Land is not rezoned unless it is developable and infrastructure funding arrangements are in place (VPA, 2020).

The effectiveness of the integration of land use and infrastructure planning and the Victorian PSP process can be observed in the relative pricing of dwellings in greenfield areas. In Sydney, a typical house and land package in a greenfield area is $1,000,000 while in Melbourne, a typical house and land package in a similar greenfield area is $650,000.

The coordinated and orderly release of land in Victoria has meant that land value movements have been more tempered. In contrast, Sydney land value movements have risen at exponential proportions.

Strategic Land Supply Policy

Victoria and Queensland both have strategic land supply policies that are given statutory weight. Both state planning frameworks require 15 years of land supply that is zoned and serviced, or capable of being serviced.

Victoria Planning Provisions

In Victoria, the Victoria Planning Provisions (**VPP**) are the standard provisions that form the framework for all of Victoria's planning schemes.

- Clause 11.02-1S of the VPP notes an objective of ensuring sufficient supply of land is available for residential, commercial, retail, industrial, recreational, institutional and other community uses.

  It further notes a strategy "*plan to accommodate projected population growth over at least a 15-year period and provide clear direction on locations where growth should occur…*" It notes that planning for urban growth should *inter alia*, consider "*service limitations and the costs of providing infrastructure*".

  It requires development trends and land supply and demand for housing and industry to be monitored and access to an adequate supply of well-located land for energy generation, infrastructure and industry is maintained.
- Clause 17.03-1S was recently introduced with the objective of ensuring availability of land for industry.

  It requires provision of an "*adequate supply of industry land in appropriate locations including sufficient stocks of large sites for strategic investment*".
- Clause 17.03-3S protects industrial land of state significance. It ensures sufficient availability of strategically located land for major industrial development, particularly for industries and storage facilities that required significant threshold distances from sensitive or incompatible uses.

The VPP embeds *Melbourne Industrial and Commercial Land Use Plan* as a relevant policy document (DTP, 2020).

In Queensland, Shaping SEQ Regional Plan 2023 (QLD Government, 2023) is the statutory spatial growth strategy for SEQ prepared by the Queensland Government under the Planning Act 2016. It provides a regional framework to manage growth, change, land use and development and sets targets for residential capacity and policies for industrial land provision.

Shaping SEQ - 15 years Land Supply (Zoned and Able to be Serviced)

Shaping SEQ makes provision for the delivery of adequate housing supply to 2046 to meet the full spectrum of housing demand. It notes maintaining a minimum of 4 years of approved supply and a minimum of 15 years of supply of land that has been appropriately zoned and planned to be serviced. The minimum performance metric of 15 years applies to each land use type in each LGA.

Shaping SEQ forecasts an industrial land supply shortfall in Brisbane (as soon as 10-15 years, expected to be felt within 5-10 years) which would lead to increased land prices, new businesses choosing to locate outside Brisbane and existing lower-value, land- expansive industrial uses seeking to locate outside of Brisbane. It recognises that a regional approach to industrial land is needed to position SEQ to realise opportunities of national significance.

Shaping SEQ identifies that well-positioned, well-serviced and timely supply of industrial land is needed, along with the safeguarding of regionally significant industrial locations to ensure ongoing supply over the next 25 years. It requires a need for development in and around these areas to be compatible with their role and function so as not to jeopardise the future development and operation of critical industrial land uses within SEQ.

Shaping SEQ describes extensive monitoring activities by region to ensure industrial land supply is sufficient and viable.

NSW would benefit from implementing a strategic land supply policy for all land uses (residential and employment). This would ensure a healthy and viable supply of land. This is essential to temper land value movements - which have occurred at runaway proportions in Sydney over the last decade.

6.4 The Cost of Doing Nothing

Sydney has no capacity to respond to the Housing Accord in a timely or cost-effective manner. Without the large-scale unlocking of serviced industrial land, the twin objectives of housing supply and housing affordability will not be met.

Immediate interventions are needed at the Mamre Road Precinct to urgently unlock zoned land as longer-term strategies are also pursued but that take time to bear result.

If allowed to continue, the industrial lands crisis in Sydney will continue to:

- Stymie employment growth in the industrial sector.
- Drive up land values and rents, and cumulatively impact the cost of doing business and cost-of-living.
- Stymie business growth and shift investment away from Sydney.
- Increase the environmental cost through greater trucking movements from regional and interstate locations.

The construction supply chain will be serviced from outside Sydney and the costs of construction will be higher. These costs will be passed on to the consumer and the cost of housing will be less, not more affordable.

Flow-on Implications

The Study has identified serious ramifications for Sydney if business-as-usual is allowed to continue.

Its direct consequences are evidenced through data observations.

- Industrial employment growth has stalled.
- Land values and rents have risen sharply - to double and treble peer capital cities of Melbourne and Brisbane.
- All businesses consulted have dismissed any growth prospects for Sydney, focusing instead on Melbourne, Brisbane and regional sites.
- Despite the NSW Government's recent planning reforms, additional capacity for the 'big housing build' can only be found outside Sydney. This would lead to higher construction cost and higher environmental cost.

Without the large-scale unlocking of serviced industrial land, the construction supply chain will be serviced from outside Sydney and the costs of construction will be less, not more affordable.

The Study continues to investigate:

- The additional cost of housing if sourced from outside of Sydney.
- The additional time required to deliver housing if sourced from outside Sydney.
- The carbon emissions generated from greater trucking movements from regional and interstate locations.
- The cost on the intrastate and interstate road network.
- The construction supply chain risks associated with material sourced from outside Sydney (e.g. industrial action and strikes, natural disasters).

The outcomes of these additional lines of investigation will be published in due course.

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Schedules

SCHEDULE 1

Input-Output Modelling Methodology

Input-Output models are a method to describe and analyse forward and backward economic linkages between industries based on a matrix of monetary transactions. The model estimates how products sold (outputs) from one industry are purchased (inputs) in the production process by other industries.

The analysis of these industry linkages enables estimation of the overall economic impact within a catchment area due to a change in demand levels within a specific sector or sectors.

Impacts are traced through the economy via:

- Direct impacts, which are the first round of effects from direct operational expenditure on goods and services.
- Flow-on impacts, which comprise the second and subsequent round effects of increased purchases by suppliers in response to increased sales. Flow-on impacts can be disaggregated to:
  - Industry Support Effects (Type I) derived from open Input-Output models. Type I impacts represent the production induced support activity as a result of additional expenditure by the industry experiencing the stimulus on goods and services, and subsequent round effects of increased purchases by suppliers in response to increased sales.
  - Household Consumption Effects (Type II) derived from closed Input-Output Models. Type II impacts represent the consumption induced activity from additional household expenditure on goods and services resulting from additional wages and salaries being paid within the catchment economy.

Economic analysis considers the following four types of impacts.

Table S1-1: Economic Activity Indicators

Indicator	Description
Output	The gross value of goods and services transacted, including the cost of goods and services used in the development and provision of the final product. Care should be taken when using output as an indicator of economic activity as it counts all goods and services used in one stage of production as an input to later stages of production, thus overstating economic activity.
Gross Product	The value of output after deducting the cost of goods and services inputs in the production process. Gross product (e.g. Gross Regional Product (GRP)) defines a net contribution to economic activity.
Incomes	The wages and salaries paid to employees as a result of the Project or Proposal either directly or indirectly.
Employment	Employment positions generated by the Project or Proposal (either full time or part time, directly or indirectly). Employment is reported in terms of Full-time Equivalent (FTE) positions or person-years.

Source: Atlas

Regional Model Development

Multipliers used in this assessment have been created using a regionalised Input-Output model derived from the 2020-2021 Australian transaction table (ABS, 2023a).

Estimates of gross industry production in the catchment area were developed based on the share of employment (by place of work) of the catchment area within the Australian economy (ABS, 2022) using the Flegg Location Quotient and Cross Hauling Adjusted Regionalisation Method (CHARM). See Norbert (2015) and Kronenberg (2009) for further details. Where required, values were indexed to current dollar values using CPI (ABS, 2023b).

Modelling Limitations and Assumptions

Input-Output modelling is subject to a number of key assumptions and limitations (ABS, 2023a):

- **Lack of supply–side constraints:** The most significant limitation of economic impact analysis using multipliers is the implicit assumption that the economy has no supply–side constraints. That is, it is assumed that extra output can be produced in one area without taking resources away from other activities, thus overstating economic impacts. The actual impact is likely to be dependent on the extent to which the economy is operating at or near capacity.
- **Fixed prices:** Constraints on the availability of inputs, such as skilled labour, require prices to act as a rationing device. In assessments using multipliers, where factors of production are assumed to be limitless, this rationing response is assumed not to occur. Prices are assumed to be unaffected by policy and any crowding out effects are not captured.
- **Fixed ratios for intermediate inputs and production:** Economic impact analysis using multipliers implicitly assumes that there is a fixed input structure in each industry and fixed ratios for production. As such, impact analysis using multipliers can be seen to describe average effects, not marginal effects. For example, increased demand for a product is assumed to imply an equal increase in production for that product. In reality, however, it may be more efficient to increase imports or divert some exports to local consumption rather than increasing local production by the full amount.
- **No allowance for purchasers' marginal responses to change:** Economic impact analysis using multipliers assumes that households consume goods and services in exact proportions to their initial budget shares. For example, the household budget share of some goods might increase as household income increases. This equally applies to industrial consumption of intermediate inputs and factors of production.
- **Absence of budget constraints:** Assessments of economic impacts using multipliers that consider consumption induced effects (type two multipliers) implicitly assume that household and government consumption is not subject to budget constraints.

Despite these notable limitations, Input-Output techniques provide a solid approach for assessing the direct and flow on economic impacts of a project or policy that does not result in a significant change in the overall economic structure.

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Appendix E
Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-Use Planning Decisions

Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions

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Achieving healthy waterways

Children at The Basin, Ku-ring-gai Chase National Park. Photo: D Finnegan/OEH

A healthy waterway provides essential services and functions to support environmental, social and economic outcomes, including more liveable cities and healthy, resilient communities.

The *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* (the Framework) is a protocol that decision-makers, such as councils and environmental regulators, can use to help manage the impact of land-use activities on the health of waterways in New South Wales.The Framework brings together existing principles and guidelines recommended in the National Water Quality Management Strategy, which the federal and all state and territory governments have adopted for managing water quality. It allows decision-makers to determine management responses, which meet waterway health outcomes that reflect the community's environmental values and uses of waterways.

Management responses could include specific development controls for stormwater management, informing license limits for waterway discharges, or programs that raise awareness of land use activities that protect and enhance the health of rivers and creeks. Where appropriate, the management responses can be implemented through regional and local planning instruments, environmental regulation, integrated water cycle management plans, Coastal Management Programs required under the *Coastal Management Act 2016* or other catchment management plans for restoring and protecting the health of waterways. Overall, the Framework can support decision making by any authority responsible for the management of land and waterways.

About this document

This document should be used as an introductory resource on the Framework. Further guidelines for implementing the Framework, including a range of case studies, will be available from the Coastal Management Manual – Toolkit.

The primary audiences for this document are natural resource managers, local and state government authorities and agencies, and water industry professionals.

The document includes:

- an overview of the five steps in the Framework
- a flow chart summarising the Framework
- a brief description of a case study on the application of the Framework for assessing the effectiveness of current stormwater management responses in the Lake Illawarra catchment. Full details of the case study will be available from the Coastal Management Manual – Toolkit
- a list of definitions that are specific to New South Wales (NSW) and consistent with the terminology used in the following:
  - Using the ANZECC Guidelines and Water Quality Objectives in NSW
  - Local planning for healthy waterways – using NSW Water Quality Objectives
  - The Treasury Risk Management Toolkit for NSW Public Sector Agencies.

The purpose of the Framework is to:

- ensure the community's environmental values and uses for our waterways are integrated into strategic land-use planning decisions
- identify relevant objectives for the waterway that support the community's environmental values and uses, and can be used to set benchmarks for design and best practice
- identify areas or zones in waterways that require protection
- identify areas in the catchment where management responses cost-effectively reduce the impacts of land-use activities on our waterways
- support management of land-use developments to achieve reasonable environmental performance levels that are sustainable, practical, and socially and economically viable.

About the Framework

The Framework was developed by the Office and Environment and Heritage and the NSW Environment Protection Authority in direct response to increasing urban development and a lack of integrated management of urban development, waterway health, and the community's expectations of the state's waterways. If not managed appropriately, urban development can increase the loads of pollutants and volume of stormwater and wastewater entering our waterways. Impacts may include erosion, sedimentation, habitat loss, algal blooms, excessive aquatic weed growth, altered flow regimes and reduced aquatic biodiversity. These impacts diminish the benefits communities derive from healthy waterways.

There are a growing number of management responses that can help mitigate or minimise the impacts of urban development and other land-use activities on the state's waterways (e.g. Blacktown Showground Precinct Water Sensitive Urban Design Redevelopment; Leura Falls Catchment Improvement Project; Blackmans Swamp Creek Stormwater Harvesting Scheme; Fish Friendly Farms; Smart Farms). The Framework allows decision-makers to determine management responses that meet waterway health outcomes which reflect the **community's environmental values and uses** of waterways – what the community believes is important for a healthy ecosystem, for public benefit, welfare, safety or health.

Waterway objectives

In NSW, environmental values and uses for all major waterways were identified through community consultation by the Department of Environment, Climate Change and Water (now Office of Environment and Heritage). These values and uses were adopted by the NSW Government in 1999 and are known as the NSW Water Quality and River Flow Objectives.

NSW Water Quality and River Flow Objectives

The Water Quality Objectives consist of three parts, following the recommended approach in the National Water Quality Management Strategy (NWQMS): environmental values and uses, their indicators and their guideline trigger values. The indicators and guideline trigger values are used to help assess whether a waterway will support a particular environmental value. For example, if the objective is to protect primary contact recreation (environmental value), we would need to manage the enterococci concentrations in the waterway (indicator) so they remained below a specified number/numerical criteria (guideline trigger value).

The River Flow Objectives are the agreed high-level goals for surface water flow management. They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses.

The NSW Water Quality and River Flow Objectives are only one factor to consider when making decisions affecting the future of a waterway. Local objectives, identified through an appropriate cummunity consultation process, are preferable because they will reflect current environment values and uses, and the waterway's sensitivity to the land-use activity(ies).

In this document, objectives are referred to as **waterway objectives** to acknowledge both the existing environmental values and uses for the waterway, and to recognise the expanding range of indicators that can be used to assess whether the waterway will support a particular environmental value or use. These could be contemporary measures of waterway health such as macrophyte and fish abundance or biodiversity, or fringing and instream habitat measures (Roper et al. 2011). In more complex situations, they can also be a sustainable or target load for the waterway, a descriptive statement or an index. Choosing the appropriate indicator(s) is critical and the choice should be based on the key issues in the waterway and the main stressor(s) (e.g. pollutants) that might be generated by the activity(ies) under consideration. For example, streamflow indicators may be necessary to protect against erosion in freshwater tributaries under local urban development scenarios, but traditional water quality indicators (e.g. nutrients, turbidity, dissolved oxygen, chlorophyll *a*) may be needed to protect against eutrophication in a downstream estuary as a result of systemic catchment runoff and/or point source discharges. Multiple indicators may be needed to represent a range of environmental values and uses of the waterway.

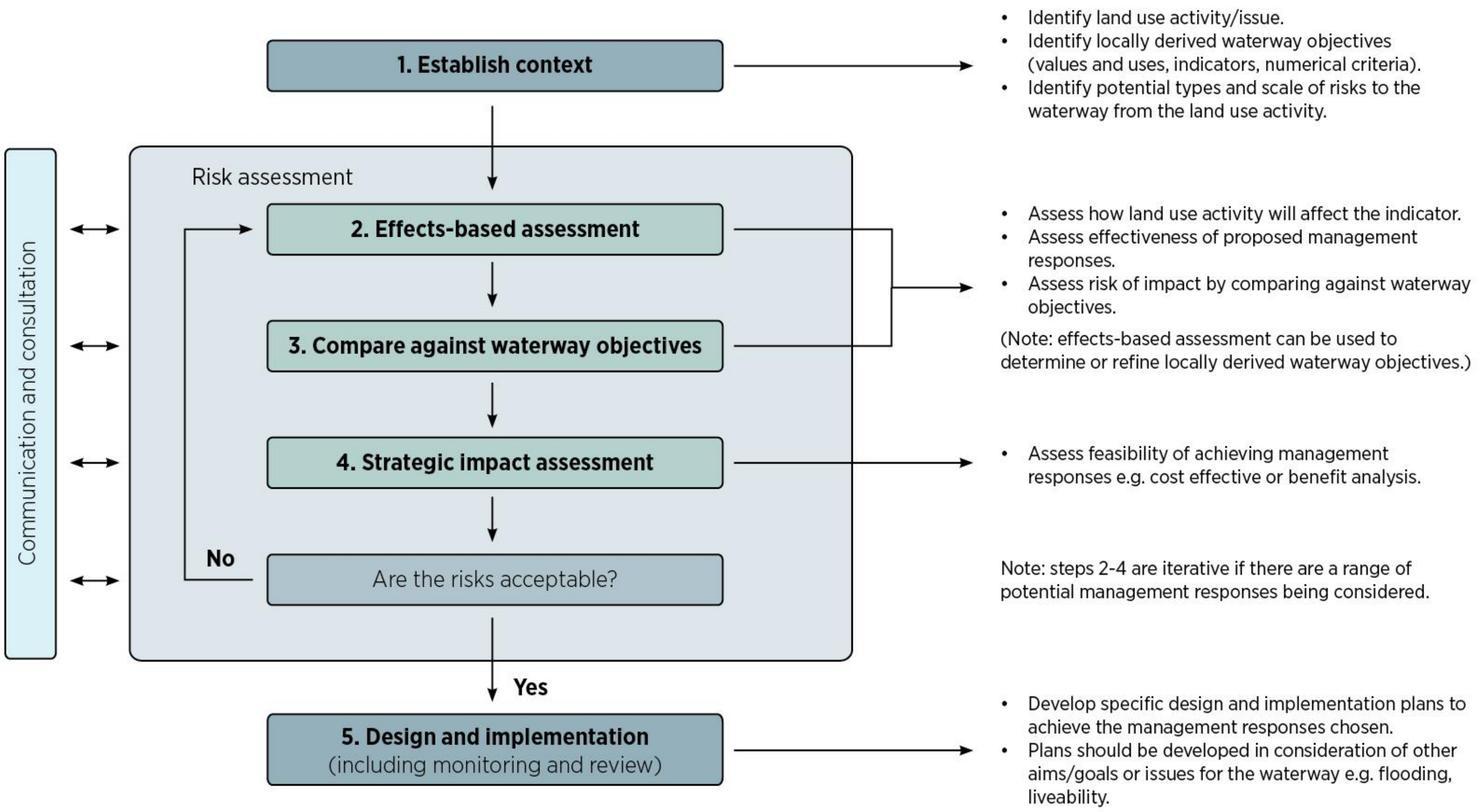
Scale of implementation

The Framework is best implemented at the catchment or subcatchment scale by an overall managing authority, such as a council, or regional or state agency. Most councils are already implementing some steps of the Framework, often in-house or in collaboration with state agencies, practitioners and industry experts. For example, Step 2 of the Framework is an effects-based assessment and is often undertaken by industry experts or water professionals on behalf of councils to inform decisions on large development applications. Ideally, the overall managing authority should implement the Framework in consultation or partnership with a range of stakeholders such as local residents, community groups, adjoining councils, state agencies and water authorities.

The steps in the Framework are closely aligned with many activities required for the preparation of Coastal Management Programs under the *Coastal Management Act 2016*, such as characterising the current health of a waterway, assessing cumulative effects of land-use activities and assessing the sensitivity of a waterway to land-use activities. The Framework is also consistent with the key initiatives of the Marine Estate Management Authority, including recognising a need to communicate and develop an understanding of the environmental, social and economic values and threats to a waterway.

Framework flowchart

Risk-based framework for considering waterway health outcomes in strategic land-use planning decisions



Step 1: Establish context

The first step *establishes the context* for applying the Framework. It involves identifying the:

- land-use activity(ies), for example, urban residential and industrial developments, and/or agriculture
- waterway type, and how the waterway has responded to previous land-use activities and the likely trajectory of the waterway in response to future land-use activities
- waterway objectives, consisting of:
    - community's environmental values and uses of the waterway, as identified in the NSW Water Quality and River Flow Objectives and/or through locally-derived environmental values and uses
    - indicator(s) and corresponding numerical criteria to assess whether the waterway will support a particular environmental value or use. The selected indicator(s) should have a direct relationship to the risks/impacts posed by the land-use activity and be at the appropriate scale to manage those risks/impacts
- potential types of impact(s) of the land-use activity on the waterway objectives, and therefore which objectives may be most relevant to manage the activity

The above process should aim to derive local waterway objectives, either via the **referential approach** or by **direct measurements and/or the numerical modelling of impacts** of the land-use activity on the waterway.

- The **referential approach** is based on reference sites, where the waterway health is considered suitable for baseline or benchmark assessment. The numerical criteria for the indicator(s) of waterway health are typically based on percentiles (e.g. 80th percentiles) of data collected by monitoring the reference site, as outlined in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (the ANZECC guidelines).
- **Direct measurements and/or numerical modelling of impacts** of the land-use activity can be made in Step 2 of the Framework, where an effects-based assessment is tailored to the specific issue and waterway type.

Step 2: Effects-based assessment

An effects-based assessment is used to quantify how the land-use activity will change the health of the waterway, as given by the indicator(s) and numerical criteria used to assess whether the waterway will support a particular environmental value or use. Where appropriate, the effects-based assessment can be used to develop or refine the indicator(s) and numerical criteria to account for the natural local variation in the waterway. An effects-based assessment can also be used to quantify the effectiveness of any management responses intended to protect, maintain and/or improve the health of waterway.

A typical effects-based assessment:

a. determines whether the current health of a waterway is supporting the waterway objective(s), typically using data on indicators from local observations and/or monitoring programs
b. identifies a level of protection based on a level of quality desired by stakeholders and implied by the management goals and waterway objectives. For example, it is

common to protect waterways of high conservation value; to maintain and/or improve the health of slightly to moderately disturbed waterways; and to improve the health of highly disturbed waterways

c. quantifies the stressor(s) arising from the land-use activity that can affect the health of the waterway. For example, stormwater from urban developments can deliver relatively high loads of nutrients (stressor) to estuaries, and these directly impact on the ambient micro-algal concentrations (indicator) in the estuary. A list of stressors and associated land-use activities is available from the Marine Estate Management Authority Threat and Risk Assessments (TARAs). The TARAs show that multiple stressors can affect the health of the waterway, and are often interlinked. As with the selection of indicators, it is important to select stressors that are relevant to the land-use activity/issue being considered
d. quantifies the sensitivity of the waterway to the stressor(s). For example, intermittent estuaries are sensitive to land-use activities because they have limited connections to the sea, and as a result, are poorly flushed and retain a relatively large proportion of nutrient loads from land-use activities
e. quantifies the extent to which the stressor(s) affects the health of the waterway. For example, this might involve determining the amount of nutrients (delivered from stormwater) that will increase the micro-algal concentrations in the waterway above a certain numerical criterion
f. quantifies the effectiveness of the management responses in protecting, maintaining and/or improving the health of the waterway. For example, this might involve determining the extent to which a management response mitigates nutrients loads, and improves the ambient micro-algal concentrations in an estuary.

Effects-based assessments are increasingly implemented using numerical models, but can be implemented more simply via desktop assessments of readily available datasets. The type of effects-based assessment chosen will depend on the waterway type, the level of risk to the waterway, the complexity of the issue and/or the data and information available for the assessment. Examples of different types of effects-based assessments will be available in further guidelines for implementing the Framework in the Coastal Management Manual - Toolkit.

Step 3: Compare against waterway objectives (analysing risks of impact)

The risk of not achieving the community's environmental values and uses is considered high if the measurement or assessment of the indicator exceeds the numerical criterion or is outside the desirable range. A high risk indicates a potential for impact but does not provide any certainty that an impact will occur (or has occurred).

Determining an acceptable level of change from a numerical criterion depends on the extent and frequency of exceedance (Mawhinney & Muschal 2015; OEH 2016). The tendency of allowing waterways to be affected up to the numerical criterion should be avoided to reserve the maximum opportunity for other present and future uses of the waterway, and allow adoption of a precautionary approach where there is uncertainty about the environmental outcomes of the land-use activity.

Step 4: Strategic impact assessment (evaluating risks based on feasibility)

This step involves *evaluating the risks* of impacts of the land-use activity on the waterway based on the feasibility of achieving the intended outcomes of each management response. This step ensures that the selected management responses are reasonable, practical and cost-effective. 'Practical' means considering what will work in a given situation: for instance, it might be difficult to protect, maintain and/or improve waterway health with traditional stormwater management alone; more water-sensitive approaches might be required such as stormwater harvesting, re-use and use of green infrastructure. Cost-effectiveness analysis can be extended to a cost-benefit analysis to recognise the full suite of environmental, socio-economic co-benefits of the management response. Cost-effectiveness analysis should ideally include (but not be limited to) the life-cycle costs of infrastructure (including green infrastructure), changes to costs if the management response is deferred, and costs of clean-up where there has been no management intervention or only little.

As shown in the flowchart, Steps 2 to 4 of the Framework are iterative to allow several management responses to be considered. The strategic impact assessment informs the decision as to which management response(s) will best treat the risks of the land-use activity affecting the waterway. In some cases, the decision may involve reconsidering the land-use activity because of the sensitivity and high conservation or ecological value of the waterway, or because it is not possible to minimise the risks. In other cases, a compromise based on interim management responses that show progress towards achieving the waterway objectives may be considered. The overall decision on the degree of intervention should be commensurate with the level of the risk.

Communication and consultation is an integral part of steps 2 to 4, and involve providing information on any trade-offs that might be required to meet the waterway objectives. The level of communication and consultation will vary depending on the nature of the land-use activity under consideration. Guidance for effective consultation is available from a range of sources: for example, the International Association for Public Participation provides guidelines and strategies for involving those who are affected by a decision in the decision-making process. The strategies promote sustainable decisions by providing information to those affected by the decision in a meaningful way, and communicating how their inputs have affected the decision. Case studies of previous projects, such as those developed under the Coastal councils Initiative, show other approaches that have been effective (Tucker & Tuckerman 2012).

Step 5: Design and implementation

The last step of the Framework aligns with the practicalities of *risk treatment*, and involves detailed planning of specific controls or treatment measures to achieve the intended outcomes of the chosen management response. For example, the chosen management response for a greenfield development might be to ensure that the post-development total nitrogen (TN) loads in stormwater are the same as the pre-development TN loads. The pre-development TN load is used as a benchmark to determine the amount, type and location of stormwater infrastructure at the development site.

The detailed planning may also identify the need for environmental offsets that could arise through technological and/or site constraints. Water utilities and councils, for example, have a growing interest in stormwater offsets as a way of meeting stormwater-quality management targets (see, for example, Blacktown City Council water quality offset scheme for infill development or Melbourne Water stormwater offsets). As described in the case study (below), the outcomes of the Framework can be used to develop ‘benefit maps’ that help to identify the best sites for management or environmental offsets.

Land-use planning involves a broad range of constraints, and so the design and implementation step of the Framework should take into account other aims or issues for the waterway (for example, devices to improve stormwater quality may make an area more attractive, help address flooding, or help to manage wastewater). Again, the ‘benefit maps’ may be used as overlays on other strategic maps (such as flood-risk maps) to help guide land-use planning and development decisions.

The design and implementation step should set up a **monitoring and review** process. This will ensure that the intended outcomes of the Framework are implemented and achieved, and remain relevant. Several mechanisms can be used to monitor and review but a typical process involves monitoring the indicator(s) that supports the community’s environmental values and uses, reporting on the indicator(s) to inform the community (for instance, through report cards), and using the outcomes of the monitoring and review to improve management of the waterway.

Applying the Framework

Case study: Stormwater management strategies and responses to accommodate urban growth in the Lake Illawarra catchment

The Framework was used to identify cost-effective stormwater management responses that accommodate urban growth in the Lake Illawarra catchment while maintaining and/or improving the water quality and health of the lake. Applying the Framework led to two Actions (5.4.2 and 5.4.3) in the Illawarra-Shoalhaven Regional Plan.

The need for this case study arose from the current practice of using a general set of post-development stormwater pollutant-load reduction targets, which were developed in the late 1990s. The targets have led to clear improvements in water quality in some cases, such as that of Wallis Lakes (Weber & Tuckerman 2014), but there has not been enough data and information to determine if the targets have achieved waterway objectives for other estuaries. A growing body of literature indicates that the targets are ineffective in protecting freshwater ecosystems if other drivers of ecological health, such as stream flows and geomorphology, are not considered (Burns et al. 2012; Walsh et al. 2012; Walsh et al. 2016). The targets appear to be increasingly applied without considering the sensitivity of different waterway types to land-based pollutants, and the differing amount of pollutants generated by different types of development.

The Office of Environment and Heritage (Science Division and Regional Operations South Branch) conducted the case study on behalf of the NSW Environment Protection Authority. Steps 1–4 were carried out in collaboration with consultants in the stormwater industry and in consultation with Wollongong City Council and the Department of Planning and Environment. The data and models to inform the Framework were sourced from the Office of Environment and Heritage, Wollongong City Council, published scientific literature and readily available industry data. It took 2–3 months to do steps 1–4 of the Framework using existing data. Additional time was needed for consultation on the wider application of the Framework in the lead up to its adoption in the Illawarra-Shoalhaven Regional Plan.

Entrained entrance of Lake Illawarra. Photo: OEH

Step 1: Establish context for Lake Illawarra

Environmental values and uses

The Lake Illawarra catchment is located on the NSW south coast. The lake is a popular tourist destination, and supports a productive commercial fishery and numerous primary and secondary recreational uses. The lake is environmentally significant because it supports a range of endangered ecological communities (including coastal saltmarsh, swamp oak flood-plain forest, littoral rainforests) and many animal species.

Land-use activity/issue

Extensive urban developments are planned for west of the lake, covering a total of 13.5% of the catchment area. These developments form a significant component of the urban growth strategy for the region and the area of land is the second-largest released by the NSW Government in 2015. The developments include a range of housing and employment lands on a mixture of greenfield, brownfield, infill and re-development sites.

Potential risks

The planned developments have prompted some community concerns that the increased stormwater runoff could affect the lakes' water quality and health, and consequently affect their environmental values and uses including the protection of aquatic ecosystems, their visual amenity, and their use for boating, swimming and fishing.

Indicator(s) and numerical criteria

The micro-algal concentration in the water column (namely, chlorophyll *a*) is a specific indicator for aquatic ecosystems, and was considered to be appropriate in this case study because it:

- responds to nutrient loading from the catchment in a predictable manner
- is used as a representative waterway health indicator for estuaries in NSW, since it plays a key role in supporting and influencing the structure and function of aquatic ecosystems
- is used directly by the local council for reporting of lake health.

A numerical value (the criterion) of 3.6 µg/L chlorophyll *a* was selected because it is specific to open lakes ecosystems in NSW (Roper et al. 2011) and is already used by the local council for reporting on lake health.

According to the ANZECC guidelines, if water quality levels are met for local aquatic ecosystems, other environmental values and uses will usually also be protected. As a result, the micro-algal concentration in the water column was used as the representative indicator for assessing whether the lake is supporting the community's environmental values and uses, or will continue to support them under planned development.

Step 2: Effects-based assessment for Lake Illawarra

a. **Health of the waterway.** Water quality issues in the lake are long-standing and have led to the permanent opening of the lake entrance to the sea in 2007. Waterway health report cards for the lake indicate that the water quality, including micro-algal concentrations, at numerous monitoring sites exceed guideline values in ANZECC.

b. **Level of protection.** The lake can be classified as a moderately disturbed waterway, based on the current health. The optimal management response would be to maintain and/or improve the health of the waterway, while accommodating the urban developments planned for west of the catchment.

c-e. **Risk of impact of the land-use activity.** Risks of impacts were analysed through numerical models. Catchment models are commonly used by the stormwater industry to predict the amount of stormwater leaving the site of development, and to also plan stormwater infrastructure to meet development controls or other stormwater policies or objectives identified by the local council. In this case, the outcomes of the catchments models were used as inputs to hydraulic and ecological response models that predict the transport of stormwater out of the lake (flushing), and the subsequent risk of impacts of stormwater on the micro-algal concentrations in the lake, respectively.

Multiple model runs were completed to set a baseline of the current micro-algal concentrations in the lake, the projected impact on the micro-algal concentrations as a result of developments with no stormwater control/treatment, and the maximum catchment load that the lake can receive while still meeting or remaining below the micro-algal concentration (numerical criteria) value. This latter load is known as the sustainable load in the ANZECC guidelines, and was used in this case study to represent the maximum load that the lake can sustain to meet the community's environmental values and uses. While stormwater can introduce a range of pollutants (stressors), the sustainable load was based on the total nitrogen (TN) load because nitrogen is considered to be the primary limiting nutrient for micro-algae in Lake Illawarra.

The effects-based assessment for this case study was specific to an assessment of stormwater impacts on the lake. A discussion on the risk of impacts of other sources of TN input such as wastewater discharges and overflows, and internal TN cycling processes within the lake will be provided in a full description of the Lake Illawarra case study in the Coastal Management Manual – Toolkit. Impacts of stormwater on the health of freshwater tributaries in the lake's catchment were not explicitly quantified in the effects-based assessment, but were qualitatively considered in Step 5 of the Framework through the integration of the River Styles stream fragility index in the benefit maps. Key fish habitats in lake and freshwater tributaries were also integrated into the benefit maps. An example of an effects-based assessment for freshwater ecosystems will be provided in detailed guidelines for implementing the Framework in the Coastal Management Manual – Toolkit.

f. **Management responses.** Three management responses were considered in this case study i) post-development stormwater TN load-reduction targets specified in the local council's Development Control Plan (DCP), ii) 'no net increase' or 'no worsening' of existing of TN loads exported from the catchment, and iii) post-development stormwater TN load-reduction targets that achieve the sustainable TN load (or better).

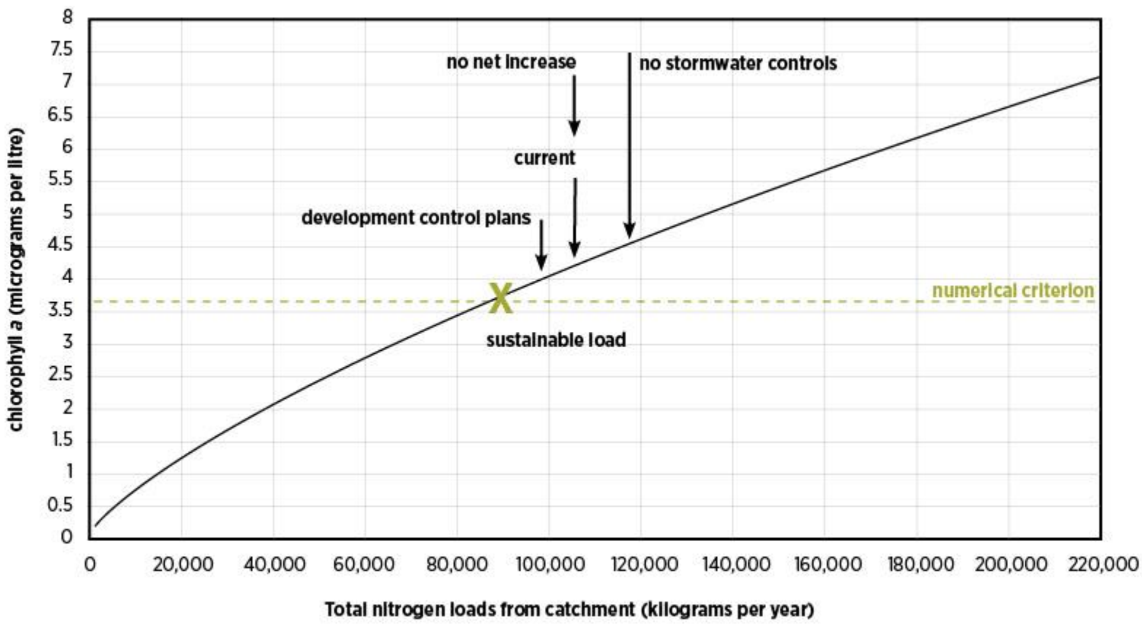


Figure 1 **Chlorophyll *a* concentration in Lake Illawarra as a function of TN (total nitrogen) load. The dotted green line denotes the numerical criterion for chlorophyll *a*, which was used to determine the sustainable TN load (X) for the lake. Arrows indicate the change to chlorophyll *a* concentrations under a range of management responses: TN load-reduction targets in Council's development control plan; no net increase in TN load target; no stormwater controls.**

Step 3: Compare against waterway objectives for Lake Illawarra

As shown in Figure 1, the post-development stormwater TN load-reduction targets specified in the local council's DCP improve the micro-algal concentration in the lake, but not enough to meet the sustainable TN load. The 'no net increase' or 'no worsening' management response provides no improvements, if used ubiquitously. To meet the sustainable TN load, post-development stormwater TN load-reduction targets must be at least 20 per cent less than the existing load from the planned sites of development.

Step 4: Strategic impact assessment for Lake Illawarra

The strategic impact assessment was designed around the council's concerns on the costs for stormwater management. The cost-effectiveness analysis showed that the feasibility of meeting the sustainable TN load was dependent on the development type.

The post-development stormwater TN load-reduction targets required to achieve the sustainable TN load may not be feasible for greenfield developments. The capital infrastructure and maintenance costs for traditional stormwater treatment (e.g. bioretention basins), as well as the land required for stormwater treatment would be relatively high/large for greenfield developments. These results point to a need to invesitage more water sensitive approaches to stormwater management, such as stormwater harvesting and re-use schemes and restoration of riparian corridors.

Under brownfield and re-development scenarios, the post-development stormwater TN load-reduction targets required to achieve the sustainable TN load are feasible, and in some cases, present opportunities for less expenditure on stormwater management than current specifications in the council's DCP.

A cost benefit analysis showed that costs of stormwater management were outweighed by direct beneficial costs to the community, such as commercial and recreational fishing (BMT WBM & AR Volders Environmental Consulting 2015; Weber et al. 2015).

Step 5: Design and implementation for Lake Illawarra

Design and implementation plans were not developed as part of the case study but are currently being discussed by relevant stakeholders involved in managing Lake Illawarra.

The strategic impact assessment resulted in an extensive set of post-development stormwater load-reduction targets for management responses that achieve the no net increase in loads or sustainable load for the lake. The new targets cover the full range of urban-development scenarios proposed for the Lake Illawarra catchment. Wollongong City Council, and other councils within the catchment, can use the new targets to compliment or replace the general targets in their existing DCPs. As well or instead, the councils can use 'benefit maps' like those developed for this case study (see below), to assist with design and implementation plans (Figure 2). The benefit maps reflect a trade-off between meeting the sustainable load and the council's current management responses and concerns about the high costs of ongoing stormwater management.

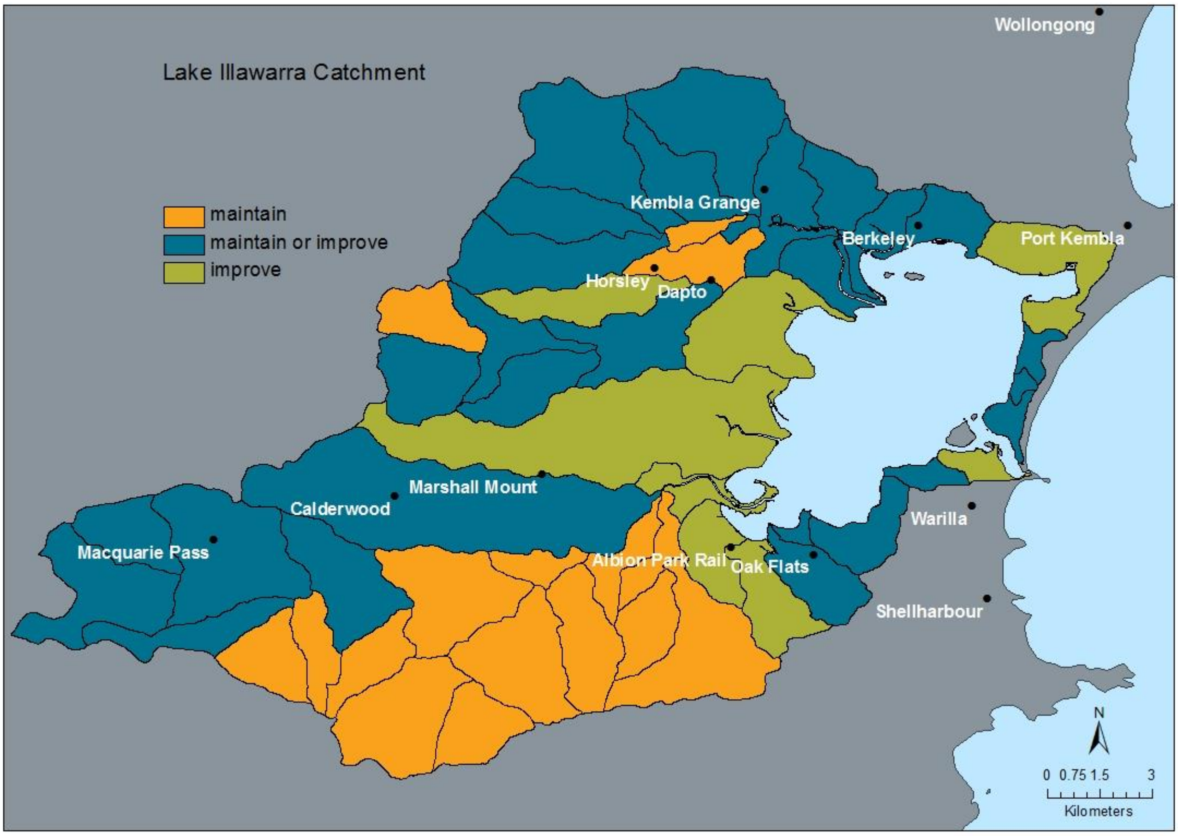


Figure 2 Benefit map identifying priority areas in the Lake Illawarra catchment for cost-effective stormwater management.

Benefit maps

Benefit maps integrate the outcomes of the effects-based assessment and the strategic impact assessment, to identify priority areas in the catchment for cost-effective stormwater management. For example, the following map identifies **green** areas in the catchment that pose the highest risk to waterway health but are also where traditional stormwater management would improve the health of the lake cost-effectively. In these areas, reaching (or going beyond) the general set of stormwater load-reduction targets currently specified in the council's development control plan would improve the lake's health. The green areas are thus 'improvement catchments', where resources for stormwater management would achieve the best benefits for the lake and ideally be prioritised.

The **orange** areas in the catchment are where more water sensitive approaches to stormwater management would be needed to have any effect in maintaining or improving the health of the lake. The orange areas are where the existing land-use is of low intensity, indicating that the optimal management response for these areas would be the no net increase in loads or no worsening option. The orange areas could essentially be used or zoned as 'maintenance catchments'.

The **blue** areas were designed to provide more flexibility and be used as offset areas or areas for adaptive management, in cases where stormwater controls cannot be met in green or orange areas. At the bare minimum, the council should apply its general set of stormwater load reduction targets in the blue areas.

Definitions

Waterway

A waterway is any navigable body of water, but is specifically defined here as any body of water that can be affected by land-use activities.

National Water Quality Management Strategy

The National Water Quality Management Strategy is a joint national approach to improving water quality in Australia and New Zealand. The NWQMS was originally endorsed by two ministerial councils - the former Agriculture and Resources Management Council of Australia and New Zealand, and the former Australian and New Zealand Environment and Conservation Council. Ongoing development of the NWQMS is currently overseen by the Standing Council on Environment and Water and the National Health and Medical Research Council.

Environmental values and uses of waterways

Environmental values and uses of waterways are those that the community believes are important for a healthy ecosystem, for public benefit, welfare, safety or health. There are seven broad categories of environmental values and uses of waterways, as identified in the National Water Quality Management Strategy:

1. protection of aquatic ecosystems
2. aquatic foods
3. recreational water quality and aesthetics
4. primary and secondary contact, including visual appreciation
5. drinking water supply
6. agricultural water use
7. industrial water quality.

ANZECC guidelines, indicators, and guideline trigger values

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality, widely referred to as the ANZECC guidelines, is the central technical document that underpins the National Water Quality Management Strategy. The ANZECC guidelines were published in 2000, and were informed by all relevant government jurisdictions, water quality experts, industry and conservation groups. The ANZECC guidelines describe a range of indicators to help assess whether the waterway will support a particular environmental value or use. For example, the presence of bacteria such as enterococci is an indicator for recreational and drinking water quality because they directly put those uses at risk, but is not an indicator for the protection of aquatic ecosystems.

The ANZECC guidelines also describe a range of methods and case studies for determining guideline trigger values for the indicators, which are referred to water quality guidelines in ANZECC. The guideline trigger values indicate whether further investigation or management is required to minimise the risk of impacts on the community's environmental values and uses of the waterway. Guideline trigger values are expressed as a single number or a range of desired numbers, and are usually concentrations of an indicator, but can be a descriptive statement to support and maintain the community's environmental values and uses.

Guideline trigger values are available for some indicators in the ANZECC guidelines, predominantly for slightly to moderately disturbed ecosystems, or highly disturbed ecosystems. The ANZECC guidelines recognise that there is inherent variability among waterways that could affect their capacity to receive some level of human induced input without unacceptable changes occurring (viz. sensitivity or assimilative capacity). So it is important to consider that the guideline trigger values do not account for varying local conditions and are best refined with local information. The current review of the ANZECC guidelines seeks to incorporate the latest scientific assessments of site-specific trigger values and associated uncertainties (Warne et al. 2014).

NSW Water Quality and River Flow Objectives

Environmental values and uses, indicators and guideline trigger values for all major waterways in NSW have been identified through community consultation by the Department of Environment, Climate Change and Water (now Office of Environment and Heritage), and are known as the NSW Water Quality and River Flow Objectives. Current policy in NSW indicates that the NSW Water Quality and River Flow Objectives should be used when there is limited data available for local derivations of objectives.

Relationship to other management approaches

The ANZECC guidelines provide a national framework for managing water quality that can be adapted to state, regional and local scales to address specific issues and account for specific environmental conditions. The Framework described in this document is an adaptation of the national framework to specifically guide strategic land-use planning decisions that protect waterways at local scales (subcatchment, precinct and/or lot scale). The Framework integrates NSW Policy and is more operational than the national framework because it explicitly includes an effects-based assessment to assist decisions on identifying management options for a particular problem and waterway type. The Framework also has an explicit step (step 4) for evaluating the feasibility of meeting water quality objectives, such as through cost effectiveness and/or cost benefit analysis.

The five steps of the Framework are consistent with the risk assessment approaches described for the Marine Estate Management Authority Threat and Risk Assessment, and the Coastal Risk Assessments in the Coastal Management Manual. All follow the risk management process recommended in The Treasury Risk Management Toolkit for NSW Public Sector Agencies and the international standard for risk management (ISO 31000 – Risk Management).

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Appendix F
Performance Criteria for protecting and improving the blue grid in the Wianamatta-South Creek catchment

Department of Planning and Environment

Performance criteria for protecting and improving the blue grid in the Wianamatta–South Creek catchment

Water quality and flow related objectives for use as environmental standards in land-use planning

environment.nsw.gov.au

Cover photo: Wianamatta–South Creek and Thompsons Creek, Western Sydney. Carl Tippler/CTENVIRONMENTAL

Authors: Jocelyn Dela-Cruz, Carl Tippler, Marnie Stewart, William Chirgwin, Georgina Dawson, Martin Krogh and Tim Pritchard.

In Honour of Shane Barter, whose passion for our waterways and kind and humble leadership in the water industry will not be forgotten by those who worked with him.

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1. Protected to the most insignificant jet

‘On 28 August 1826 a truly remarkable public meeting was held in Windsor Courthouse attended by notable local Aboriginal figures of the day. In this remarkable meeting it was resolved “that the rivers be protected to the most insignificant jet”, a poignant resolution still pertinent for the waters of the Wianamatta system.

Water resources have important cultural, spiritual, and practical values for First Peoples. Waterways are crucial for cultural practices and knowledge transfers as part of a healthy, flowing, connected system.

The Cannemegal and Wianamattagal peoples of the Dharug nation still care for the Country of Wianamatta and carry the stories and knowledges of that landscape. Dharug Elders describe Wianamatta as an interconnected system, formed through the Dreaming, this cultural landscape connects from beyond the mountains out to the sea. It is a particularly important place for pregnant women as the place of the mother creek – a female landscape relating to motherhood and creation.

The floodplains of Wianamatta remain a significant place for Aboriginal communities. South, Ropes, Badgerys, and Thompsons Creeks form a major part of the Aboriginal infrastructure which has provided resources such as food, medicine, and recreation over thousands of generations of people. It is imperative to respect these waterways and their dynamic movements, and to learn from their capacity to find the path of least resistance. Allowing one part to become ill through pollution, mismanagement or overuse will cause the whole system to suffer. All the waters must be protected to ensure the health of the whole system – to the most insignificant jet.’

Dr Danièle Hromek is a Budawang woman of the Yuin nation – she has spent some time yarning with the Aboriginal Elders in Wianamatta to help translate cultural values into land-use planning

2. About this document

This document describes the background and methods for developing performance criteria for protecting and improving the health of the blue grid in the Wianamatta–South Creek catchment. The blue grid is made up of waterways, riparian vegetation communities, wetlands and other water dependent ecosystems. The performance criteria are the instream water quality and flows that each of the components or elements of the blue grid require to remain healthy and functioning. These types of performance criteria are used in several NSW Government policies and/or legislation for managing the health of the state's waterways.

The performance criteria apply to the entire Wianamatta–South Creek catchment. They are specified in the Aerotropolis Precinct Plan, as a requirement of the *State Environmental Planning Policy (Precincts – Western Parkland City) 2021*. They have also informed standard planning requirements for stormwater infrastructure in both the Aerotropolis Development Control Plan and Mamre Rd Precinct Development Control Plan. The stormwater quality load reduction targets and stormwater quantity/volumetric flow targets in these development control plans directly achieve the performance criteria.

This document is technical in nature, and its purpose is to summarise the scientific evidence base for the performance criteria. The document provides the technical background for the NSW Government *Wianamatta–South Creek stormwater management targets* (DPE 2022a). It is part of a series of technical documents released by the NSW Government to support precinct planning in Western Sydney, including:

- *Mapping the natural blue grid elements of Wianamatta-South Creek* (DPE 2022b)
- *Review of water sensitive urban design strategies for Wianamatta–South Creek* (DPE 2022c)
- *Technical guidance for achieving Wianamatta–South Creek stormwater management targets* (DPE 2022d).

3. Background

Our waterways are significant city shapers – they define geographic boundaries and the local characteristics of a place. The ecosystem services that waterways provide are well-established and include clean water for drinking, irrigation and domestic uses, drainage and flood management, nutrient cycling, control of pests, recreation and tourism, and increased property values due to amenity (e.g. de Groot et al. 2012; Böck et al. 2018). Also well-established are the intrinsic values that waterways hold (Bennett et al. 2015), and although difficult to monetise, these are partly reflected in the connection communities have with their local waterways for health and wellbeing.

A growing number of studies are quantifying the positive cognitive and physical effects of water (e.g. Nichols 2015; Francis et al. 2016). City planners and governments are also increasingly turning waterways or 'blue spaces' into essential city building infrastructure to promote community health in busy cities. A recent study arising from the BlueHealth initiative, funded by the European Union, showed that urban renewal of a riverside in a socio-economically deprived neighbourhood of Barcelona in Spain led to a 25% increase in use of the riverside for relaxation purposes (Vert et al. 2019). A broader review of up to 35 studies showed a positive association between greater exposure to outdoor blue spaces, and benefits to both mental health and wellbeing and levels of physical activity (Gascon et al. 2017).

Of equal significance is the positive relationship between human wellbeing and the wellbeing or health of the environment itself (Reed 2007; Patrick et al. 2019). This has long been recognised by indigenous knowledge holders in Australia who uphold the axiom ‘if we care for Country, it will care for us’ (WSPP 2020). In clear support of this, the strategic planning for Sydney’s second international airport and surrounding precincts of the new Western Parkland City has been Country or landscape led (WSPP 2020; DPIE 2021a). This has been achieved through the creation of a Blue and Green Infrastructure Framework, which is centred around Wianamatta-South Creek and its major tributaries (WSPP 2021a; Figure 1).

The Blue and Green Infrastructure Framework is designed to be multifunctional, by providing a range of benefits related to liveability, building resilience to city hazards like urban heat and flooding, and protecting the iconic and/or endangered ecological communities that characterise the area (GSC 2018a; DPIE 2021a; WSPP 2021a). Multifunctional infrastructure of this type will help to address the socio-economic divides in the Greater Sydney region, which are known to result in lower health outcomes (e.g. diabetes, South Western Sydney Primary Health Network 2020).

Delivering a healthy and functioning Blue and Green Infrastructure Framework requires a ‘beyond business-as-usual’ approach based on restorative and regenerative actions (Reed 2007; WSPP 2021a, b). This approach strives to reverse the current degraded ecological and hydrological state of the waterways, riparian corridors, wetlands and other water dependent ecosystems that make up the blue grid elements of the Blue and Green Infrastructure Framework (Reed 2007; DPE 2022b).

Costs for restoring and regenerating the blue grid elements vary, with lower costs in areas of the riparian corridor that are more intact, and higher costs in areas that are the most degraded (GSC 2020). The capital investment is ~16% of the total city building infrastructure costs for the Western Parkland City, due mostly to the large area of the blue grid elements. To realise the benefits of this investment into the future, the Environment and Heritage Group (EHG) of the NSW Department of Planning and Environment was tasked with developing performance criteria to not only achieve the ‘beyond business-as-usual’ approach, but to also manage the cumulative impacts of the future urban developments on the health of the blue grid elements.

The performance criteria include instream water quality and flows that each of the blue grid elements require to remain healthy and functioning. This document describes how the performance criteria were developed, and how they have driven an integrated landscape led approach to water infrastructure delivery in the Western Parkland City.

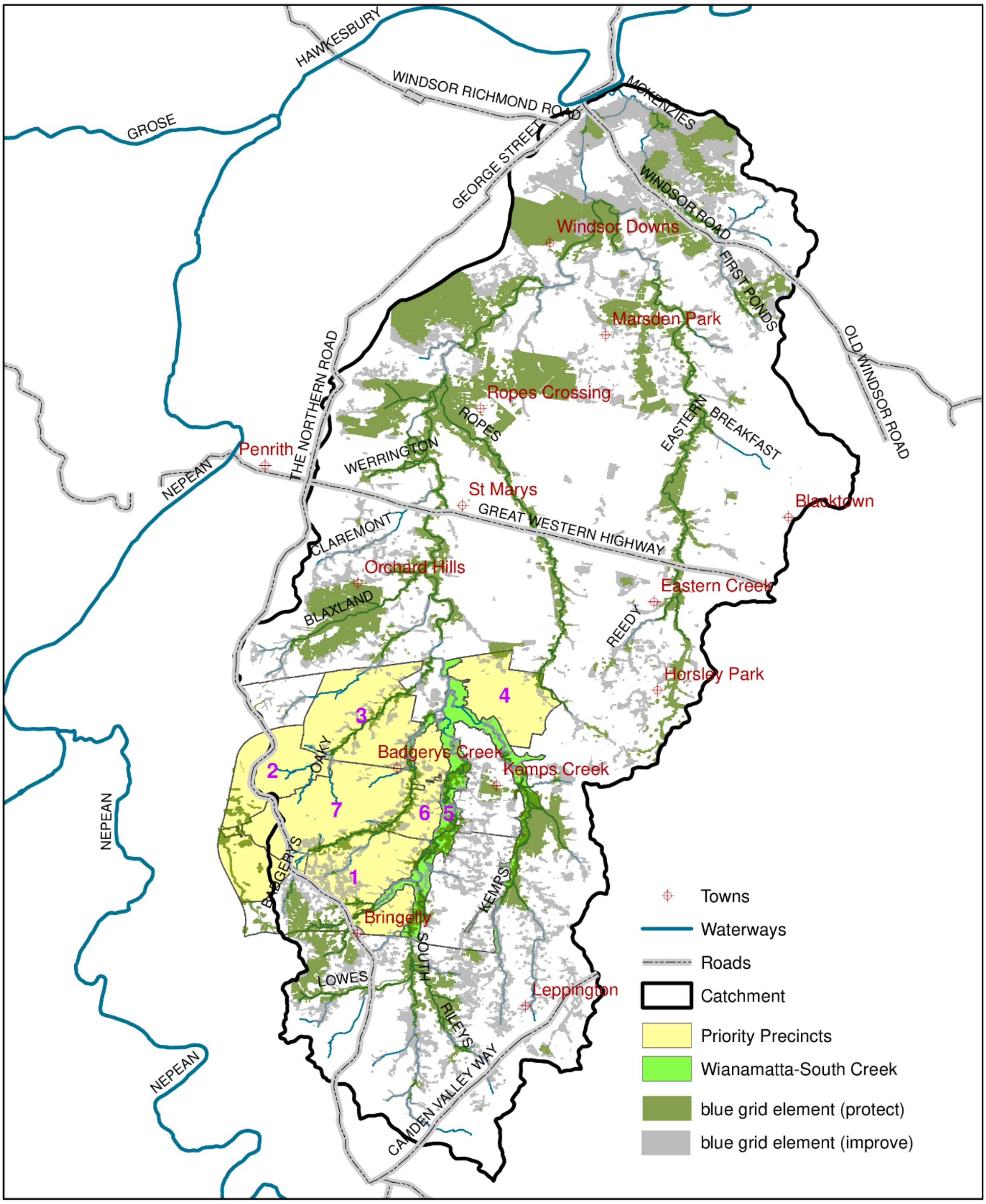

Figure 1 Wianamatta–South Creek catchment, showing the locations of the priority precincts in the Western Sydney Aerotropolis (precincts)

1 Aerotropolis Core, 2 Agribusiness, 3 Northern Gateway, 4 Mamre Rd, 5 Wianamatta–South Creek (Blue and Green Infrastructure Framework), 6 Badgerys Creek, 7 Western Sydney Airport. The natural blue grid elements are shown for the whole catchment.

4. Performance criteria – water quality and flow related objectives

Planning for the Western Parkland City has largely focused on the release of priority precincts to support the activation of Sydney's second international airport. Collectively, these priority precincts are known as the Western Sydney Aerotropolis and include a new Environment and Recreation Zone. This Zone essentially encompasses the Blue and Green Infrastructure Framework, and is predominantly located in the precinct known as Wianamatta–South Creek (Figure 1).

In accordance with the strategic plans for the area (GSC 2018a, b; WSPP 2020), standard planning requirements (viz. development controls) to protect and manage the blue grid elements of the Environment and Recreation Zone have been developed using the NSW Government *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* (the Risk-based Framework; Dela-Cruz et al. 2017). This Risk-based Framework brings together existing NSW Government policies and strategies for managing the water quality and health of the state's waterways. The first step of the Risk-based Framework is to establish waterway health objectives, using the NSW Water Quality Objectives (WQOs) as a starting point.

The WQOs are the long-term goals for how the NSW community value and use their local waterways. They consist of 3 components: i) the community's environmental values and uses of a waterway, ii) the indicators, and iii) numerical criteria or guidelines to help assess whether the community environmental values and uses are being met. A common example of a WQO for waterways designated for swimming (community use) includes the use of microbial (indicators) concentrations (numerical criteria/guideline) for assessing public health risks. Typically, the WQOs are used as environmental standards and accordingly, should be used as performance criteria for the blue grid elements of the Blue and Green Infrastructure Framework.

EHG is the current custodian of the WQOs, and is in the process of reviewing and updating them as part of its delivery of the Marine Estate Management Strategy 2018–2028, under the *Marine Estate Management Act 2014*. The work described in this present study is an exemplar of how the WQOs should be updated, and will be included in EHG's final rollout of the updated WQOs. This work also effectively describes how the first step of the Risk-based Framework was applied in the context of planning for the Western Parkland City.

A fundamental change that this work brings, is the need to augment the WQOs with flow related objectives to ensure the total loads of nutrients and sediments in stormwater discharges are managed, to mitigate erosive stormwater flows and subsequent loss of the riparian corridors, and to ensure the water requirements of the blue grid elements are being met. These flow related objectives are distinct from the flow objectives used in the NSW Government water sharing plans, as they specifically manage for excessive flows going into waterways and impacting riparian corridors. By comparison, the flow objectives specified in water sharing plans manage for extractions of water from waterways. A common goal of both types of flow objectives, however, is to protect the health of the waterway.

The importance of including flow related objectives has been known for some time, especially for the Wianamatta–South Creek catchment, which has the longest alluvial creeks in the Sydney Basin. For example, Sharpin and Barter (1997) had already noted that flow volume is a key problem for urban stormwater in NSW and that attempts to manage only water quality are 'insufficient to mitigate the impacts of urbanisation'. There is now a growing awareness of the impacts of changed flow regimes on waterways in other urban catchments of Australia (Walsh et al. 2012; Fletcher et al. 2014; Walsh et al. 2016; Vietz et al. 2016; Kermode et al. 2021), meaning that the importance of including contemporary and locally specific flow related objectives for planning of the Western Parkland City has become acute.

4.1 Community environmental values and uses

The NSW Government policy for managing water quality and waterway health defines community environmental values and uses as what the community believes is important for a healthy ecosystem, for public benefit, welfare, safety or health (DEC 2006). Previous economic valuation studies show the net benefits of protecting and improving the natural blue grid is over $1 billion (Bennett et al. 2015; INSW 2019). These net benefits include those for communities within the Wianamatta–South Creek catchment (e.g. bass fishing, riparian vegetation habitat for birds) and those for communities downstream in the Nepean River and out towards the ocean (e.g. swimming, no infestation of water weeds).

There are up to 7 existing community environmental values and uses of the waterways and riparian corridors in the Wianamatta–South Creek catchment, which were identified in 1999 when the NSW Government released the WQOs. As shown in Figure 2, some of these values and uses are unlikely to be relevant due to the future urbanisation of the catchment while others will need to be restored or regenerated. To determine the contemporary community environmental values and uses, we collected data from multiple sources:

- direct consultation with Aboriginal Elders (Section 1 – To the most insignificant jet)
- direct consultation with state agencies involved in planning for the Western Sydney Aerotropolis
- direct consultation with the 6 main local government authorities in the Wianamatta–South Creek catchment (Table 1, see also Appendix A)
- online community survey, promoted through social media during the austral summer of 2020–21 (Fig. 3)
- desktop assessment of Local Strategic Planning Statements, which set the 20-year vision for land use in the local area and identify the special character and values that need to be preserved and managed into the future
- objects/requirements of the Environment and Recreation Zone of the *State Environmental Planning Policy (Precincts – Western Parkland City) 2021*.

We found that the community environmental values of ‘Protection of Aquatic Ecosystems’, ‘Secondary Contact Recreation’ and ‘Amenity’, were the most common and prominent values that were identified and expressed in various ways by various groups, for example:

- Aboriginal communities identify the floodplains of Wianamatta as a significant place, in which ‘South, Ropes, Badgerys, and Thompsons Creeks form a major part of the Aboriginal infrastructure which has provided resources such as food, medicine, and recreation over thousands of generations of people’.
- The vision for the Western Parkland City ‘puts landscape first. Prioritising the landscape, and using water and other precious resources more efficiently, will help us make the Western Parkland City a better place for residents, workers and visitors.’… ‘above all, it will be a green city, with its waterways and scenic landscapes protected, its tree canopy increased and its biodiversity preserved…’ (WPCA 2019).
- Local governments prefer to ‘rehabilitate/restore native habitats and create healthy ecosystems including naturalised creeks, protecting fish, frogs, birds, etc’. They stated that their local communities enjoyed ‘Being near water, and enjoyed the landscape/outlook, picnics, barbeques, camping, walking, hiking, cycling, etc’.
- Top ranking values in the online community survey were ‘A place where fish, plants and animals live’ and ‘A natural place to look, walk, relax, picnic or camp’.

We also found that the ‘Protection of Aquatic Ecosystems’, ‘Secondary Contact Recreation’ and ‘Amenity’ values are included in all Local Strategic Planning Statements covering the Wianamatta–South Creek catchment:

- Camden Council has priorities for ‘Protecting and enhancing the health of Camden’s waterways, and strengthening the role and prominence of the Nepean River’ (CC 2020).
- Campbelltown City Council has several priorities for managing waterways, including to ‘Investigate opportunities to rehabilitate existing waterways within the local government area (LGA) to maximise the benefits to the community’ (CCC 2020).
- Liverpool City Council has a range of priorities for ensuring its ‘Bushland and waterways are celebrated, connected, protected and enhanced’ (LCC 2020).
- Fairfield City Council has priorities for ‘Protecting areas of high natural value and environmental significance, and improve the health of catchments and waterways’. The creek corridors are managed to provide the city with ‘great outdoor amenity, being cooler in the summer as well as providing for native flora and fauna habitat, and improving water quality’ (FCC 2020).
- Blacktown City Council has a priority for ‘Protecting and improving the health and enjoyment of waterways’ by collaborating ‘on a catchment-wide scale to improve waterway health and community access to waterways’ and collaborating ‘to deliver projects that rehabilitate waterways to a more natural condition’ (BCC 2020).
- Penrith City Council recognises that its ‘waterways and riparian corridors are an important ecological, hydrological, recreational and cultural resource. They provide habitat for native species and support groundwater-dependent ecosystems….They support recreational activities and are appreciated for their aesthetic quality within the landscape. They also provide a sense of place and identity for many in our community’. A main priority is for the council to ‘Collaborate with Infrastructure NSW, other State agencies, water service providers and councils on the South Creek Corridor Project to improve the management of water quality and quantity in the Corridor and implement through planning and development controls, where required’ (PCC 2020).
- The Hills Shire Council has priorities to ‘Retain and enhance vegetated riparian corridors, bird habitats and wildlife corridors across the Shire to support biodiversity and water quality outcomes’ and ‘Continue to protect and enhance water quality in local catchment areas’. It recognises that its ‘waterways facilitate conservation, recreation and tourism’ and there is a ‘need to work with partners to monitor, improve and maintain water quality and ensure residents and visitors use these environments responsibly’ (THSC 2020)
- Hawkesbury City Council has a priority for ‘effective management and protection of our rivers, waterways, riparian land, surface and ground waters, and natural eco-systems through local action and regional partnerships’ (HCC 2020).

The objectives of the Environment and Recreation Zone of the *State Environmental Planning Policy (Precincts – Western Parkland City) 2021* also have clear requirements to support the ‘Protection of Aquatic Ecosystems’, ‘Secondary Contact Recreation’ and ‘Amenity’ values, to:

- protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values
- protect the ecological, scenic and recreation values of waterways, including Wianamatta-South Creek and its tributaries
- provide a range of recreational settings and activities and compatible land uses
- protect and conserve the environment, including threatened and other species of native fauna and flora and their habitats, areas of high biodiversity significance and ecological communities.

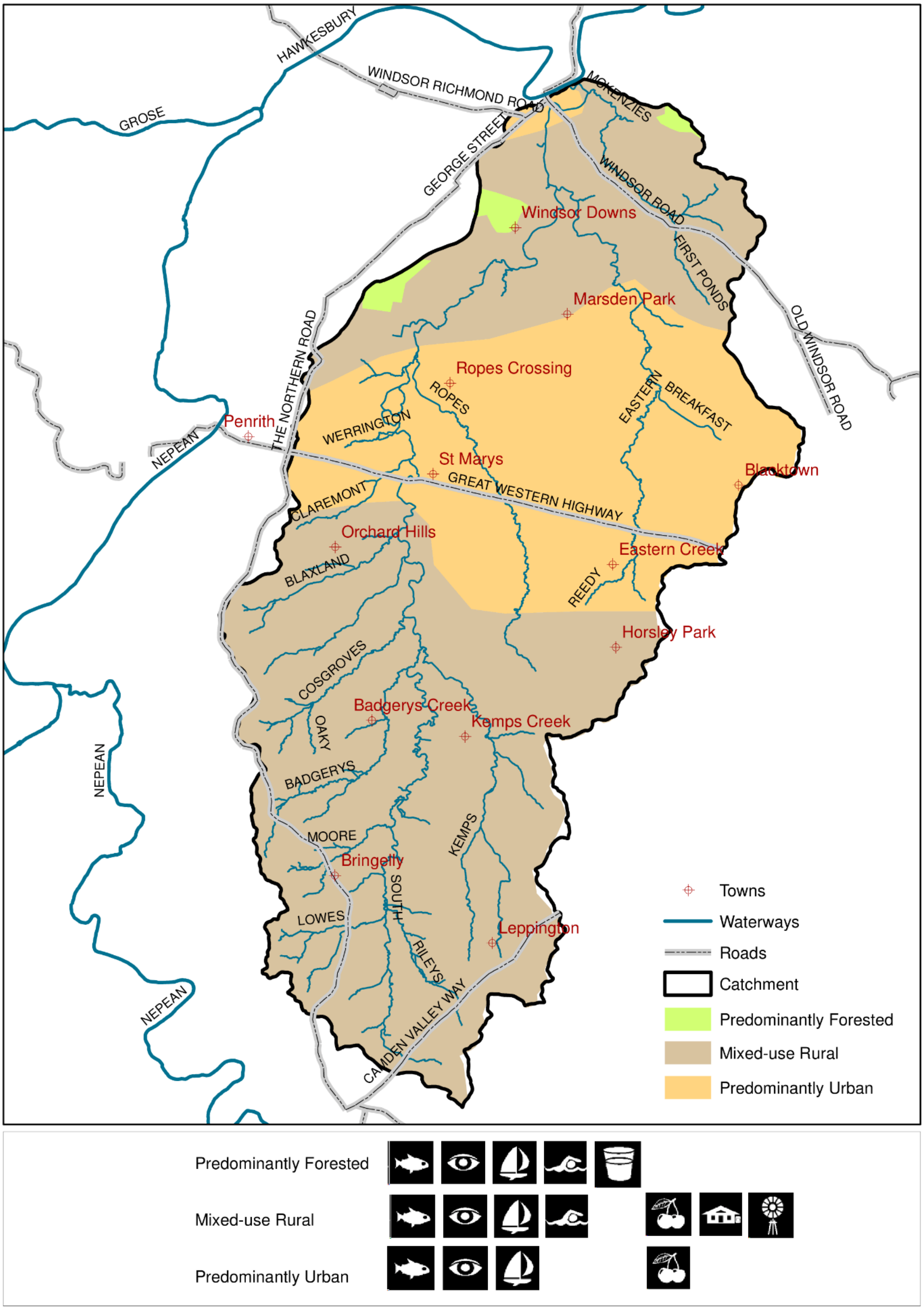

Figure 2 Community environmental values and uses of waterways and riparian corridors in the Wianamatta–South Creek identified in 1999

Some comments from local community members

‘…I would like to use it to swim, but the water quality stops me doing that…’

‘…Painting pictures of the river and surrounding country, and also photography of the river…’

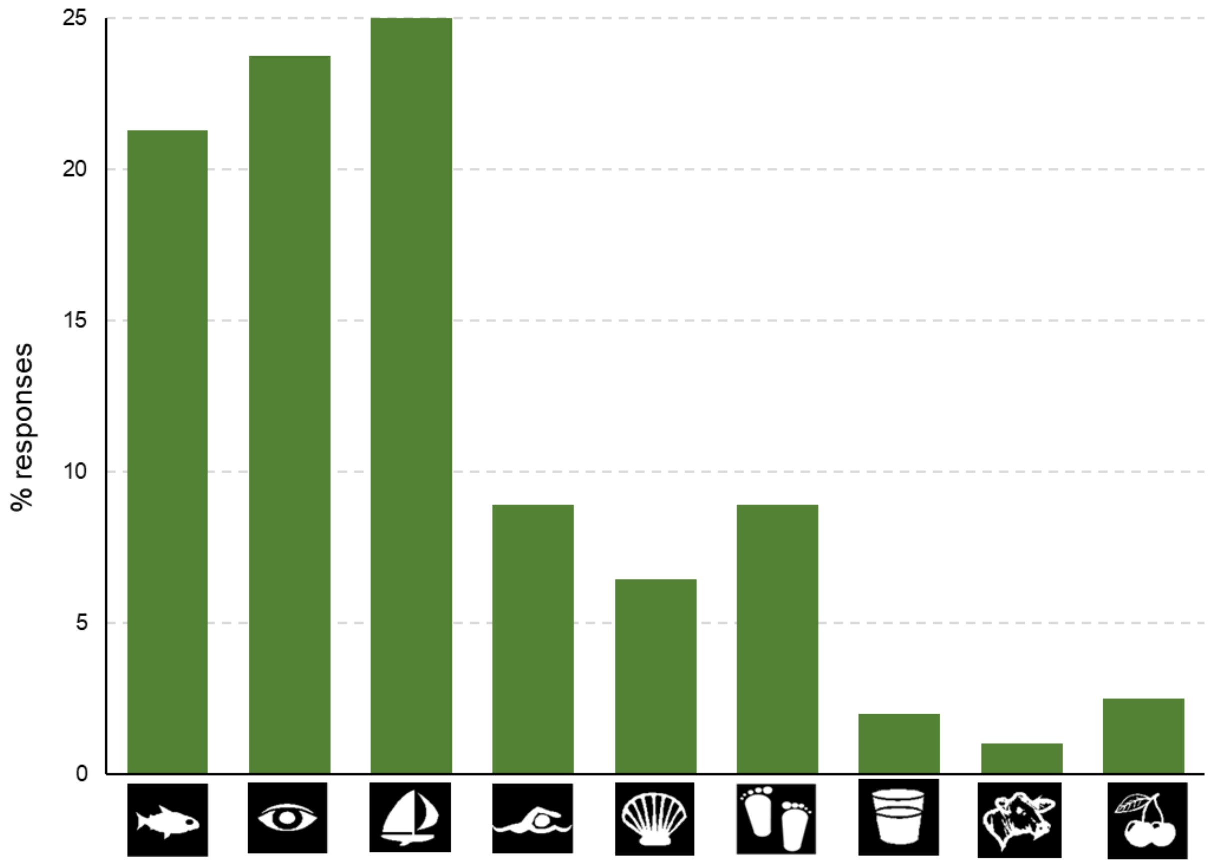

Figure 3 Community environmental values and uses of waterways and riparian corridors in the Wianamatta–South Creek identified in 2020–21

Table 1 Community environmental values and uses of waterways and riparian corridors in the Wianamatta–South Creek catchment, derived through consultation with local governments in February 2021

Community environmental value or use	Icon	Description	CC	CCC	LCC	FCC	BCC	PCC
Protection of Aquatic Ecosystems		**Maintaining or improving the ecological condition of waterways and their riparian zones over time** **Specific to the LGA:** Rehabilitating/restoring native habitats and creating healthy ecosystems including naturalised creeks, protecting fish, frogs, birds	Yes	Yes	Yes	Yes	Yes	Yes
Visual Amenity		**Aesthetic qualities of water** **Specific to the LGA:** Being near water, enjoying landscape/outlook, picnics, barbeques, camping, walking, hiking, cycling, etc.	Yes	Yes	Yes	Yes	Yes	Yes
Primary Contact Recreation		**Maintaining or improving water quality for activities where there is a high probability of water being swallowed** **Specific to the LGA:** Swimming, water skiing	Yes (lake)	Yes	No	No	No	No
Secondary Contact Recreation		**Maintaining or improving water quality for activities where there is a low probability of water being swallowed** **Specific to the LGA:** Kayaking, canoeing and paddle boarding	Yes (lake)	Yes	Yes	Yes	Yes (lake)	Yes
Secondary Contact Recreation		**Maintaining or improving water quality for activities where there is a low probability of water being swallowed** **Specific to the LGA:** Recreational fishing, wading in water	No	Yes	Yes	Yes	Yes	Yes
Cultural Activities		**Indigenous and non-indigenous cultural activities** **Specific to the LGA:** First Nations cultural activities/Care for Country activities, other spiritual and ceremonial uses (e.g. mediation, prayer), visiting cultural or historic sites	Yes		Yes	Yes	Yes	Yes

Community environmental value or use	Icon	Description	CC	CCC	LCC	FCC	BCC	PCC
Irrigation Water Supply		**Protecting the quality of waters applied to crops and pasture**	Yes		Yes	Yes	Yes	Yes
Livestock Water Supply		**Protecting water quality to maximise the production of healthy livestock**	Yes		Yes	Yes	Yes	Yes
Drinking water – groundwater		**Protecting the quality and access to ground or bore water for drinking**	Yes	Yes	Yes	No	No	Yes
Aquaculture and Human Consumption of Aquatic Foods		**Protecting water quality so that it is suitable for the production of aquatic foods for human consumption and aquaculture activities**	No		Yes	No	No	No

CC = Camden Council, CCC = Campbelltown City Council, LCC = Liverpool City Council, FCC = Fairfield City Council, BCC = Blacktown City Council, PCC = Penrith City Council

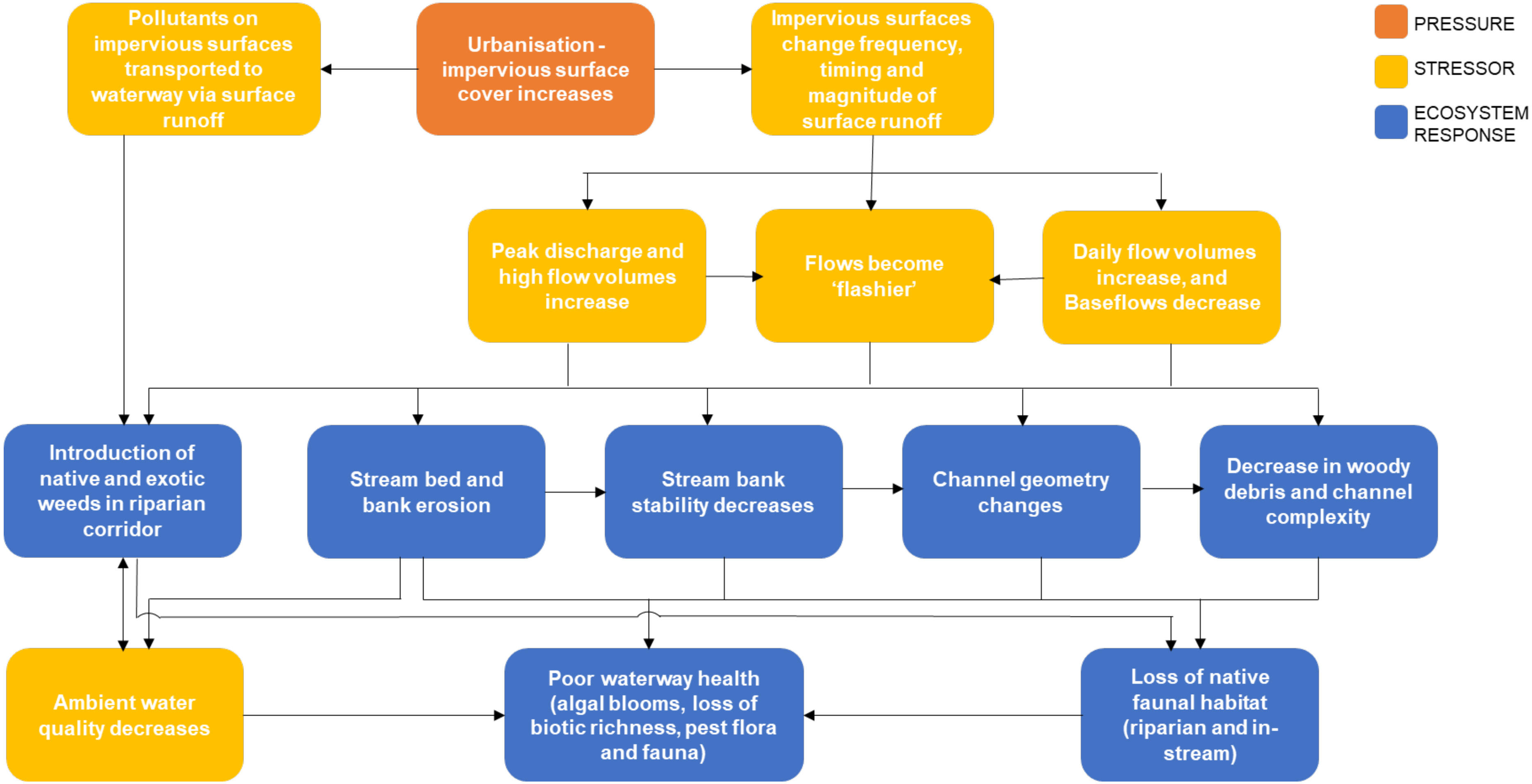

Figure 4 Pressure–stressor–ecosystem response model for streams in urban catchments

4.2 Derivation of indicators and numerical criteria

According to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ 2000), many community environmental values and uses will usually be achieved if the numerical criteria for the ‘Protection of Aquatic Ecosystems’ are being met. These numerical criteria must be derived through methods outlined in the Australian Water Quality Guidelines (Commonwealth of Australia 2018) – most notably, the use of a referential or effects-based assessment approach. The latter method is reflected in the 2nd step of the Risk-based Framework. In addition, the Australian Water Quality Guidelines specify a shift away from default numerical criteria or guideline values to more site-specific guideline values. This shift is important as it requires collection of local field data and will inherently result in a place-based or tailored outcome.

The Australian Water Quality Guidelines also specify that appropriate indicators for the ‘Protection of Aquatic Ecosystems’ must be identified through a pressure–stressor–ecosystem receptor model. Figure 4 shows the pressure–stressor–ecosystem receptor model that is specific to our case (noting that additional flows from wastewater discharge would contribute to the impact). The underlying pressure arises from stormwater discharges generated from the urban developments, the stressors are the nutrients, sediments and flows, and the ecosystem receptors are the blue grid elements of the Blue and Green Infrastructure Framework.

The causal relationships among the specific set of indicators shown in Figure 4 are best described through the well-established concept of the ‘urban stream syndrome’, in which waterways that drain urban catchments are consistently ecologically degraded (e.g. Paul and Meyer 2001; Walsh et al. 2005; Tippler et al. 2012; Walsh et al. 2012; Vietz et al. 2014; Vietz et al. 2016). Specific symptoms of the urban stream syndrome include a flashier hydrograph and elevated concentrations of ambient nutrients and contaminants, which combine to alter channel morphology and algal blooms, reduced biotic richness and prevalence of weeds (see Table 8, Appendix C). In Australian streams, these symptoms have been observed in urban catchments with as little as 2–3% effective imperviousness (Vietz et al. (2014), or 10% total imperviousness (Tippler et al. 2012). These measures of imperviousness represent the proportion of impervious (hard) surface cover within a landscape that is directly connected to streams, or total proportion of impervious surface cover in a landscape, respectively.

In consideration of the above, we selected the stressor indicators (instream water quality and flows) as performance criteria for the blue grid elements of the Blue and Green Infrastructure Framework. This is because they provide the pivotal causal links between the pressures that need to be managed and the health and functioning of the blue grid that provides for the community values and uses.

5. Data collection and analyses

The following sections summarise our methods for collecting local field data in the Wianamatta–South Creek catchment, and the subsequent analyses of the data to derive the performance criteria.

5.1 Water quality

Local field data on instream water quality were sourced directly from EHG, Penrith City Council, Liverpool City Council, Blacktown City Council and Sydney Water. All available records, dating back to 1 January 1990 were collated and the data quality checked on the basis of the following criteria:

- SI units of all measures were standardised
- obvious outliers were removed, e.g. pH values reported as 23.7
- measures below detection limits were replaced with half the detection limit value
- measures were limited to the following water quality variables: temperature (T°C), conductivity (µS/cm), pH, dissolved oxygen (DO mg/L, %), turbidity (NTU), total suspended solids (TSS, mg/L), ammonia (NH_3-N, mg/L), oxidised nitrogen (NO_x, mg/L), total nitrogen (TN, mg/L), dissolved inorganic phosphorus (DIP, mg/L), total phosphorus (TP, mg/L) and chlorophyll *a* (Chl *a*, mg/L)
- DO measures that were ≤0% and >110% saturation were excluded
- conductivity measures that were <100 µS/cm were excluded
- turbidity measures that were <1 NTU were excluded.

The total number of data points remaining after the quality checks was 61,622, and these were collected from a total of 108 monitoring sites (Figure 5).

The approach currently used by councils (in the Wianamatta–South Creek) to derive site specific guideline values for water quality is the referential one. This approach is based on the 80th or 20th percentiles of data collected monthly from reference sites over a period of at least 2 years. Reference sites are defined as those where their state is unimpacted or minimally impacted so it can serve as a suitable baseline or benchmark for the assessment and management of impacted sites in similar waterbodies. The 80th percentiles are calculated for the majority of the water quality variables. For DO, the lower 20th percentile is used as detrimental effects usually occur due to a lack of oxygen. For pH, temperature and salinity, both the 80th and 20th percentiles are calculated as impacts are seen at either extreme.

To apply the referential approach, we filtered the data points further by only including field monitoring sites where:

- sufficient water quality monitoring data is available, and data from the sites have been collected, stored and analysed using approved protocols
- there are no significant point source and diffuse source discharges nearby or upstream
- there is minimal disturbance to the local environment and upstream
- there are minimal alterations to the flow or water regime.

5.2 Ecological condition of ecosystem receptors

In a companion study, we defined and mapped the blue grid elements of the Blue and Green Infrastructure Framework (DPE 2022b). These were represented by a total of 36 indicators of ecosystem receptors. Waterways were represented by the following indicators: Shannon–

Wiener diversity index determined from field measures of macroinvertebrates, River Biodiversity Condition Index, high ecological value aquatic ecosystems, key fish habitat, condition of fish communities, fish nativeness, type or classification of waterways according to the River Styles Framework, and associated indices of the recovery potential and geomorphic condition of the waterways. Riparian vegetation, wetlands and other water dependent ecosystems were represented by 25 indicators, and these were captured either directly by endangered ecological communities that are water dependent or indirectly by the habitats of iconic and/or threatened species of waterbirds, frogs and water dependent bats.

Local field measures for each of the 36 indicators were collected in the companion study to validate the blue grid map (DPE 2022b). Data from a total of 396 monitoring sites were available, but the data for each indicator were not consistently available for all sites (Figure 5). For example, data on the geomorphic state of the streams were only available from 9 monitoring sites, whereas data on the ecological health of vegetation were available from 65 monitoring sites. Gaps in data were filled through a rapid riparian assessment (RRA) previously undertaken by councils in the catchment, and through additional RRAs specifically undertaken for this study in areas where private landholders provided access to their waterways. This resulted in a combined total of 479 RRA monitoring sites, from which the performance criteria were derived (Figure 5).

5.2.1 Rapid riparian assessment

An RRA is a robust, rapid and cost effective method for collecting data on the ecological and geomorphic condition of waterways in urban catchments. It was originally developed for the Kur-ring-gai LGA in the north of Sydney (Taylor et al. 2005; Findlay et al. 2011) but has since been augmented and optimised for several LGAs in Greater Sydney, including Blacktown, Liverpool, Penrith, Camden and those in the Georges River catchment (Dean and Tippler 2016). Figure 6 provides an example of the specific measures collected through an RRA. The example is from a site at Duncans Creek inside the Agribusiness Precinct, where we found the site to be in very good condition. The overall site score was 81%, and this is due to the natural bushland surrounding both sides of the creek, intact vegetation structure and (creek) channel shape. The creek provides relatively good habitat for macroinvertebrates and fish, due to the abundance of large woody debris and overhanging vegetation. In contrast, the overall condition score of a site inside the Environment and Recreation Zone of the Wianamatta–South Creek Precinct is 59%, indicative of poor condition (Figure 7). The site is surrounded by pastoral land and as a result has poor vegetation and (creek) channel structure (e.g. widening and infilling). The vegetation is 20% exotic scrubland and 80% pastoral grass, and there is severe undercutting and slumping of the creek banks.

Note that each measure has a score, based on a positive to negative scale. Highest positive scores indicate streams in very good ecological condition, and the most negative scores indicate streams that have been detrimentally impacted by urbanisation. A score of zero indicates a neutral effect of urbanisation. The scale varies depending on the specific measure to enable a relative assessment of impact (of urbanisation) for that measure, but not between or among different specific measures. The scores are, however, standardised post hoc, to produce the final site score as a percentage.

A new scale was specifically developed in this present study to provide a measure of the complexity of instream habitats for macroinvertebrates and fish. This scale ranged from 0–100, and included field measurements of the native macrophytes, natural bed detritus, gravel bed and rocks, overhanging vegetation, and the presence and size of woody debris in the waterway. These specific measures are the key criteria for fish habitat, as defined in the *Policy and guidelines for fish habitat conservation and management* (DPI – Fisheries 2013).

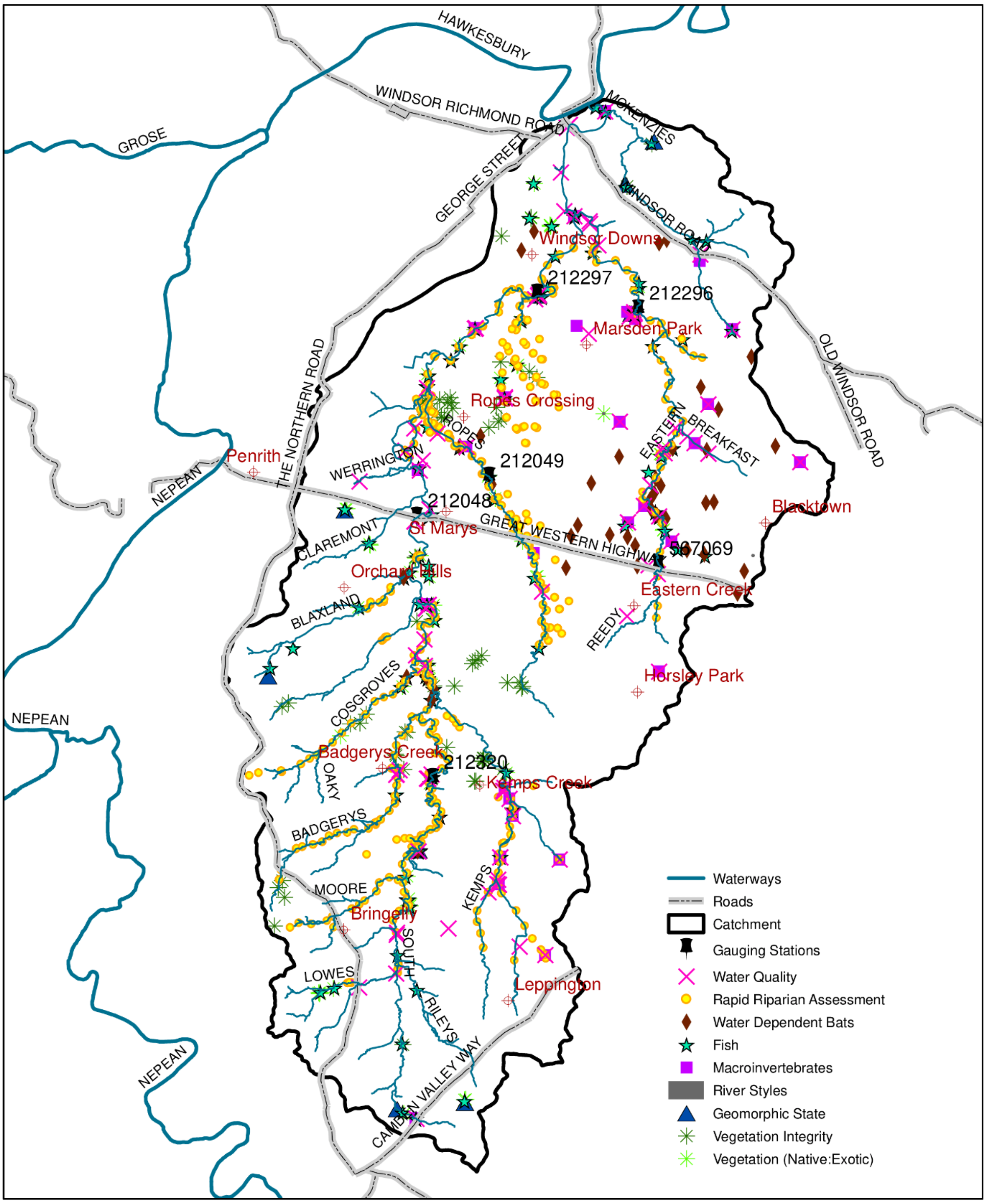

Figure 5 Local field monitoring sites

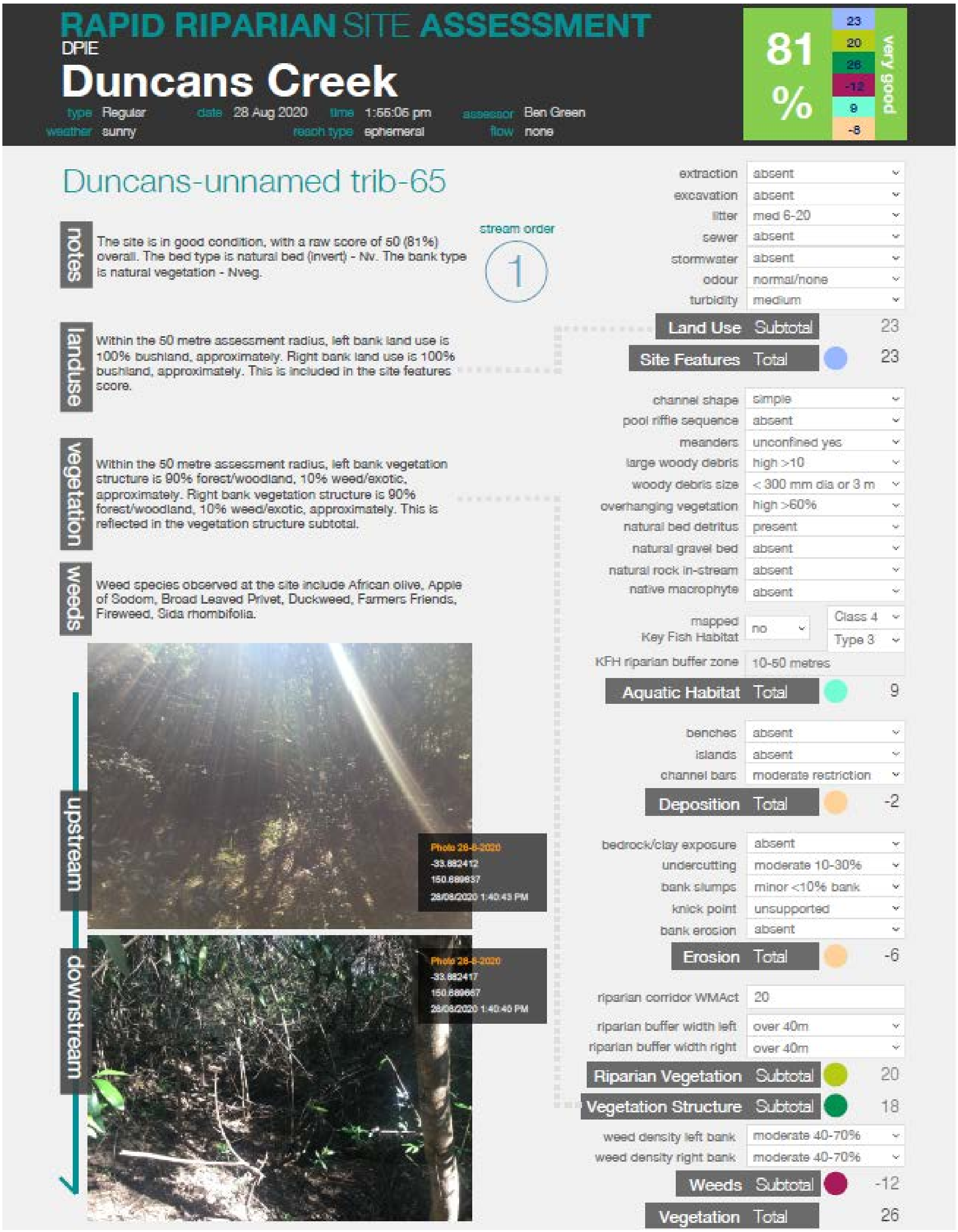

Figure 6 RRA at Duncans Creek in the Agribusiness Precinct of the Western Sydney Aerotropolis

(Image: CTENVIRONMENTAL – ECOSERVER)

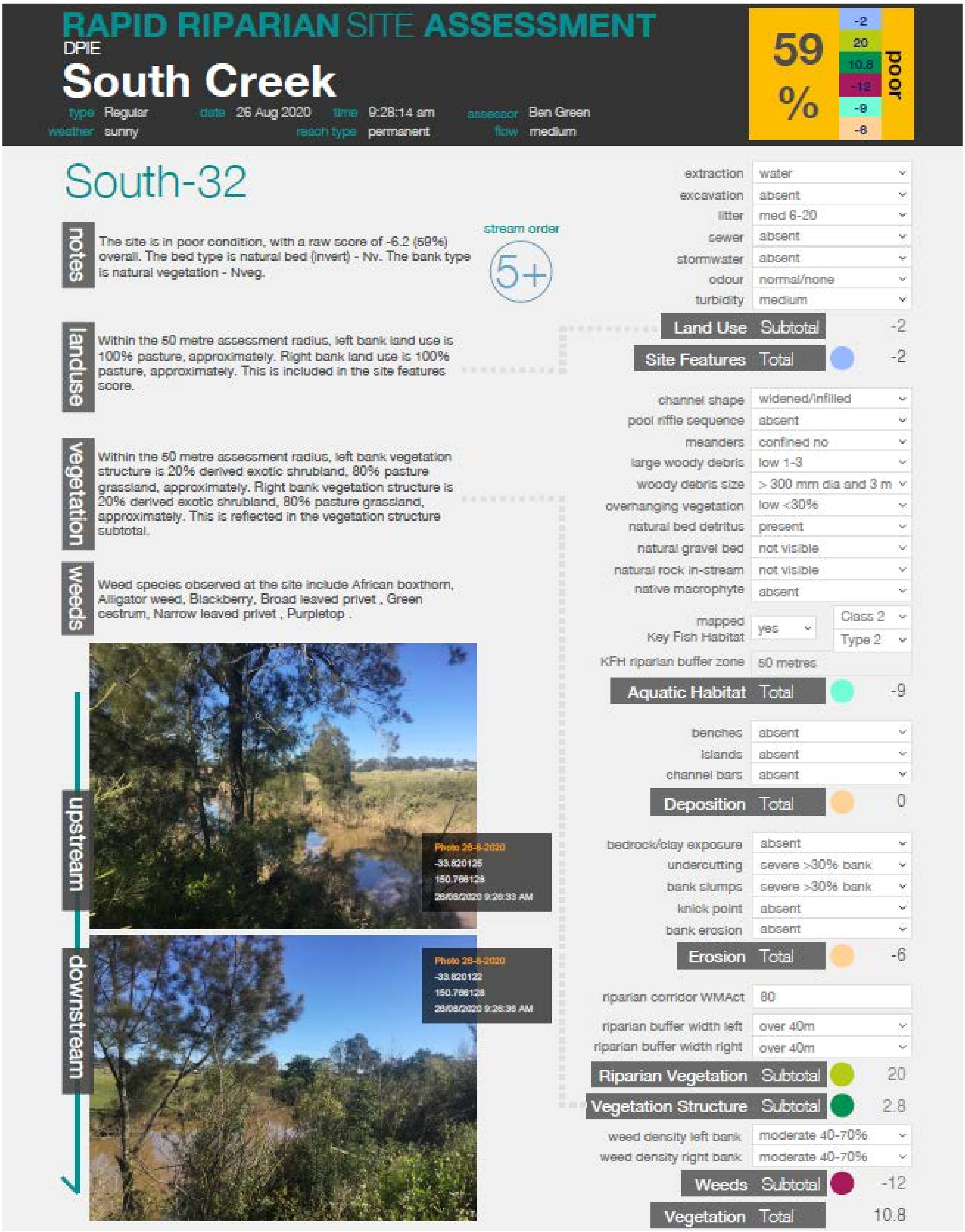

Figure 7 RRA at South Creek in the Wianamatta–South Creek Precinct of the Western Sydney Aerotropolis

(Image: CTENVIRONMENTAL – ECOSERVER)

5.3 Stream flows

Data on stream flows are publicly available from 6 gauging stations in the Wianamatta–South Creek catchment (see the WaterNSW 'Continuous water monitoring network' website). The availability and quality of daily flow records vary, with the longest available record (17 October 1995 to present) from the gauging station located in South Creek at Elizabeth Drive (station 212320), which is inside the Wianamatta–South Creek Precinct (Figure 5). Records of daily flow volumes, instantaneous discharge rates and annual average stream flow volumes were acquired for the period 1 January 2000 to 31 December 2019 from all 6 gauging stations. The records were quality checked using the data quality codes provided with the datasets, and further filtered to ensure there were >350 records of daily flows available for each year. Good data records were available from all but one (567069) gauging station.

The stream flow data were used to assess the hydrological changes resulting from land-use pressures in the upstream drainage area/sub-catchment, and cross-check modelled stream flow data that we acquired from Sydney Water. The data were modelled using the eWater Source model, which Sydney Water developed and calibrated to inform water balances as part of their Water Servicing Masterplan for the Western Parkland City (Sydney Water 2021a). The set-up and calibration of Sydney Water's model were independently reviewed by subject matter experts. A comparison between the modelled and measured daily stream flow data indicated an overall good model fit (see Moriasi et al. 2007), with an average Nash–Sutcliffe efficiency of 0.68 ± 0.3 and bias of 5.29 ± 1.88% (Sydney Water 2021b).

Sydney Water discretised the Wianamatta–South Creek catchment into 195 drainage areas of variable size for their variable purposes and produced modelled stream flows for the period between 1 October 1993 and 30 June 2020. In this present study, we used the modelled records of daily stream flow for the period 1 January 2000 to 31 December 2019, and aggregated the 195 drainage areas into 47 to correspond with an upland drainage area of ≥3rd order streams (Appendix B).

5.3.1 Literature review of flow related objectives for streams in urban catchments

Several flow related objectives were derived using the modelled daily stream flow data from each of the 47 drainage areas (Table 2). The specific set of flow related objectives was determined from a review of contemporary literature that focused on identifying the components of the hydrograph that affect the ecological and geomorphic health of waterways in urban catchments (Appendix C), and maintain the (typically natural) flow requirements of associated ecosystems (Sánchez-Montoya et al. 2017).

The resulting flow related objectives reflect the most common type identified in the literature (Appendix C), and directly align with well-established flow objectives for water sharing plans and coastal harvestable rights in NSW (DPIE – Water 2020a, b). The flow objectives identified in the recent industry recognised 'Urban Streamflow Impact Assessment' (USIA; Vietz et al. 2018; Kermode et al. 2021) are conceptually similar; however, there are some key differences in the calculation of the numerical criteria. For example, the USIA method for calculating freshes is based on 3 times the median flow volume, whereas our method for calculating freshes follows the standard method reported in the literature based on the ≥75th and ≤90th percentiles of daily flow volumes (see DPIE – Water 2020a).

The suite of flow objectives in the USIA method also includes erosion thresholds, based on the mobilisation of the stream bed and bank material. These are inherently captured in our high spell flow objective (Table 2), and have been explicitly quantified by the 95th percentile daily flow volume in our companion study (DPE 2022a). We selected percentiles as the basis for numerical criteria as they are relatively easily measured and modelled.

Table 2 Flow related objectives that affect the ecological and geomorphic health of waterways in urban catchments, and maintain the flow requirements of associated ecosystems

Flow related objective	Function
Daily flows	• Specifies amount of natural, climatic and anthropogenic flow in the system • Indicative of mean habitat flows for aquatic species, support for riparian vegetation, downstream geomorphic processes and biological responses • Urbanisation typically causes higher variation to daily flow
Baseflow	• Specifies the amount of natural flow, due to bedrock, soil and riparian zones in the system • Moderates water temperature, water quality, nutrient and carbon processing • Provides habitat for aquatic species and support for riparian vegetation • Urbanisation typically causes base flow to decrease (volume), however in some instances it increases
High spell extent (Q90) and frequency	• Specifies periods of high flow for the system • Provides habitat connectivity, complexity and ecological triggers • Redistributes sediment and forms channels • Contributes to a 'dynamic flow regime' that sustains freshwater biodiversity of high conservation value • Urbanisation typically causes high spells to increase (volume and frequency) and can cause erosion
Low spell extent (Q10) and frequency	• Specifies periods of low flow for the system • Provides habitat and refuge during low/dry periods, especially for young/developing species • Indicates periods when connectivity, migration, habitat requirements for species or water quality may not be being met • Sustains wet riverbed and lower banks, helping to maintain riparian vegetation • Contributes to a 'dynamic flow regime' that sustains freshwater biodiversity of high conservation value • Urbanisation typically causes low spells to decrease (volume and frequency)
Freshes extent (Q75) and frequency	• Specifies flows producing substantial rise in river height due to short bursts of rain • Maintains water quality by refilling pools and providing inputs of fresh water • Provides habitat connectivity, complexity and ecological triggers • Redistributes food by drifting macroinvertebrates and organic matter around the stream • Replenishes soil moisture for riparian vegetation • Cleans the bed habitat by dislodging excessive algal growth and sediment • Urbanisation typically causes freshes to increase (volume and frequency)
Cease to flow	• Specifies periods when there is no detectable flow of water • Indicates periods when connectivity, migration, habitat requirements for species or water quality may not be being met • Demonstrates times for essential refuge for species during low/dry periods • Urbanisation typically causes cease to flow spells to decrease (volume and frequency)

5.4 Pressure–stressor–ecosystem receptor relationships

Rather than a referential approach to determining flow related objectives, we undertook an effects-based assessment by quantifying the relationships between the pressure–stressor–ecosystem receptor indicators. This is because the ecology and hydrology of the Wianamatta–South Creek catchment have been altered through historical vegetation clearing and urbanisation (H–N CMA 2007).

The relationships between the pressure–stressor–ecosystem receptor indicators were quantified through empirical statistical analyses of processes captured in the model shown in Figure 4, and further illustrated in Figure 8 and Figure 9 to help visualise the changes to the waterway and riparian corridor. The model starts with an undisturbed or predeveloped state, where the hydrology has not been altered, the floodplain and riparian corridors are characterised by native vegetation, there is no erosion of the stream bed or banks and the habitats in the stream are described as ‘complex’ due to the presence of woody debris, fine sediment and native leaf litter and detritus. In the Wianamatta–South Creek catchment, the riparian and instream habitats are home to several threatened and iconic species, including frogs, water dragons and water dependent birds and bats (DPE 2022a).

Under current approaches to greenfield development, the native vegetation in the floodplain and riparian corridors is predominantly cleared and controls for managing stormwater flows are minimal. The net result is erosion of the stream bed and banks, increased turbidity and TSS, loss of instream habitats and associated flora and fauna, and the onset of ecosystem degradation. These negative processes become fully established once the urban development is complete. Over time, the streams become increasingly incised and widen, until significant financial investment is required to stabilise the streams to a new altered state.

The review by Schueler et al. (2009) shows that the trajectory of change (if not mitigated) described above is non-linear, with clear thresholds or tipping points aligned with the percentage of total imperviousness within a catchment:

- <10% total imperviousness – streams are classed as sensitive and are generally able to retain their hydrologic function and support good to excellent aquatic diversity
- 10–25% total imperviousness – streams are classed as being impacted and show clear signs of declining stream health
- 25–60% total imperviousness – streams are classed as non-supporting as they no longer support their designated uses in terms of hydrology, channel stability, habitat, water quality, or biological diversity
- >60% total imperviousness – streams are extensively modified and primarily function as a conduit for flood waters. These streams are classed as urban drainage and consistently have poor water quality, highly unstable channels, and very poor habitat and biodiversity.

5.4.1 Pressure–stressor

To quantify the pressure–stressor relationship, we initially categorised each of the 47 drainage areas into one of 3 groups on the basis of the flow related objectives listed in Table 2. The number of groups was determined through hierarchical clustering in R statistical software (version 4.1.1). We selected the Gower distance to calculate a dissimilarity matrix, which determines how different, or distant, the drainage areas are from each other. Drainage areas sharing similar flow related objectives are clustered together while those that are dissimilar are added to a different cluster/group. We used both divisive and agglomerative clustering methods and assessed the clusters using a silhouette plot to display how close each drainage area in one group is to drainage areas in neighbouring groups (Appendix D).

Once the groupings were defined, an average and standard error value for each flow related objective was calculated for each group. The averages were then compared with the mean extent (%) of land-use pressures determined for the group. We initially used non-parametric locally weighted smoothing (LOESS) to identify the relationship between the indicators, and then assessed the differences in means of percentage land-use pressures between groups via a one-way analysis of variance (ANOVA) with unequal sample sizes and post hoc Tukey's HSD test.

Pressures were represented by a range of landscape features that capture either anthropogenic changes or inherent landscape hazards. These include features like the extent of total impervious area and dominant land uses, or salinity and water erosion hazards, respectively (Figure 10, Appendix E).

5.4.2 Stressor–ecosystem receptor

The stressor–ecosystem receptor relationship was quantified in a similar manner to the pressure–stressor relationship. The average of each flow related objective for each group was compared to the average condition or health of the blue grid elements for the group. LOESS was used to identify the relationship between the indicators, and the differences among the mean condition of the blue grid elements of each group was assessed via a one-way ANOVA with unequal sample sizes and post hoc Tukey's HSD test.

For these analyses, the blue grid elements were limited to a range of condition indictors for the riparian and other water dependent vegetation communities, and condition indicators for the stream itself. Measures for the water dependent faunal species such as bats and fish were not included due to the limited sample size. It was assumed, however, that the vegetation and stream indicators were appropriate surrogates as they are the key habitats of the faunal species. If the habitats are lost or degrade, it is expected that associated fauna will also be lost.

It is important to note that the current condition of all blue grid elements is generally poor, with only limited areas of the Wianamatta–South Creek catchment remaining intact (HN–CMA 2007; BCC 2021; LCC 2021; DPE 2022b). Many of the condition measures of the first order stressor and/or ecosystem response indicators (e.g. ambient water quality or macroinvertebrate sensitivity scores) exceed current environmental standards for stream assessments.

Stage 1 – Undisturbed State

- Natural hydrology
- Native vegetation riparian and floodplain community
- Minimal or no erosion and deposition
- Large woody debris provides in-stream habitat
- Sediment, native leaf litter and detritus provide in-stream habitat
- Channel shading regulates in-stream temperature, and macrophytes and algal growth

Stage 2 – Greenfield Development

- Onset of altered hydrology
- Native riparian and floodplain vegetation cleared
- Erosion and deposition
- Increased instream turbidity and sediment
- Clay and fine sediment smother in-stream habitat
- Loss of species dependent on benthic habitat
- Onset of ecosystem degradation

Stage 3 – Development Complete

- Onset of altered hydrology
- Native riparian and floodplain vegetation cleared
- Weed invasion of edge habitat
- Erosion and deposition
- Increased instream turbidity and sediment
- Clay and fine sediment smother in-stream habitat
- Loss of species dependent on benthic habitat
- Onset of ecosystem degradation

Stage 4 – Incision

- Altered hydrology, including decreased baseflow, increased volume and frequency of flows, increased bankfull and floodplain engagement
- Accelerated erosion and channel incision
- Frequent fine sediment, native leaf litter and detritus mobilisation
- Invasive plant species begin to colonise bars, banks and floodplain
- Ecosystem degradation

Figure 8 Conceptual model of impacts of unmitigated urban development on waterways and riparian corridors – Stages 1 to 4

(Images: Carl Tippler and Duncan Reed Architects)

Stage 5 – Widening

- Altered hydrology, including increased volume and frequency of flow
- Accelerated erosion triggers channel incision and widening
- Loss of fine sediment, native leaf litter and detritus
- Large woody debris transport downstream
- Channel widening causes loss of native vegetation
- Colonisation of invasive plant species (weeds)
- Increased floodplain engagement promotes spread of weeds

Stage 6 – Baseflow Channel Re-establishment

- Further channel deepening
- Loss of temperature and sunlight penetration promotes nuisance macrophyte and algae
- Exotic shrubs and grasses replace natives
- Invasive plants colonise floodplain
- Further degradation and loss of in-stream and riparian habitats
- Simplification of habitat and biodiversity loss

Stage 7 – Further Channel Widening

- Channel widening continues
- Large woody debris, fine sediment, native leaf litter and detritus removed from stream
- Exotic shrubs and grasses replace natives
- Loss of amenity
- Degraded ecosystem

Stage 8 – Management via armouring

- Extensive armouring of stream and bank
- No inclusion of WSUD
- Ongoing weed control required

Stage 8 – Management via integration of WSUD in drainage area (not shown)

- WSUD in drainage areas to manage stormwater flows
- Minimum armouring and weed control required

Figure 9 Conceptual model of impacts of unmitigated urban development on waterways and riparian corridors – Stages 5 to 8

(Images: Carl Tippler and Duncan Reed Architects)

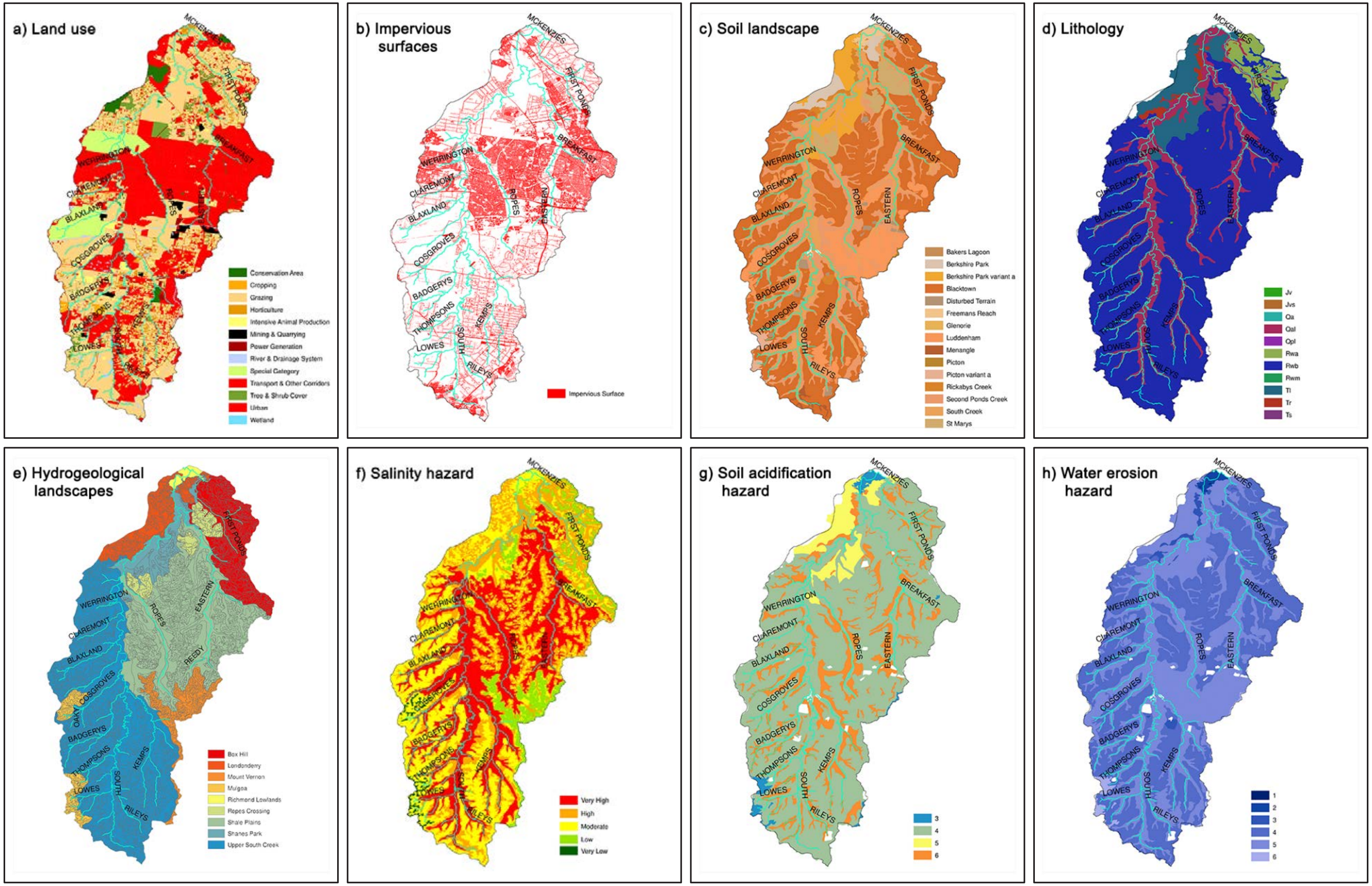

Figure 10 Pressures (a, b) and inherent landscape features (c–h) of the Wianamatta–South Creek catchment
(see Appendix E for further details on the data)

6. Key findings

6.1 Referential sites for deriving water quality objectives

Waterways in the Wianamatta–South Creek catchment have been described as the most degraded in the Hawkesbury–Nepean River system (H–N CMA 2007). Despite this, we identified a handful of sites that are in relatively better condition using the criteria specified for the referential approach in the Australian Water Quality Guidelines (Commonwealth of Australia 2018). Of the 108 water quality monitoring sites (Figure 11a), only 63 met the sampling frequency criterion, which was based on sites having ≥24 data points (Figure 11b). This number of data points enables robust estimates of percentiles and was considered a good surrogate for monthly sampling over 2 years. Of the 63 sites, an additional 16 were eliminated as they were located downstream of the discharge points of sewage treatment plants (STPs; Figure 11b). All but 4 (Figure 11d) of the remaining water quality monitoring sites were subsequently eliminated as they did not meet the criteria for minimal disturbance (Figure 11c). These criteria were assessed through the percentage of natural bushland within the drainage area, and the overall condition of riparian vegetation determined via the RRA. Specifically, water quality monitoring sites were eliminated if they were located in drainage areas with <20% natural bushland and where the score for overall vegetation condition at the site was <0.

Of the 4 remaining water quality monitoring sites, 2 are located just upstream of the Wianamatta Regional Park on South Creek (site names NS23, NS26), one located in Kemps Creek adjacent to Cecil Park (site name KC10) and the last located in an unnamed tributary of Little Creek running through Shanes Park. The last site is the ‘referential’ site that Blacktown City, Penrith City and Liverpool City councils are currently using for their state of the environment reporting. We compared the water quality data at this referential site to the water quality at the 3 remaining sites (Table 3), and found that the water quality at Kemps Creek and one site at South Creek (NS23) significantly exceeded the site specific guideline values/numerical criteria of the councils’ referential site. For example, the 80th percentiles of TN and TP at the South Creek site identified as NS23 were 2 and 5 times greater than at the councils’ referential site. At the Kemps Creek site, the 80th percentiles of TN and TP concentrations were 3.5 and 10.5 times greater than at the councils’ referential site. This large difference is most likely due to the time series of water quality data available for the Kemps Creek site, which was limited to monitoring over long periods of drought, with very little or no stream flow.

The water quality of the one site at South Creek that was retained (NS26) was within the ranges of the site specific guideline values/numerical criteria at the councils’ referential site. The difference between the 80th percentiles of TN and TP concentration at the sites was only 1.4%, but the ratios of dissolved inorganic forms of nitrogen and phosphorus were different, with higher concentrations at the South Creek site (Table 3). Generally, the 80th percentiles of the water quality measures at the South Creek site were greater (albeit within the range) than at the councils’ referential site (Table 3). It is worth noting however that the councils’ referential site is located on a 2nd order stream in a part of the Wianamatta–South Creek catchment that has inherently different soil and lithology characteristics compared to the broader catchment, especially the Western Sydney Aerotropolis area (Figure 10, Appendix E). These inherent differences would affect the ambient/instream concentrations of TSS, conductivity and pH. For example, the site at South Creek sits within the Upper South Creek Hydrogeological Landscape (HGL) which has a higher and more severe salinity hazard and impact rating than the Shanes Park HGL where the councils’ referential site is located. Accordingly, the 80th percentile of the ambient/instream conductivity concentration at the South Creek site (1,103 µS/cm, Table 3) is almost double the councils’ referential site (575 µS/cm).

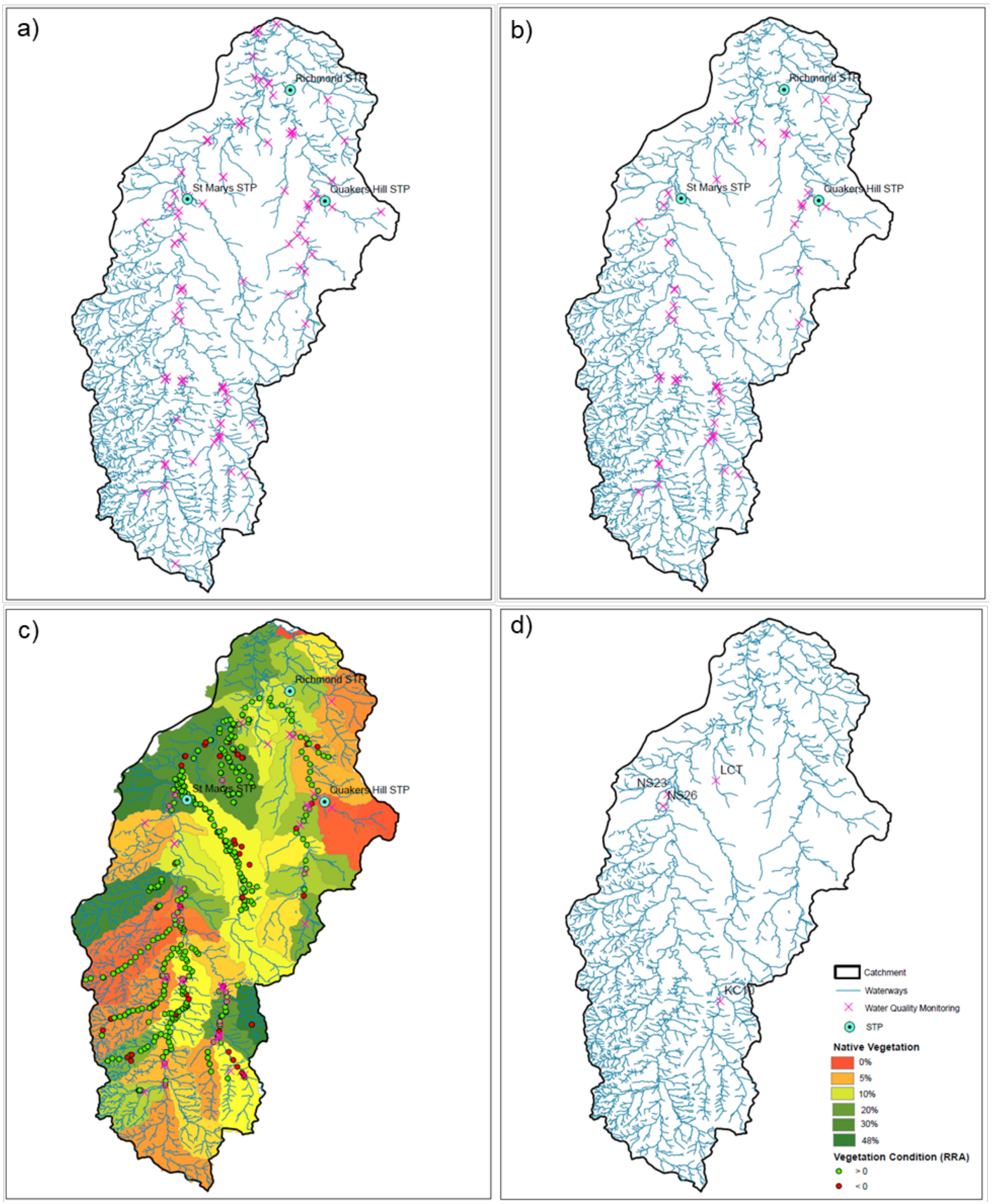

Figure 11 Identification of potential referential sites for setting instream WQOs

From a total of 108 monitoring sites (a), only 4 sites (d) remained after assessing the number of data points available for each site (b), whether the sites were upstream of STPs (b), and whether the sites were in a disturbed drainage area (c).

Table 3 The 80th percentiles of water quality measures at 4 sites in the least disturbed areas of the Wianamatta–South Creek catchment, and default ('ANZECC') guidelines for lowland rivers in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality

	South Creek (NS26)	South Creek (NS23)	Kemps Creek (KC10)	Unnamed tributary of Little Creek	ANZECC
					
TN (mg/L)	1.72	9.04	6.08	1.80	0.5
DIN (mg/L)	0.74	7.57	3.92	0.05	–
NH_3-N(mg/L)	0.08	0.11	0.14	0.04	0.02
NOx (mg/L)	0.66	7.46	3.78	0.01	0.04
TP (mg/L)	0.14	0.29	1.43	0.19	0.05
DIP (mg/L)	0.04	0.25	–	0.01	–
Turbidity (NTU)	50	35	20	9	50
TSS (mg/L)	37	20	–	20	–
Conductivity (µS/cm)	1,103	897	2,472	564	2,200
pH	7.16–7.60*	7.19–7.69	7.31–7.64	6.20–7.00	6.5–8
DO (%SAT)	43–75	64–90	23–42	9–49	85–110
DO (mg/L)	8	9	–	–	–

* performance criteria for pH widened to 6.20–7.60 to include the lower pH value for the unnamed tributary of Little Creek

It is also worth noting that the 80th percentiles for the water quality measures at both the councils' referential site and the South Creek site are different to the default guideline values provided in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC & ARMCANZ 2000). Specifically, the 80th percentiles of the nutrient concentrations at both sites are predominantly greater than the default guideline values. The 80th percentile of turbidity at the councils' referential site was lower than the default, but at the South Creek site, the 80th percentile for turbidity is the same as the default. The range in pH values for the councils' referential site and the South Creek site was within the range of the default guideline value, whereas the range in DO values was lower than the minimum DO default guideline value.

Rather than selecting the 80th percentiles for the water quality measures at the councils' referential site as the performance criteria, we recommended the 80th percentiles for the water quality measures at the South Creek site. Our only exception was to extend the range of the pH values, to encompass the lower pH range (6.20) at the councils' referential site.

Our overall recommendation to use the South Creek site was based on a compromise between the water quality at the councils' referential site (i.e. within the range), the need for representativeness, and practical achievability. Our assessment of achievably was based on the reported performance of stormwater quality improvement devices in the literature (eWater 2014; Stormwater Australia 2018; Wright et al. submitted). The concentrations of the dissolved fractions of the nutrients would not be met through conventional treatment, such as via wetlands, ponds, swales and bioretention systems. We also consulted with state and local governments, and leading stormwater industry practitioners on the WQOs prior to their release in the draft Aerotropolis Precinct Plan (Appendix F). Many raised issues with the ability to achieve the objectives, especially given that the Wianamatta–South Creek catchment will never be in a pre-European or undisturbed state.

6.2 Characterising stream flows

Figure 12 compares the daily stream flows at the 5 gauging stations that had good quality data for use in analyses. There is a distinct gradient in daily stream flows from the lowest flows at the gauging station located at Elizabeth Drive within the Wianamatta–South Creek Precinct (212320), to the highest flows at the gauging station at Ropes Creek (212049). At these 2 extremes, the dominant land uses of the drainage areas are agricultural and urban, respectively. The gauging station located in South Creek at Great Western Highway (212048) drains an upland area of mixed land uses, as does the gauging station located further downstream near Richmond Rd (212297). However, it's important to note that this latter gauging station is also affected by sewage discharges from the St Marys STP. The gauging station located in Eastern Creek, near Garfield Rd (212296), drains an upland area of predominantly urban land and is also affected by sewage discharges from the Quakers Hill STP.

Not all spatial differences in daily stream flow across the Wianamatta–South Creek catchment can be attributed to land-use impacts. As shown in Table 4, the flow characteristics determined from the gauging station at Elizabeth Drive (212320) are relatively drier, and those at the gauging stations in the north-east corner of the catchment (212296, 212297) are relatively wetter. These spatial differences align with the gradients/distribution of annual average rainfall within the catchment (see Singh et al. 2009).

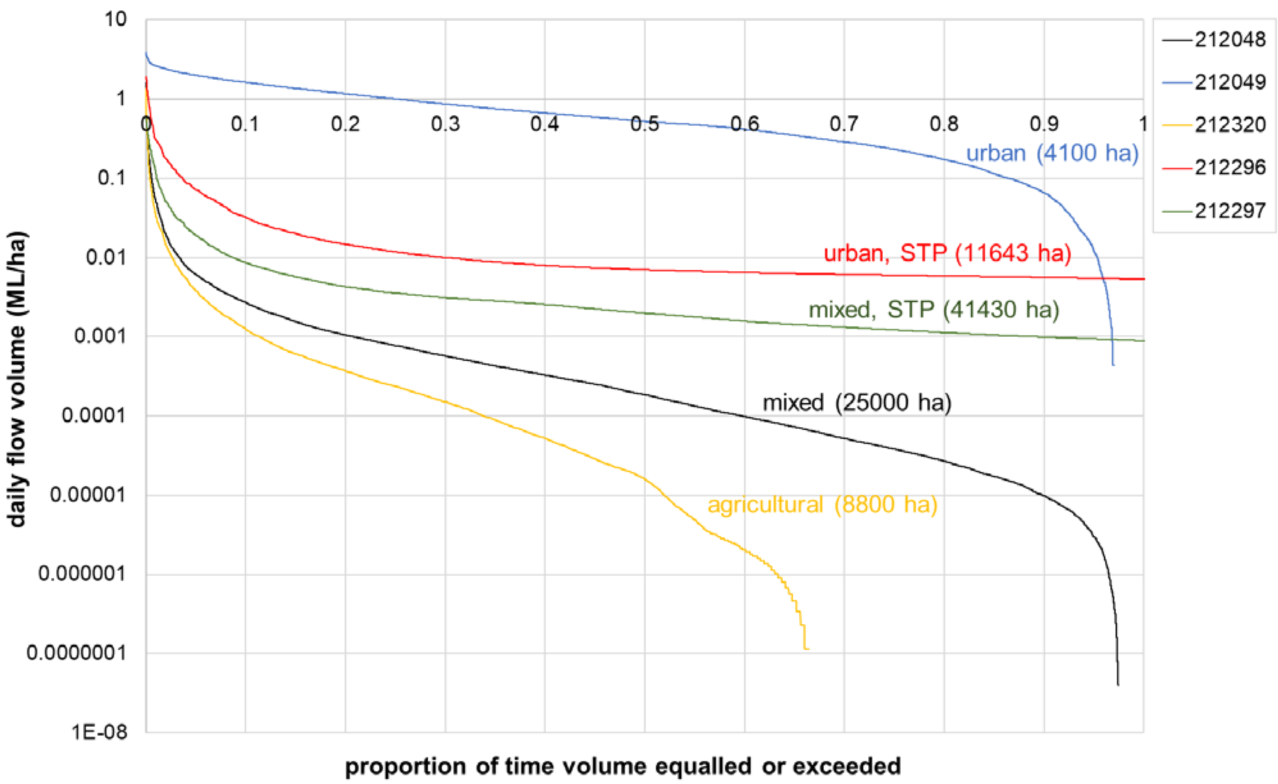

Figure 12 Flow-duration analyses of daily flow volumes of streams that drain agricultural, urban and mixed use areas in the Wianamatta–South Creek catchment, including those with STPs

The total catchment area (ha) is shown in brackets.

Table 4 Flow characteristics determined at gauging stations in the Wianamatta–South Creek catchment for the period 2000–2019

	212048	202049	212320	212296	212297
Median daily flow volume (L/ha/day)	256.2 ± 43	684.8 ± 105.7	68.8 ± 23.5	5,179.6 ± 441.1	1,012.9 ± 156.4
Mean daily flow volume (L/ha/day)	2,530.1 ± 546.8	6,205.5 ± 1,067.5	1,493.5 ± 419.9	13,184.2 ± 2,069.3	4,249.9 ± 736.9
High spell (L/ha/day) ≥90th percentile daily flow volume	2,850.4 ± 466.2	11,160.7 ± 3,075.3	1,520.9 ± 375.1	14,397.3 ± 1,934.5	5,311.3 ± 867.2
High spell – frequency (number/y)	9.1 ± 0.5	13.3 ± 0.9	6.8 ± 0.6	15 ± 0.7	12.7 ± 0.5
High spell – average duration (days/y)	4.3 ± 0.2	3.1 ± 0.4	6.3 ± 0.6	2.5 ± 0.1	3.1 ± 0.1
Freshes (L/ha/day) ≥75th and ≤90th percentile daily flow volume	897.9 – 2,850.4	3,078.7 – 11,160.7	308 – 1,520.9	6,740 – 14,397.3	1,823.8 – 5,311.3
Freshes – frequency (number/y)	6.4 ± 0.6	8.4 ± 0.7	2.8 ± 0.5	10.8 ± 1.1	7.4 ± 0.9
Freshes – average duration (days/y)	2.2 ± 0.2	1.7 ± 0.20	3.2 ± 0.8	1.8 ± 0.1	1.8 ± 0.2

	212048	202049	212320	212296	212297
Low spell (L/ha/day) ≤10th percentile daily flow volume	17.6 ± 3.6	93.5 ± 19.8	0.8 ± 0.3	3,950.2 ± 343.6	702.7 ± 139.1
Low spell – frequency (number/y)	6.7 ± 0.6	7.7 ± 0.6	3.7 ± 0.4	13.8 ± 1.8	12.2 ± 1.3
Low spell – average duration (days/y)	6.7 ± 0.8	5.3 ± 0.6	54.5 ± 19.6	2.8 ± 0.3	3.4 ± 0.4
Cease to flow (proportion of time/y)	0.01 ± 0.004	0.03 ± 0.01	0.34 ± 0.05	0	0
Cease to flow – duration (days/y)	2.6 ± 0.9	3.9 ± 1.2	39.2 ± 8	0	0
Baseflow index	0.29 ± 0.02	0.30 ± 0.02	0.14 ± 0.02	0.73 ± 0.01	0.63 ± 0.03
Drainage area (ha)	25,000	4,100	8,800	11,643	41,430

Figure 13 shows the spatial variation of the modelled flow related objectives (see Table 2) across the 47 drainage areas in the Wianamatta–South Creek catchment (see Section 5.3 and Appendix B). The last plot in the figure (Figure 13f) shows the subsequent categorisation of the drainage areas into 3 groups.

The first of the groups has been shaded in light blue to denote that these drainage areas have the lowest daily flows, high spells and freshes but greater baseflow and low spell volumes than the drainage areas shaded in the darker blues. The drainage areas in this first group are predominantly located in the southern upstream part of the Wianamatta–South Creek catchment and include the Western Sydney Aerotropolis precincts. This first group is distinct because they have long periods of no flows (i.e. cease to flow 34% of the time).

The drainage areas shaded in the darkest blue (identified in this study as group 3) are those located in the north-east corner of the Wianamatta–South Creek catchment, and have the highest daily flows, high spells and freshes. While these drainage areas have lowest baseflows and low spells, the streams are flowing for most of the year, with only 3% of the time recorded as cease to flow.

Most drainage basins have been categorised into a large group (group 2) in which the ranges of the flow related objectives sit between the other 2 groups. For example, the mean daily flow volume (5,542.2 ± 320.9 L/ha/day) is around double the first group (1,748 ± 106), and half the volumes of those in drainage areas located in the north-east corner (9,432.7 ± 868.9). The differences are not always linear, however, with the high spell volumes (10,091.7 ± 769.7 L/ha/day) and freshes (2,642.9–10,091.7 L/ha/day) in this large group being 5 and 8 times greater than those of the first group, respectively. Appendix B provides a summary table of the modelled flow dataset used to define the groupings.

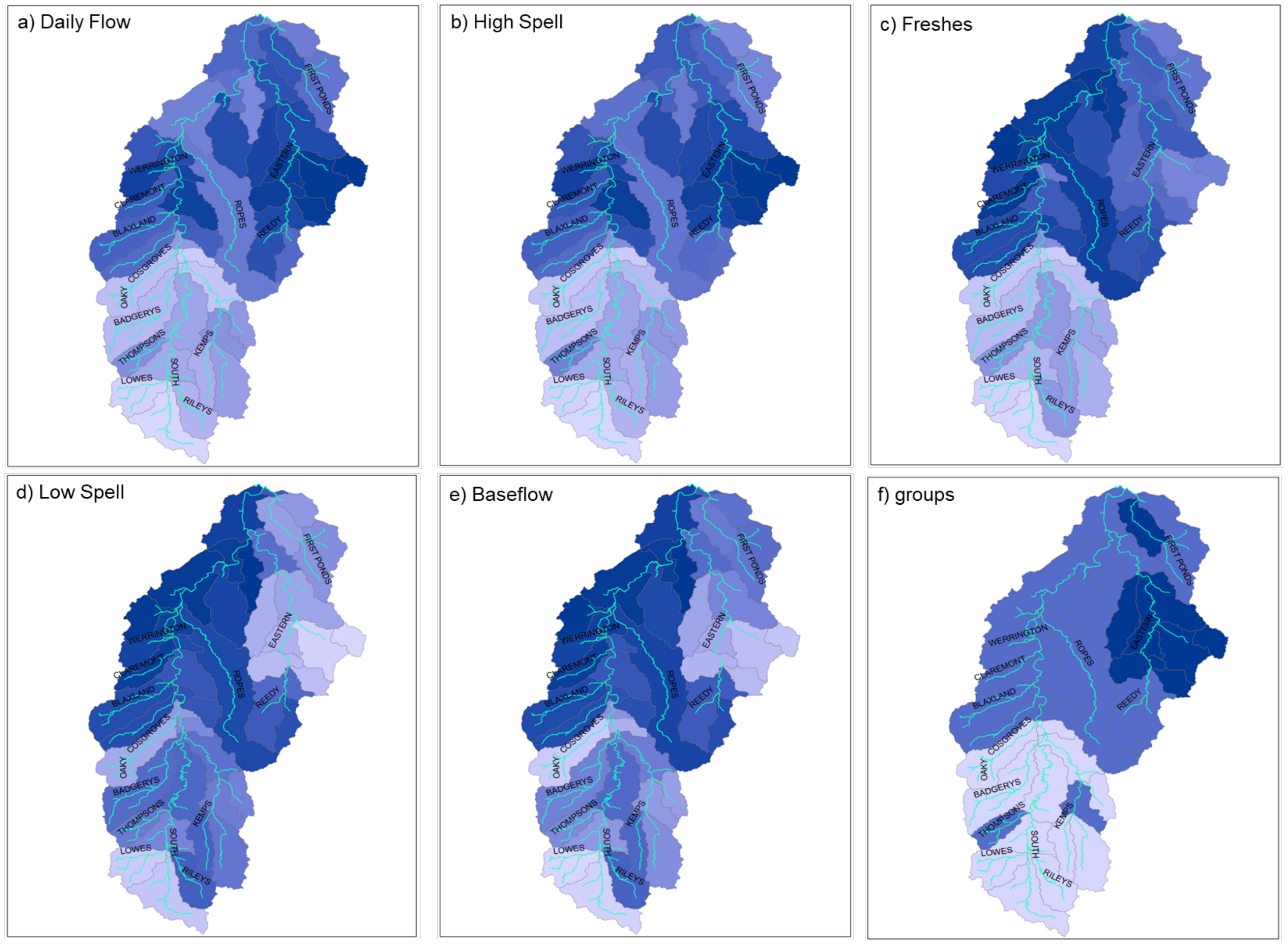

Figure 13 Spatial variation of flow related objectives across 47 drainage areas in the Wianamatta–South Creek catchment, and subsequent categorisation of the drainage areas into 3 groups

Dark blue denotes high flow and light blue denotes low flow.

As inferred above, the extent and type of land-use change (disturbance) in the drainage areas can influence the spatial variation in stream flows across the Wianamatta–South Creek catchment. The group (group 3) with the highest daily flows, high spells and freshes is predominantly made up of drainage areas that are urbanised, with an average total impervious area of 28% (Figure 14). The (first) group with the lowest mean daily flows, high spells and freshes is predominantly made up of drainage areas that are agricultural, and the large group (group 2) of drainage basins has mixed land uses with a marginally greater area of remnant native vegetation. As shown in Appendix E, there is a clear relationship between the pressures (land use, % total impervious area) and flows. The differences in the percentage of urban land and imperviousness between all groups are significant ($p<0.01$). The differences in the percentage of agricultural land between the first group and third group are significant ($p<0.01$), but not significant between the first and second group.

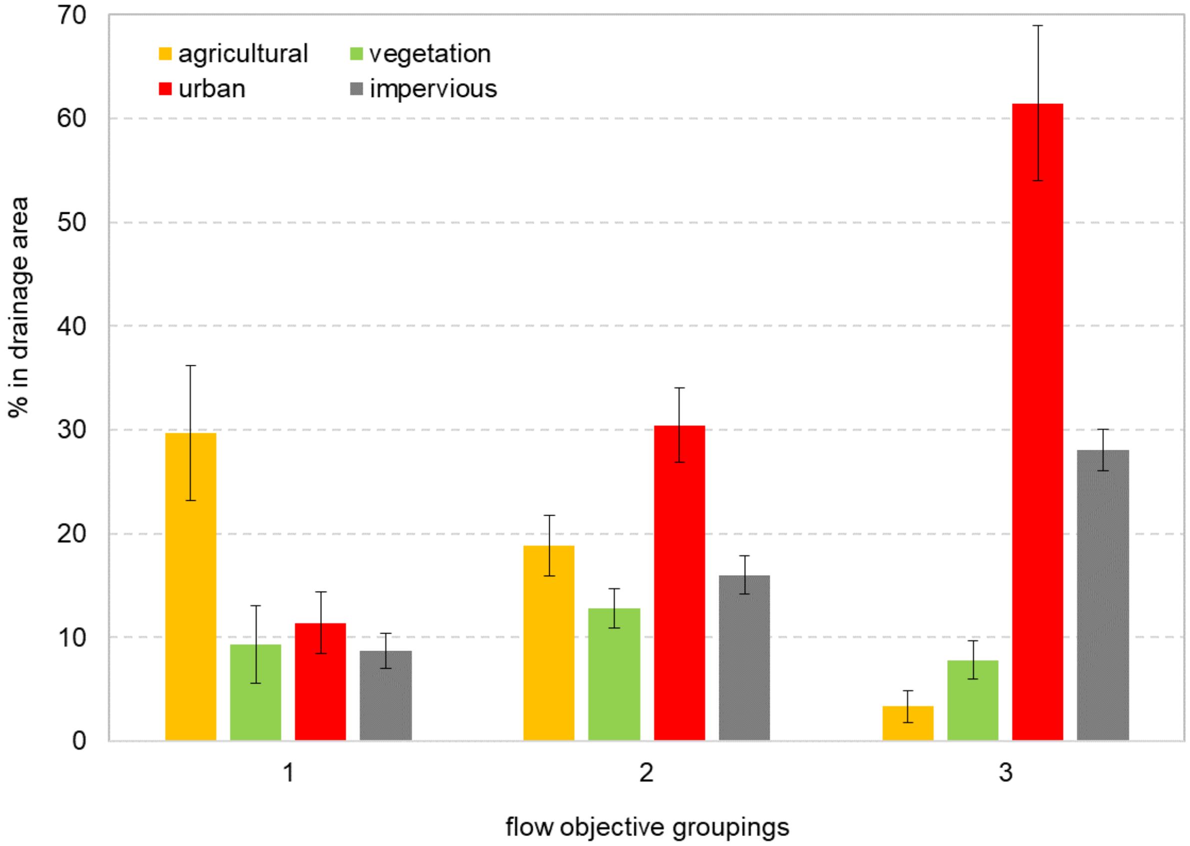

Figure 14 Effects of land-use type and extent on stream flows in the Wianamatta–South Creek catchment

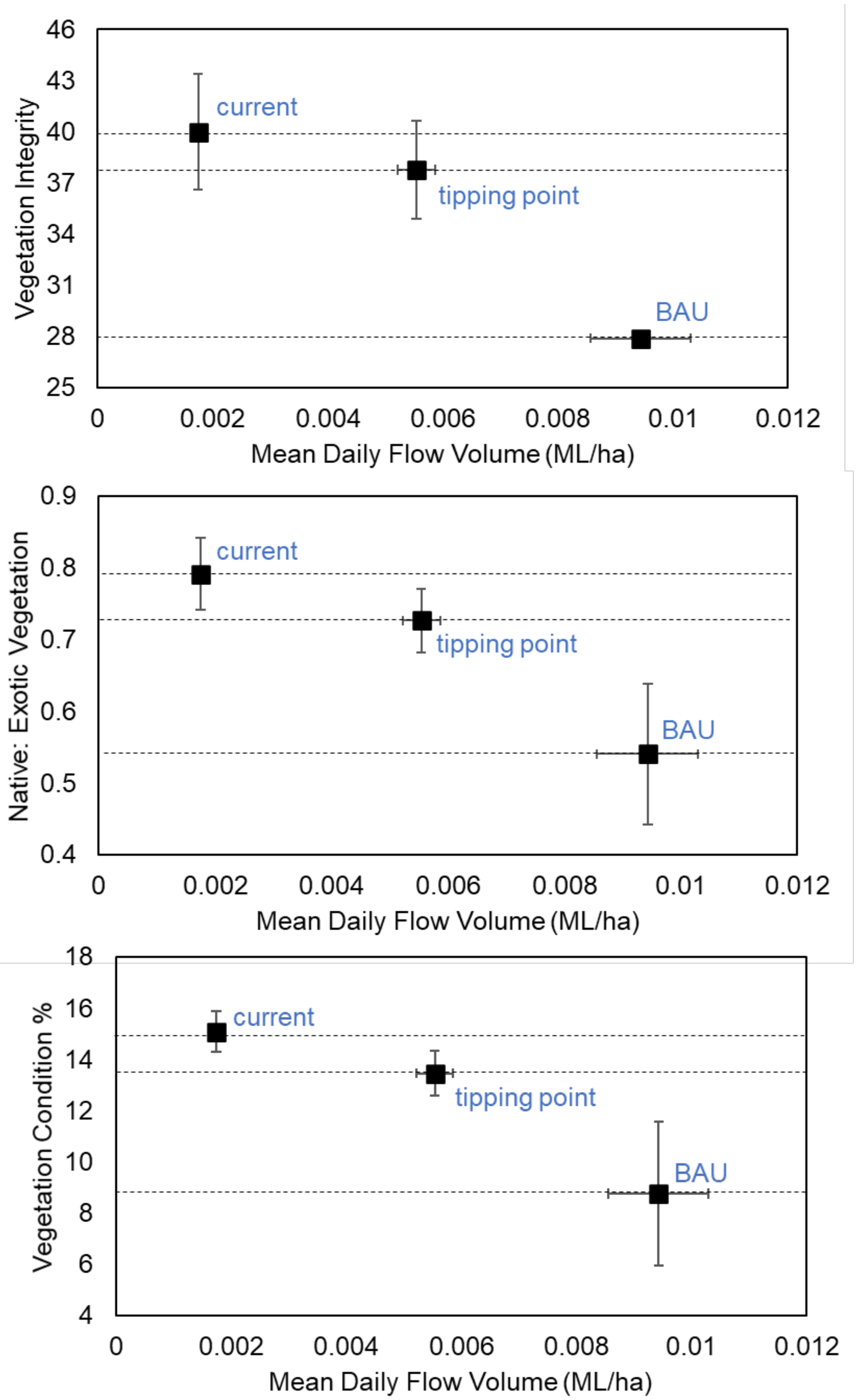

Figure 15 Relationships between instream daily flow volumes and condition of riparian vegetation

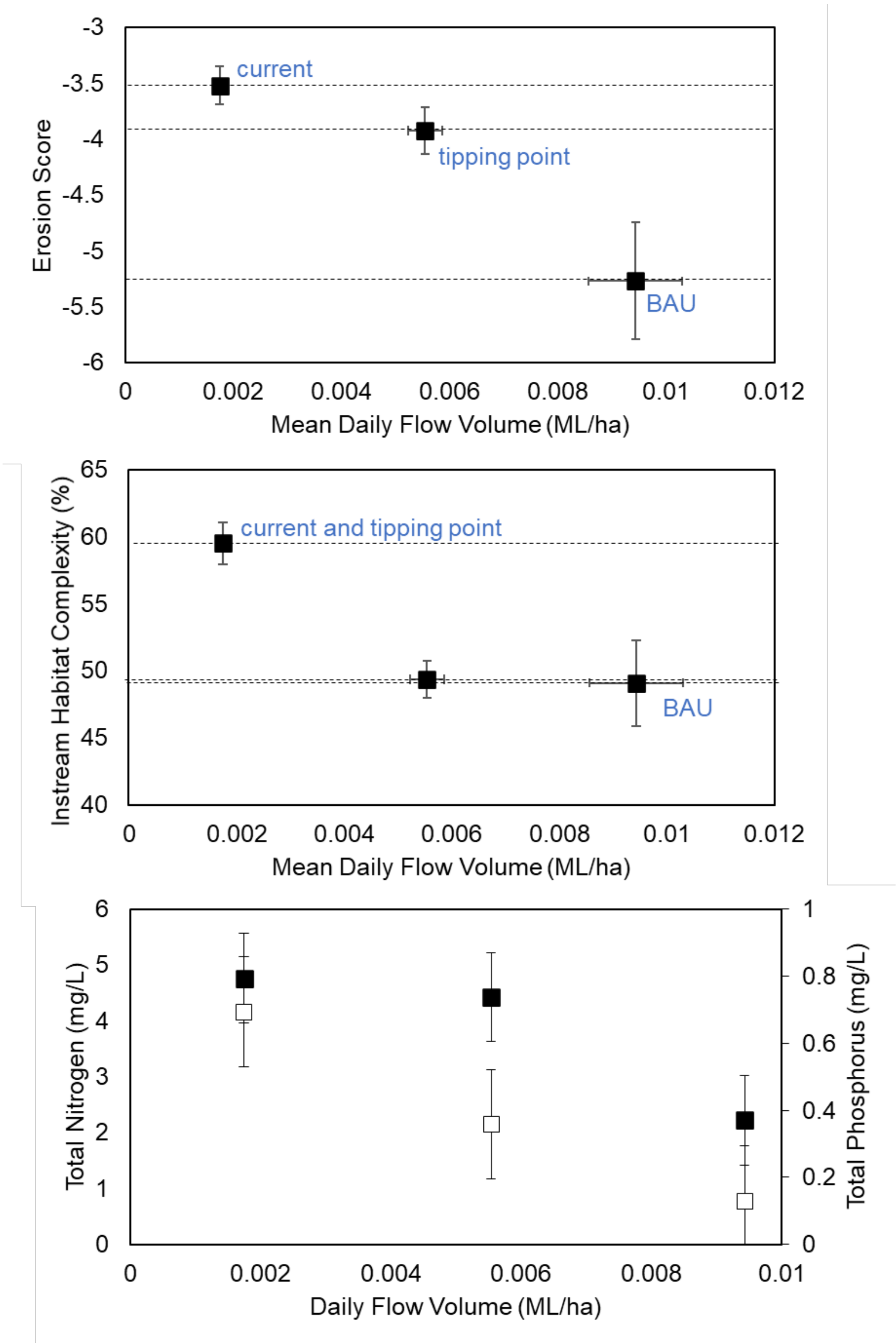

Figure 16 Relationships between instream daily flow volumes and condition of the stream bank and instream habitats

6.3 Impacts on blue grid elements

The spatial variation in flow objectives is reflected in the condition or health of the riparian and instream habitats (i.e. ecosystem receptors). The plots in Figure 15 and Figure 16 show the empirical relationships between the mean daily stream flow volume and various condition indicators for riparian vegetation, stream bed and bank erosion, and instream habitats of fish and macroinvertebrates. The mean daily flow volumes were used as a surrogate for all flow related objectives listed in Table 2, as daily flows are typically indicative of both the amount of natural, climatic and anthropogenic flow in the system, and mean flows required to support aquatic species, riparian vegetation, downstream geomorphic processes and biological responses (Table 9, Appendix C).

As described above, the lowest daily flow volumes correspond with the first grouping of drainage areas that are predominantly agricultural and located in the southern part of the Wianamatta–South Creek catchment. These have been labelled as 'current' daily flow volumes in Figure 15 and Figure 16 as these represent the current or pre-development flows in the Western Sydney Aerotropolis. The condition of all ecosystem receptors is better under current daily flows, but progressively worsens as the flows increase. The highest flows are the drainage areas that are predominantly urbanised and located in the north-east part of the catchment. These have been labelled as 'BAU' daily flow volumes in Figure 15 and Figure 16 on the assumption that these flows are an outcome of the business-as-usual approach to land-use planning and stormwater management in urban catchments. The daily flows in these drainage areas are up to 4–5 times greater than the current flows, consistent with independently modelled estimates in our companion studies (DPE 2022a, c).

As shown in Figure 15, the daily flows from drainage areas with the mixed land uses were considered the 'tipping point' at which the health, ecology and biodiversity of the riparian vegetation habitats declined. The results of the non-parametric locally weighted smoothing (LOESS), which was used to identify the (non-linear) nature of the relationship between the flows and the condition of the riparian vegetation indicated that there is an inflection (downward) when daily flows are 0.004–0.006 ML/ha/day (Section D.1, Appendix D), i.e. between the second and third group of drainage basins. This inflection occurs at a point when there is the greatest relative change in the average condition of riparian vegetation of drainage areas among the groups (Figure 15). The change is not statistically significant however (Section D.1, Appendix D), most likely due to the overall poor ecological state of the riparian vegetation in the catchment.

The middle plot in Figure 16 indicates that the (tipping) point at which the daily flows cause a decline in the condition of instream habitats occurs between 0.002 and 0.004 ML/ha/day, characteristic of current daily flows. This lower tipping point is presumably due to the sensitivity of these habitats, which are instream and are easily washed away (see Figure 8, Figure 9). This lower tipping point occurs when there is the greatest relative change in the average condition of the stream bank and instream habitat complexity among the groups (Figure 16), with mean differences in condition being statistically significant (Section D.1, Appendix D).

The last plot in Figure 16 shows the empirical relationship between the daily flow volumes and ambient water quality. The TN and TP concentrations are relatively lower than in the drainage areas with the lowest daily flows. This would seem counter-intuitive based on the concepts of the urban stream syndrome, but not unexpected in this specific catchment due to the intense agricultural land uses. Exports of nutrients and sediments from fruit and vegetable market gardens and turf farms in the catchment are up to 30 times greater than exports from urban areas (Young et al. 1996; Wells and Chan 1997; Baginska et al. 1998; Hollinger et al. 2001; Haine et al. 2011). These exports represent up to 78% of the total nutrient (438 TN tonnes/y; 83 TP tonnes/y) and sediment exports (21,333 TSS tonnes/y) from the Wianamatta–South Creek catchment to the Hawkesbury River system (Dela-Cruz et al. 2019).

Irrespective of the distribution of average annual rainfall, 2 processes appear to be occurring in the Wianamatta–South Creek catchment – symptoms of the urban stream syndrome in existing urban areas and eutrophication in existing agricultural areas. It is expected that the urbanisation of the agricultural areas will help improve the eutrophication issues in that part of the catchment in the short term, but the cumulative impacts of the future urbanisation will still need to be considered in setting standard planning requirements for stormwater quality management. The impact of flows on the health of streams in urban areas is almost universally implied in many existing local government development control plans, with standard controls requiring minimal changes to the flow regime. For example, Penrith City Council's Mamre West Land Investigation Area Development Control Plan (PCC 2016) specifies that 'Any changes to the flow rate and flow duration within the receiving watercourses as a result of the development shall be limited as far as practicable. Natural flow paths, discharge point and runoff volumes from the site should also be retained and maintained as far as practicable'. If this same control was applied to the Western Sydney Aerotropolis precincts, we would need to recommend flow related objectives based on the current or pre-development flow regime, in which the mean annual daily flow volume is limited to 0.9 ML/ha/y. However, as shown in this present study, it is practicable to adopt the flow related objectives represented by tipping point flows, in which the mean annual daily flow volume (2 ML/ha/y) is double the current flows.

7. Recommendations

In 2018, the Greater Sydney Commission released the Greater Sydney Region Plan – A Metropolis of Three Cities. The plan included a clear vision for Wianamatta–South Creek (and its tributaries) to become a cool green corridor through the Western Parkland City and be the core element of liveability and amenity for the residents. This vision relies on urban planners to explicitly integrate waterways into the design of the city and residential neighbourhoods, and for the waterways and other water dependent ecosystems to be healthy so they can provide the essential services and functions expected of a cool green corridor. Accordingly, all strategic planning for the Western Parkland City has since focused on achieving the vision, through a 'beyond business-as-usual' approach (WSPP 2020; WSPP 2021a, b).

The work presented in this study delivers this vision through a restorative and landscape led approach, at the direction of the Western Sydney Planning Partnership Office. This partnership was established between Commonwealth, state and local governments for the specific purpose of developing relative planning instruments for the Aerotropolis. Other strategic drivers for this work include the NSW Government direction under the Marine Estate Management Strategy 2018–2028 to address the priority threat of urban discharges to the state's coastal catchments. Stakeholder consultation and detailed threat and risk assessments under this strategy have indicated that current approaches to stormwater management in NSW, such as via the 'one-size fits all' stormwater quality post-development load reduction targets, is insufficient to protect the community environmental values and uses of the state's waterways (MEMA 2017).

The key recommendations arising from this study are the performance criteria for the Western Sydney Aerotropolis Precinct Plan, which seek to deliver the following goals for keeping 'Water in the Landscape':

- the protection, maintenance and/or restoration of waterways, riparian corridors, waterbodies, and other water dependent ecosystems that make up the blue grid elements of the Blue and Green Infrastructure Framework
- a landscape led approach to integrated stormwater management and water sensitive urban design (WSUD).

The performance criteria are instream or ambient water quality and flow related objectives (Table 5 and Table 6) which are consistent with the types of environmental standards that the NSW Government currently uses for managing the water quality and health of the state's waterways. They will help operationalise the Environmental and Recreational Zone requirements under the *State Environmental Planning Policy (Precincts – Western Parkland City) 2021*.

It is important to note that the instream or ambient water quality and flow related objectives do not represent existing or pre-development conditions, nor do they represent a pre-European state. So unlike recommendations in contemporary literature, they do not mimic natural conditions (Walsh et al. 2012; Tippler et al. 2013; Walsh et al. 2016) and the qualitative specifications in many existing development control plans; rather, they are based on the tipping point at which the health, ecology and biodiversity of water dependent ecosystems is expected to decline according to best available data at the time of this study. The tipping point occurs at a level of imperviousness (~10%, see Figure 25 in Appendix E) that is consistent with previous findings for the Greater Sydney Region (Tippler et al. 2012) and follows the well-established pressure–stressor–ecosystem response model for the urban stream syndrome.

Given the highly dispersive soils in the Wianamatta–South Creek, it is expected that some level of stream stabilisation will still be required. As an additional 'safeguard', we have recommended 2 sets of flow related objectives. The first set reflects the current or pre-development flows based on the flow data at the gauging station at South Creek near Elizabeth Drive (212320), which we recommend for use in more sensitive and intermittent stream types like chain of ponds and 1st and 2nd order streams. The second set reflects the modelled flow related objectives derived from the group of drainage areas with mixed land uses and identified as the tipping point in this study. This second objective is recommended as the post development flows that should be achieved for larger perennial waterways in the Wianamatta–South Creek catchment such as ≥3rd order streams. The range and characteristics of flows for this second set of objectives is within the ranges for the gauging stations in South Creek at Great Western Highway (212048) and Ropes Creek at Debrincat Avenue (212049).

The flow volumes in the first set of objectives will do a better job at protecting the instream habitats for macroinvertebrates and fish (see Figure 16) and may also minimise the extent to which the 1st and 2nd order streams are lost through re-alignment and piping. Degradation of these stream types results in poorer water quality, less reliable water flows, and less diverse aquatic life in downstream ecosystems (Wohl 2017). This is because these headwater streams have a pivotal ecosystem function in flood control, recharging of groundwater, nutrient attenuation and recycling, and trapping sediment.

The ambient WQOs presented in Table 5 are relevant to protecting aquatic ecosystems. For recreational uses of the waterways and waterbodies, it is recommended that the relevant National Health and Medical Research Council guidelines be consulted for managing human health risks (NHMRC 2008).

Overall, our approach to developing the performance criteria has been necessarily pragmatic to address key stakeholder concerns related to achievability and costs (Appendix F) in accordance with the strategic impact assessment step of the Risk-based Framework (Dela-Cruz et al. 2017). NSW Government endorsement of this approach is through the adoption of the performance criteria in the Western Sydney Aerotropolis Precinct Plan and associated development control plan. It is also worth highlighting again that the South Creek Sector Review, led by Infrastructure NSW as part of its delivery of the State Infrastructure Strategy 2018, identified that a business-as-usual approach to land-use and water cycle management would compromise the Western Parkland City outcomes, and that an integrated land-use and water cycle management approach would best deliver the outcomes (INSW 2019).

Table 5 Ambient water quality of waterways and waterbodies in the Wianamatta–South Creek catchment

Water quality objectives	
Total Nitrogen (TN, mg/L)	1.72
Dissolved Inorganic Nitrogen (DIN, mg/L)	0.74
Ammonia (NH_3-N, mg/L)	0.08
Oxidised Nitrogen (NOx, mg/L)	0.66
Total Phosphorus (TP, mg/L)	0.14
Dissolved Inorganic Phosphorus (DIP, mg/L)	0.04
Turbidity (NTU)	50
Total Suspended Solids (TSS, mg/L)	37
Conductivity (µS/cm)	1103
pH	6.20–7.60
Dissolved Oxygen (DO, %SAT)	43–75
Dissolved Oxygen (DO, mg/L)	8

Table 6 Ambient stream flows to protect waterway and water dependent ecosystems in the Wianamatta–South Creek catchment

Flow related objectives		
	Current* (apply to 1st and 2nd order streams)	**Tipping point** (apply to ≥3rd order streams)
Median daily flow volume (L/ha/day)	71.8 ± 22.0	1,095.0 ± 157.3
Mean daily flow volume (L/ha/day)	2,351.1 ± 604.6	5,542.2 ± 320.9
High spell (L/ha/day) >90th percentile daily flow volume	2,048.4 ± 739.2	10,091.7 ± 769.7
Freshes (L/ha/day) ≥ 75th and <90th percentile daily flow volume	327.1 to 2,048.4	2,642.9 to 10,091.7
Cease to flow (proportion of time/y)	0.34 ± 0.05	0.03 ± 0.01
Cease to flow – duration (days/y)	39.2 ± 8	3.9 ± 1.2
Baseflow index	0.13 ± 0.02	0.30 ± 0.02

* gauging station data (1990–2019) in South Creek at Elizabeth Drive (212320)

8. Technical support to demonstrate compliance with the performance criteria

The performance criteria are relevant to waterways in the entire Wianamatta–South Creek catchment. Notably they are a mandatory consideration for all new urban developments on land in the Western Sydney Aerotropolis and Mamre Rd Precinct, where they must inform the stormwater and WSUD requirements. The performance criteria were developed using the protocols outlined in the Australian Water Quality Guidelines (Commonwealth of Australia 2018), which have been operationalised in NSW via the *Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions* (Dela-Cruz et al. 2017). The Risk-based Framework has been used in 2 companion studies, to develop stormwater quality and quantity management targets and exemplar WSUD strategies that achieve the performance criteria (DPIE 2022a, c*)*. The targets are included as standard planning requirements in respective development control plans (DPIE 2021b; WSPP 2021a), and the WSUD strategies are included in a technical compliance guide that is referenced in the Western Sydney Aerotropolis Precinct Plan (WSPP 2022).

The technical compliance guide (DPE 2022d) was specifically commissioned to address stakeholder feedback on the need for technical support to shift towards the new or 'beyond business-as-usual' approach to stormwater management (Appendix F). As such, the purpose of the technical compliance guide is to support state and local government planning teams in their assessments of state significant developments, state significant infrastructure and development applications. The technical compliance guide responds to widely used industry standard software and includes calibrated modelling parameters, a (MUSIC) model and a post processing tool to make it easy for stormwater engineers to assess whether their WSUD strategies comply. The exemplar WSUD strategies provided with the technical compliance guide include options to achieve the performance criteria at the allotment, estate or more regional catchment scale and have been optimised to be as cost effective as possible. The preferred regional strategy involves integration of WSUD with a reticulated stormwater harvesting system that is best managed by a regional trunk drainage manager. A staged approach to regional delivery has been provided as an interim measure for the trunk drainage manager. The approach is based on setting aside a proportion of the site for WSUD (e.g. onsite wetland, storage and irrigated pasture) to achieve the objectives initially and then decommissioned and developed into industrial lots with all drainage contributing to a regional treatment and harvesting scheme.

8.1 A note on transferability

The numerical values of the performance criteria are specific to the Wianamatta–South Creek catchment. This means that they cannot be used as instream water quality and flow related objectives in other waterways. It is most likely that the *types* of performance criteria are transferable however, and current work is now underway to specifically assess the transferability of the flow related objectives *types* to other waterways in coastal NSW.

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11. More information

- Australian Land Use and Management Classification Version 8
- Australian Water Quality Guidelines
- Blacktown City Council Local Strategic Planning Statement
- Camden Council Local Strategic Planning Statement (PDF 14.5MB)
- Campbelltown City Council Local Strategic Planning Statement
- Elvis – Elevation and Depth – Foundation Spatial Data
- eWater Source model
- Fairfield City Council Local Strategic Planning Statement (PDF 11MB)
- Geoscape Buildings
- Hawkesbury City Council Local Strategic Planning Statement (PDF 9.1MB)
- Land and Soil Capability Mapping for NSW
- Liverpool City Council Local Strategic Planning Statement (PDF 10MB)
- NSW Government Water Sharing Plans
- NSW Landuse 2017 v1.2
- NSW Marine Estate Management Strategy 2018–2028 (PDF 12.3MB)
- Penrith 1:100 000 Geological Map
- Penrith City Council Local Strategic Planning Statement (PDF 17MB)
- Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-use Planning Decisions (PDF 1.4MB)
- Soil and Land Resources of the Hawkesbury-Nepean Catchment
- State Environmental Planning Policy (Precincts – Western Parkland City) 2021
- The Hills Shire Council Local Strategic Planning Statement (PDF 13MB)
- WaterNSW Continuous water monitoring network
- Western Sydney Hydrogeological Landscapes: May 2011 (First Edition)
- Wollongong Port Hacking 1:100 000 Geological Map

Appendix A – Community environmental values and uses identified through local government consultation

On 13 February 2020, the Environment, Energy and Science Group of DPIE convened a workshop with 16 council representatives from 6 LGAs making up the Wianamatta–South Creek catchment. Representatives from The Hills Shire Council and Hawkesbury City Council were unable to attend.

The purpose of the workshop was to:

- identify key community groups for an engagement strategy
- collect data on community environmental values and uses as defined under the National Water Quality Management Strategy and reflected in the NSW WQOs. The underlying assumption is that council representatives have in-depth knowledge of their waterways and community expectations based on past engagement activities.

Table 1 in Section 4.1 of this document provides a summary of the data collected at the workshop, and the figures below capture the location of key environmental assets and management issues within each LGA.

Blacktown City Council identified the following key assets that their local communities use for recreation, amenity and a sense of place to value: chain of ponds/unnamed tributary of Little Creek, several fishing locations along the tidal and freshwater parts of South Creek, freshwater wetlands, Blacktown Showground, Nurragingy Reserve near Eastern Creek, Lake Woodcroft, Bells Creek, Marsden Creek, Angus Creek and Bungambie Creek. Representatives highlighted management issues related to flood prone land downstream of Richmond Rd and Marsden Rd, water quality and weeds.

Penrith City Council only listed Tench Reserve as an asset but highlighted the need for blue and green infrastructure in the new urban release areas. Representatives highlighted management issues related to flooding, weeds and major changes to the flow regime of ephemeral creeks in newly urbanised areas like Erskine Park.

Fairfield City Council identified the Western Sydney Parklands as their key asset and raised concerns about the management of creeks in private ownership. Liverpool City Council indicated they were mapping the blue and green grid, and flagged that the planning for the Western Sydney Aerotropolis will be determining how the blue and green grid will be managed into the future.

Camden Council identified that their WSUD infrastructure and many of their creeks are the key assets their local communities use for secondary contact recreation and amenity. The main management issue is the risk that private ownership of creeks poses to these values, and a main management strategy is the harvesting of stormwater and roof water. The LGA of Campbelltown City Council is mostly outside of the Wianamatta–South Creek catchment, but the council identified visual amenity of the waterways as a key value of their local communities and stormwater runoff as a key management issue.

A total of 83 community groups were identified by the councils as key stakeholders for engagement. Unfortunately, these groups were not engaged directly (through a face-to-face workshop) due to COVID-19 restrictions. The online public consultation that was conducted in the summer of 2021 returned a combined total of 202 votes for the full range of environmental values and uses in the area (see Figure 3, Section 4.1).

Figure 17 Key environmental assets and management issues in the Blacktown City Council and Penrith City Council LGAs

Figure 18 Key environmental assets and management issues in the Fairfield City Council, Liverpool City Council, Camden Council and Campbelltown City Council LGAs

Appendix B – Aggregation of drainage areas

This appendix describes the aggregation of Sydney Water's 195 drainage areas into 47 drainage areas (see Section 5.3). The number of drainage areas needed to be reduced to ensure there was enough ecological data in each drainage area to develop empirical stressor–ecosystem response relationships.

The boundaries of the 47 drainage areas were delineated using 5 m resolution elevation and depth data (Elvis – Elevation and Depth – Foundation Spatial Data) and the hydrological terrain modelling tools available in ArcGIS version 10.4. The boundaries of the resulting drainage areas were then manually edited using the stormwater network to reflect changes to the natural drainage from urbanisation. The stormwater network datasets were sourced from all councils in the Wianamatta–South Creek catchment.

The alignment between Sydney Water's 195 drainage areas and the 47 drainage areas developed in this study was assessed by intersecting the 2 spatial datasets, and determining the proportion in which Sydney Water's drainage areas fell within the 47 drainage areas. Note that in most cases, the boundaries of the 47 drainage basins aligned with the boundaries of groups of Sydney Water's drainage areas. This means that the daily flows from Sydney Water's drainage areas could either be simply summed or multiplied by the proportional area. Figure 19 provides a summary of the key steps for the alignment.

B.1 Quantifying the magnitude, duration and frequency of each flow related objective

The mean value of daily flows, high spells, freshes, low spells, baseflow indices and cease to flow were calculated following the methods outlined in the hydrostats package (Bond 2021) available in R statistical software (version 4.1.1). This package uses the Lyne and Hollick baseflow filter to derive the baseflows, and standard percentiles to estimate the magnitude of the daily flows, high spells and low spells. The numerical range of the freshes were determined manually in excel, as were the frequency and duration of the different flow related objectives including the cease to flow. Frequency was determined by counting the number of times the percentile was encountered in a calendar year, and the duration was determined by counting how long each of the flow events lasted within that percentile. The average duration of all events for a calendar year was calculated using the following equation: total duration in a calendar year/frequency of event in a calendar year. The frequency and duration statistics were double checked by manually inspecting each time series of flows. An example of the events is shown in Figure 20 and Table 7 provides a summary of the flows for each of the 47 sub-catchments.

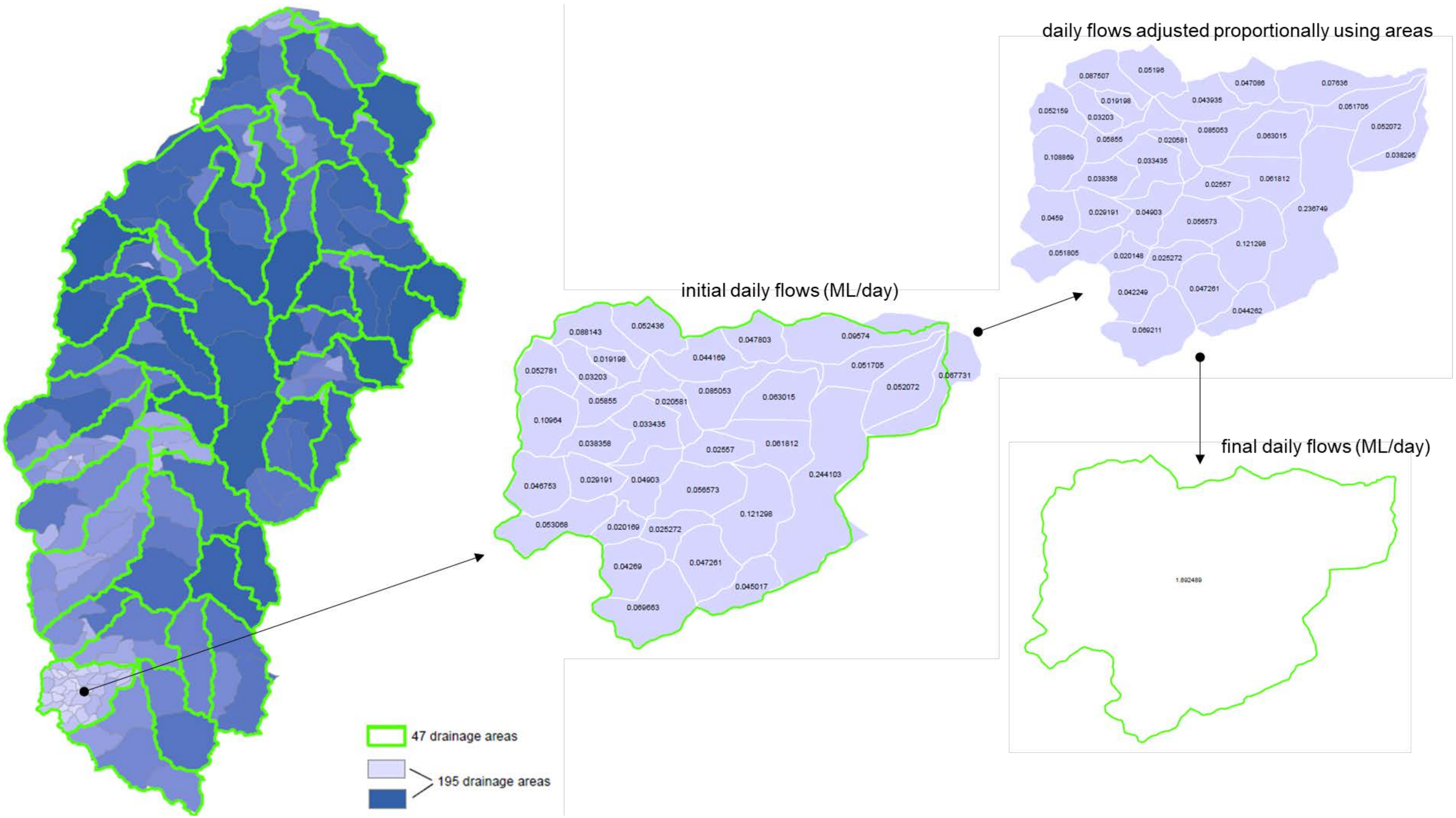

Figure 19 Checking the alignment between Sydney Water’s 195 drainage areas and the 47 drainage areas used in this study

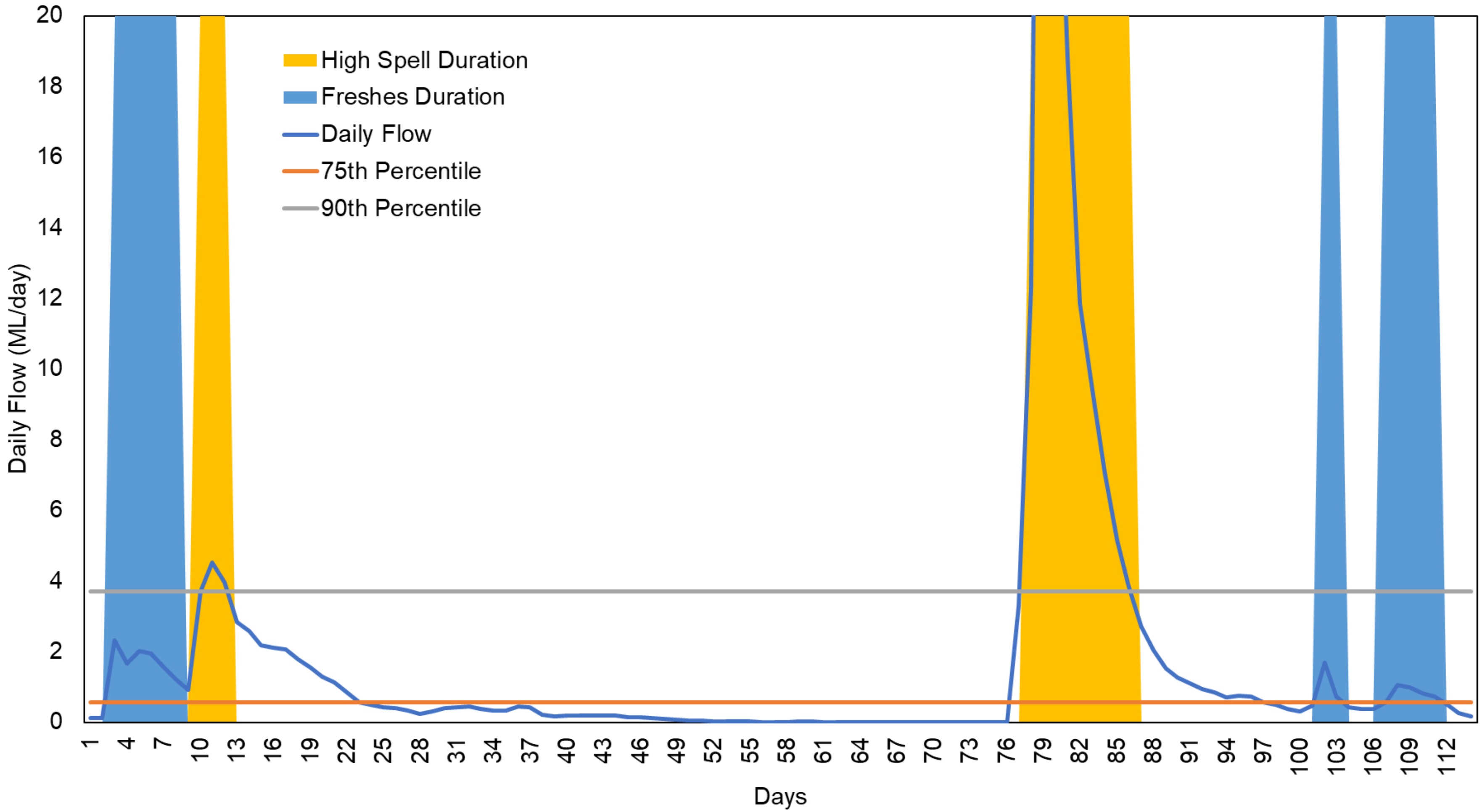

Figure 20 Characterisation of flow events observed at the gauging station in South Creek at Elizabeth Drive (212320)

Table 7 Modelled flows* for 47 main drainage areas in the Wianamatta–South Creek catchment, derived from the Sydney Water Source Model

Drainage area #	Area (ha)	Median daily flow (L/ha/d)	Mean** daily flow (L/ha/d)	High spell – Q90 (L/d)			Freshes – lower limit Q75 (L/d)			Low spell – Q10 (L/d)			Base** flow (L/ha/d)	Flow group
				Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)	Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)	Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)		
1	657.6	236.9	13,103.9	29,611.4	24.0	1.6	1,736.0	13.3	1.1	236.9	5.4	8.4	86.6	1
2	791.8	206.3	2,412.6	4,552.5	21.1	1.8	770.3	11.8	1.2	196.8	6.5	6.7	133.1	2
3	2,203.8	297.7	1,985.8	3,550.7	20.4	1.8	743.3	11.0	2.0	70.7	7.1	6.1	208.9	2
4	1,038.3	207.5	2,417.2	4,559.3	21.2	1.8	772.4	11.7	1.2	150.1	6.5	6.7	134.0	3
5	965.4	221.3	3,459.7	6,682.2	22.5	1.7	881.0	11.5	1.3	161.4	6.6	6.6	140.3	3
6	1,381.2	207.0	1,883.9	3,337.3	18.6	2.0	662.6	11.3	1.2	112.8	7.1	6.1	134.8	2
7	1,083.4	301.6	1,883.6	3,271.3	19.4	1.9	702.4	10.9	1.2	143.8	7.1	6.2	211.5	2
8	1,420.8	106.4	1,331.4	1,862.3	14.8	2.6	451.0	11.0	1.2	109.7	6.4	6.3	57.4	2
9	1,895.5	208.3	2,178.9	3,997.9	20.8	1.8	699.6	11.6	1.2	82.2	7.0	6.3	138.1	2
10	1,490.6	328.6	1,812.8	3,004.8	20.0	1.9	715.3	11.0	1.2	104.5	6.7	6.5	232.3	2
11	2,207.5	104.6	1,230.8	1,757.9	15.8	2.4	437.7	10.8	1.2	70.6	6.9	6.3	59.4	2
12	115.1	440.3	4,176.4	4,747.9	13.0	2.9	1,433.1	9.9	1.2	1,354.1	6.1	7.1	239.8	3
13	842.0	388.7	4,631.3	5,833.4	14.3	2.6	1,615.2	9.0	1.2	185.0	5.5	8.9	177.9	3
14	1,402.3	383.9	6,138.3	10,367.5	20.8	1.8	1,976.3	9.0	1.2	111.1	5.5	8.0	171.1	1
15	1,215.5	391.0	4,847.0	6,096.0	15.1	2.5	1,617.8	7.9	1.2	128.2	5.4	10.0	180.7	3
16	1,214.0	384.5	6,185.7	10,580.5	21.5	1.7	1,922.6	8.8	1.2	128.3	5.9	8.4	193.1	3
17	754.6	2,382.2	4,910.9	8,738.4	22.2	1.6	3,886.6	6.9	1.2	206.5	7.3	5.0	1,826.2	3
18	1,049.2	391.0	4,964.4	7,422.1	18.0	2.1	1,771.7	9.0	1.2	148.5	5.4	9.2	174.7	3
19	1,021.1	2,576.4	3,770.1	6,227.0	17.0	2.4	3,934.0	5.2	1.2	152.6	6.7	6.6	2,061.1	3
20	2,600.0	2,374.9	4,400.0	7,907.4	20.8	1.8	3,936.5	6.7	1.3	59.9	7.0	6.3	1,843.7	3

Drain-age area #	Area (ha)	Median daily flow (L/ha/d)	Mean** daily flow (L/ha/d)	High spell – Q90 (L/d)			Freshes – lower limit Q75 (L/d)			Low spell – Q10 (L/d)			Base** flow (L/ha/d)	Flow group
				Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)	Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)	Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)		
21	2,218.2	350.6	7,715.1	14,348.4	23.2	1.6	2,125.6	10.7	1.2	70.2	5.2	9.0	148.9	1
22	606.6	2,087.1	6,441.0	12,014.3	24.0	1.5	3,681.3	8.3	1.1	256.8	7.2	6.2	1,595.1	3
23	1,103.3	2,592.3	6,111.5	11,373.1	22.7	1.6	4,520.9	8.4	1.2	141.2	6.6	7.0	1,996.9	3
24	2,091.2	1,304.3	7,046.7	13,534.3	24.5	1.5	2,482.4	9.7	1.2	74.5	7.1	6.2	964.7	3
25	304.8	597.1	8,001.7	16,582.9	24.5	1.5	1,627.4	11.2	1.2	511.2	6.5	6.6	414.7	3
26	1,465.9	278.5	7,971.9	15,068.5	23.4	1.6	1,769.9	10.3	1.2	106.3	5.3	8.0	131.0	1
27	847.4	259.7	9,223.0	17,874.5	24.3	1.5	1,687.4	10.5	1.2	183.9	5.5	9.3	123.3	1
28	1,068.9	1,448.3	8,568.0	16,712.5	24.7	1.5	2,988.1	11.0	1.2	145.8	7.1	6.6	1,081.3	3
29	1,033.4	258.0	9,057.0	17,375.0	24.0	1.6	1,737.1	10.5	1.2	150.8	5.7	8.1	121.3	1
30	1,658.3	233.7	12,017.6	26,384.3	24.2	1.5	1,656.6	12.3	1.2	94.0	5.8	7.9	89.3	1
31	1,064.0	2,196.3	5,791.0	10,443.8	23.1	1.6	3,821.7	8.2	1.2	146.4	6.9	6.5	1,667.6	3
32	665.0	242.7	10,234.7	20,794.5	23.7	1.6	1,674.7	11.5	1.2	234.3	5.4	9.5	108.5	1
33	1,467.4	613.8	8,896.7	19,421.2	23.6	1.6	2,360.3	10.5	1.1	106.2	6.1	7.5	374.8	3
34	269.8	840.7	5,993.0	13,595.3	16.1	2.3	3,478.6	10.5	1.2	577.5	6.1	7.1	446.3	3
35	1,077.7	478.5	7,858.9	15,001.6	22.7	1.7	2,329.9	10.8	1.2	144.6	6.4	6.7	257.5	3
36	273.7	253.4	2,388.8	4,673.0	16.7	2.3	1,159.7	10.5	1.2	569.3	6.2	6.8	137.7	3
37	657.5	838.3	5,691.3	12,645.0	15.8	2.4	3,386.3	10.4	1.2	237.0	6.0	7.1	447.1	3
38	443.9	175.2	1,362.1	2,091.8	17.6	2.1	516.1	10.5	1.2	351.0	6.8	6.4	121.4	2
39	2,304.6	978.6	5,678.3	9,923.3	6.9	5.7	3,197.7	5.8	2.3	67.6	6.0	7.4	489.5	3
40	1,292.0	914.5	5,385.5	9,499.8	6.5	6.2	2,996.7	5.0	2.6	120.6	5.4	8.2	462.1	3
41	1,205.2	638.2	6,238.6	9,994.2	20.6	1.8	2,397.8	9.2	1.1	129.3	6.1	7.0	373.3	3

Drain-age area #	Area (ha)	Median daily flow (L/ha/d)	Mean** daily flow (L/ha/d)	High spell – Q90 (L/d)			Freshes – lower limit Q75 (L/d)			Low spell – Q10 (L/d)			Base** flow (L/ha/d)	Flow group
				Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)	Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)	Vol.** (L/ha/d)	Freq. (#/y)	Dur. (d/y)		
42	814.7	777.3	5,449.8	9,558.0	17.5	2.1	2,663.8	8.3	1.2	191.2	6.0	7.4	453.0	3
43	5,104.7	1,499.7	4,689.5	8,271.3	17.4	2.2	3,294.0	7.9	1.2	30.5	7.1	6.4	992.0	3
44	1,388.7	222.7	1,601.1	2,679.8	18.9	2.0	629.6	10.9	1.2	112.2	7.4	5.9	153.8	2
45	2,137.0	138.9	1,609.7	2,610.8	17.4	2.2	575.1	11.9	1.2	72.9	7.1	6.3	86.0	2
46	2,774.1	226.6	1,683.3	2,791.0	17.7	2.1	641.9	11.4	1.2	56.2	7.4	5.8	153.0	2
47	1,892.3	1,748.5	5,646.3	10,438.2	23.8	1.6	3,201.3	9.3	1.2	82.3	7.2	6.0	1,299.4	3

* Cease to flow estimates for the 1st–2nd order streams and ≥3rd order streams were sourced directly from the available gauging stations that were located within the sub-catchment(s) of the specific flow group. These were the gauging station in South Creek at Elizabeth Drive (212320) and the gauging station in Ropes Creek at Debrincat Ave, respectively.

** Flow related objectives used for the hierarchical clustering of drainage areas.

Appendix C – Review of literature

C.1 Pressure–stressor–ecosystem response model (urban stream syndrome)

This section provides a summary of the literature that was used to inform the pressure–stressor–ecosystem response model described under Section 4.2 of this document. The model is based on the concept of the urban stream syndrome, with the percentage imperviousness in an urban area as a key pressure of the extent of ecological impact.

The following key words were used in the literature search: impervious surface cover, imperviousness, urbanisation, urban stream syndrome, urban ecology, urban hydrology.

Table 8 Literature used to inform the pressure–stressor–ecosystem-response model

Indicator	Response	Literature (see Section C.3 below)
Hydrological	Increased peak flow Decreased 'lag time' Decreased flood/flow duration Frequency of high-flow events Decreased baseflow	CWP 2003; Walsh et al. 2005a, b, Huang et al. 2008, Kauffman et al. 2009; Gholami et al. 2010; Haase 2009; Hawley and Bledsoe 2011; Miller et al. 2014
Physical	Increased channel size Altered channel geometry Decreased bank stability Decreased embeddedness Decreased baseload sediment Decreased bars and benches Decreased woody debris	CWP 2003; McBride and Booth 2005; Walsh et al. 2005a; Scheuler et al. 2009; Vietz et al. 2014; Blauch and Jefferson 2019
Water quality	Poor water quality	CWP 2003; Walsh et al. 2005a, b; Schueler et al. 2009; Davies et al. 2010; Wright et al. 2011; Tippler et al. 2012, Liu et al. 2013; Kim et al. 2016; Luo et al. 2018
Ecological	Decreased diversity of macroinvertebrate assemblages Decreased sensitivity of macroinvertebrate assemblages Degraded riparian conditions	CWP 2003; Walsh et al. 2005a, b; Davies et al. 2010; Barnum et al. 2017

*Details provided in Chirgwin W and Dela-Cruz J (2022) *Nominal impervious surfaces 2018: A dataset to quantify nominal impervious surfaces in the Greater Sydney Region*, NSW Department of Planning and Environment, Parramatta.

C.2 Flow related objectives

This section provides a summary of the literature that was used to identify the types of flow related objectives listed in Table 2, under Section 5.3.1 of this document. The focus of the review was to identify components of the flow regime or hydrograph that are essential for protecting and improving the health of waterways and water dependent ecosystems in urban areas. Note that many of the studies listed below are also reviews of the literature and almost all studies recommend that stream flows should be characterised according to the magnitude, duration and frequency of the specific flow related objective.

The following key words were used in the literature search: flow, ecology, urban stream, ecosystems, hydrology, environmental flow, stormwater, water requirements, flow regime, ecological response, flow requirements, flow metrics, storm flows, flow component.

Table 9 Literature used to inform flow related objectives that affect the ecological and geomorphic health of waterways in urban catchments, and maintain the flow requirements of associated ecosystems

Flow related objective	Literature (see Section C.3 below)
Daily flows	Poff et al. 1997; Olden and Poff 2003; Monk et al. 2007; Chowdhury et.al. 2012; McIntosh et al. 2013; Webb et al. 2013; Duncan et al. 2014; Kermode et al. 2016; Steel et al. 2017; Zeiger and Hubbart 2018; Yarnell et al. 2020
Baseflow	Poff et al. 1997; Mitchell et al. 2007; Monk et al. 2007; Chowdhury et.al. 2012; Walsh et al. 2012; Duncan et al. 2014; Fletcher et al. 2014; Yarnell et al. 2015; Bhaskar et al. 2016; Walsh et al. 2016; Gawne et al. 2018; Palmer and Ruhi 2019; Yarnell et al. 2020
High spell extent (Q90), duration and frequency	Richter et al. 1996; Poff et al. 1997; Cottingham et al. 2003; Olden and Poff 2003; Mitchell et al. 2007; Monk et al. 2007; Poff and Zimmerman 2010; Poff et al. 2010; Steuer et al. 2010; Shenton et al. 2011; Chowdhury et al. 2012; Walsh et al. 2012; McIntosh et al. 2013; Webb et al. 2013; Duncan et al. 2014; Fletcher et al. 2014; Yarnell et al. 2015; Steel et al. 2017; Opperman et al. 2018; Zeiger and Hubbart 2018; Horne et al. 2019; Palmer and Ruhi 2019; Pander et al. 2019; Yarnell et al. 2020
Low spell extent (Q10), duration and frequency	Richter et al. 1996; Jowett 1997; Poff et al. 1997; Cottingham et al. 2003; Olden and Poff 2003; Monk et al. 2007; Poff and Zimmerman 2010; Poff et al. 2010; Steuer et al. 2010; Shenton et al. 2011; Chowdhury et al. 2012; Walsh et al. 2012; Bradford and Heinonen 2013; McIntosh et al. 2013; Duncan et al. 2014; Fletcher et al. 2014; Yarnell et al. 2015, Kermode et al. 2016; Steel et al. 2017; Opperman et al. 2018; Zeiger and Hubbart 2018; Horne et al. 2019; Palmer and Ruhi 2019; Yarnell et al. 2020
Freshes extent (Q75), duration and frequency	Cottingham et al. 2003; Shenton et al. 2011; MDBA 2012; NCCMA 2017; Gawne et al. 2018; MDBA 2018; DPIE 2020a; DPIE 2020b; Amtstaetter et al. 2021;
Cease to flow	Jowett 1997; Cottingham et al. 2003; Shenton et al. 2011; Duncan et al. 2014; Gawne et al. 2018

C.3 Literature

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Appendix D – Hierarchical clustering

Figure 21 and Figure 22 show the results of our hierarchical clustering of the flow related objectives, which were used to quantify how the stream flows varied spatially across the Wianamatta–South Creek catchment. The hierarchical clustering was done on the modelled estimates of daily flow, high spells, freshes, low spells and baseflow objectives. The modelled estimates were initially categorised into quartiles to reduce the variability.

The main output of the hierarchical clustering is a dendrogram, which is shown in the top panel of each figure. The main use of a dendrogram is to work out the best way to allocate objectives, in our case drainage areas, into clusters or groups. The differences between the dendrograms in the figures relates to the clustering algorithm used. The agglomerative hierarchical clustering algorithm starts with 'n' clusters, where n is the number of drainage areas, and assumes that each drainage area is its own separate cluster (i.e. starts with n=47). The algorithm then tries try to find the most similar drainage areas (based on the flow related objective data) and group them, so they start forming clusters. The divisive hierarchical clustering algorithm goes the opposite way, by assuming as a starting point that all the drainage areas are one big cluster and then dividing (out) the most dissimilar ones into separate groups. Of significance is the similarity in the number of groups and the components of each group (i.e. which drainage areas are grouped together) produced by the different clustering methods, suggesting that the groupings are robust.

The bottom panel in each figure is a silhouette plot, which is used to identify the optimal number of groups. The general rule is to select the number of groups that maximises the silhouette width because groups are distinctive (far away from each other). The silhouette width ranges between –1 and 1, with 1 indicating good consistency within groups. As shown in Figure 21 and Figure 22, the optimal number of groups is 3, with the grouping arising from the divisive hierarchical clustering having marginally greater silhouette width.

The last section of this appendix (Section D.1) provides a summary of the statistical analyses used to relate the ecosystem response indicators to the resulting flow groups (clusters), and assess whether the differences in the mean condition or state of the ecosystem response indicators between the flow groups are significant.

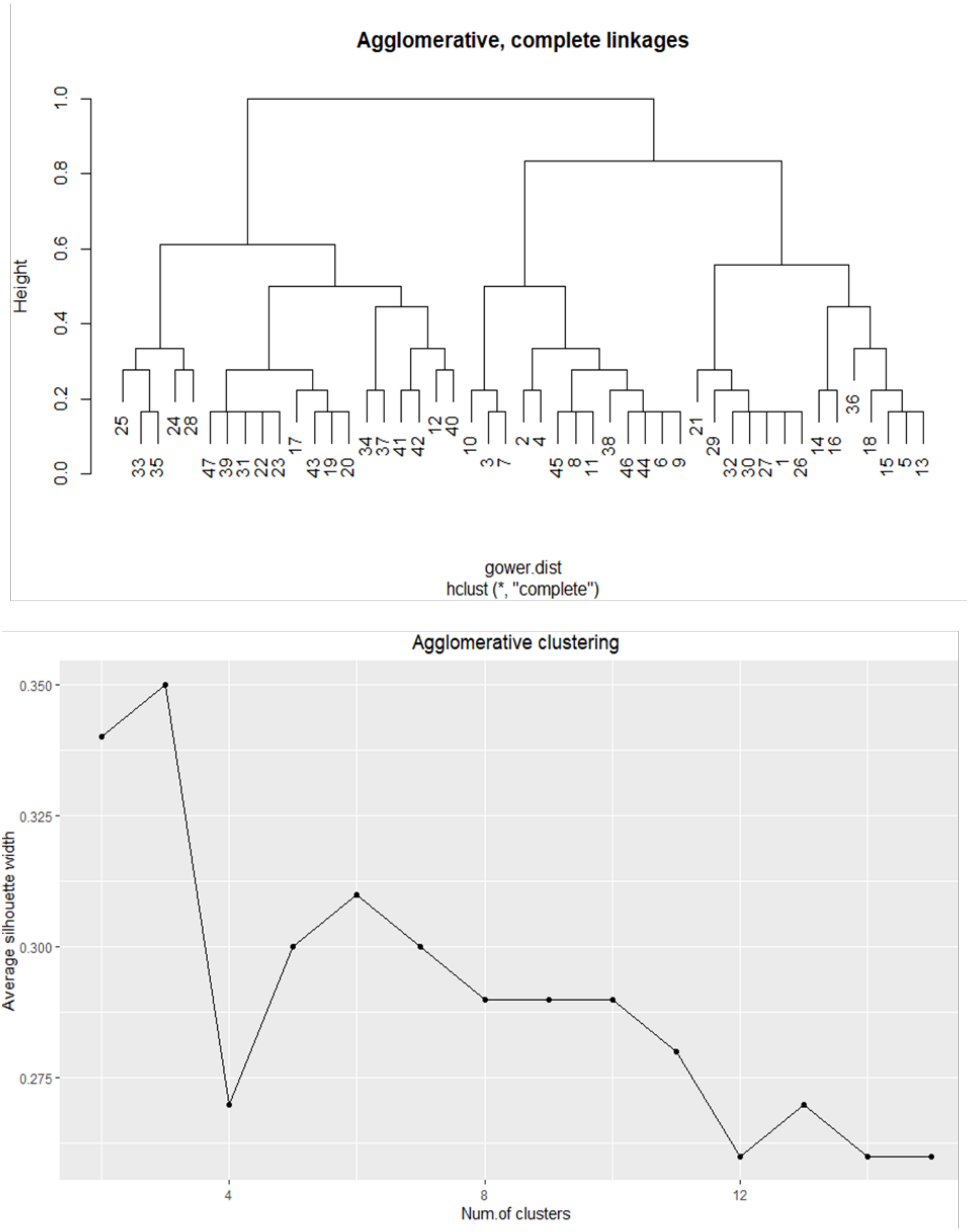

Figure 21 Dendrogram and silhouette plot resulting from the agglomerative hierarchical clustering of the flow related objectives for the 47 drainage areas in the Wianamatta–South Creek catchment

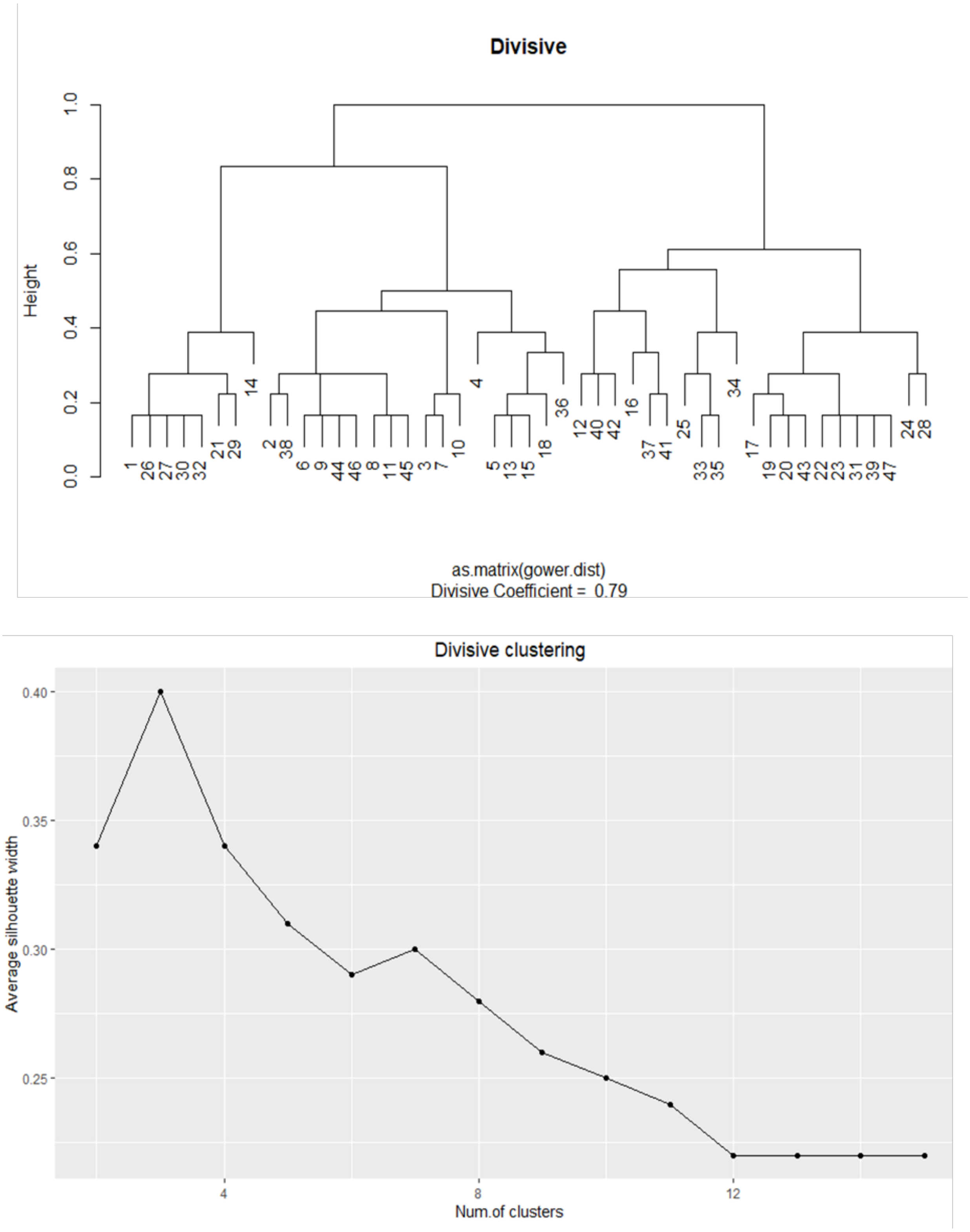

Figure 22 Dendrogram and silhouette plot resulting from the divisive hierarchical clustering of the flow related objectives for the 47 drainage areas in the Wianamatta–South Creek catchment

D.1 Statistical analysis to assess stressor–ecosystem response relationships

Figure 23 and Figure 24 shows the results of the non-parametric locally weighted smoothing (LOESS) used to identify the (non-linear) nature of the relationship between the flows and the condition of the riparian and instream habitats. The mean daily flow volume (MDF) was used as a surrogate stressor indicator to represent the other flow objectives, and the habitats used to represent the ecosystem response indicators. The LOESS shows an inflection point when the MDF is from 0.004–0.006 ML/ha/day for the riparian habitats (Figure 23), and from 0.002–0.004 ML/ha/day for the instream habitats (Figure 24).

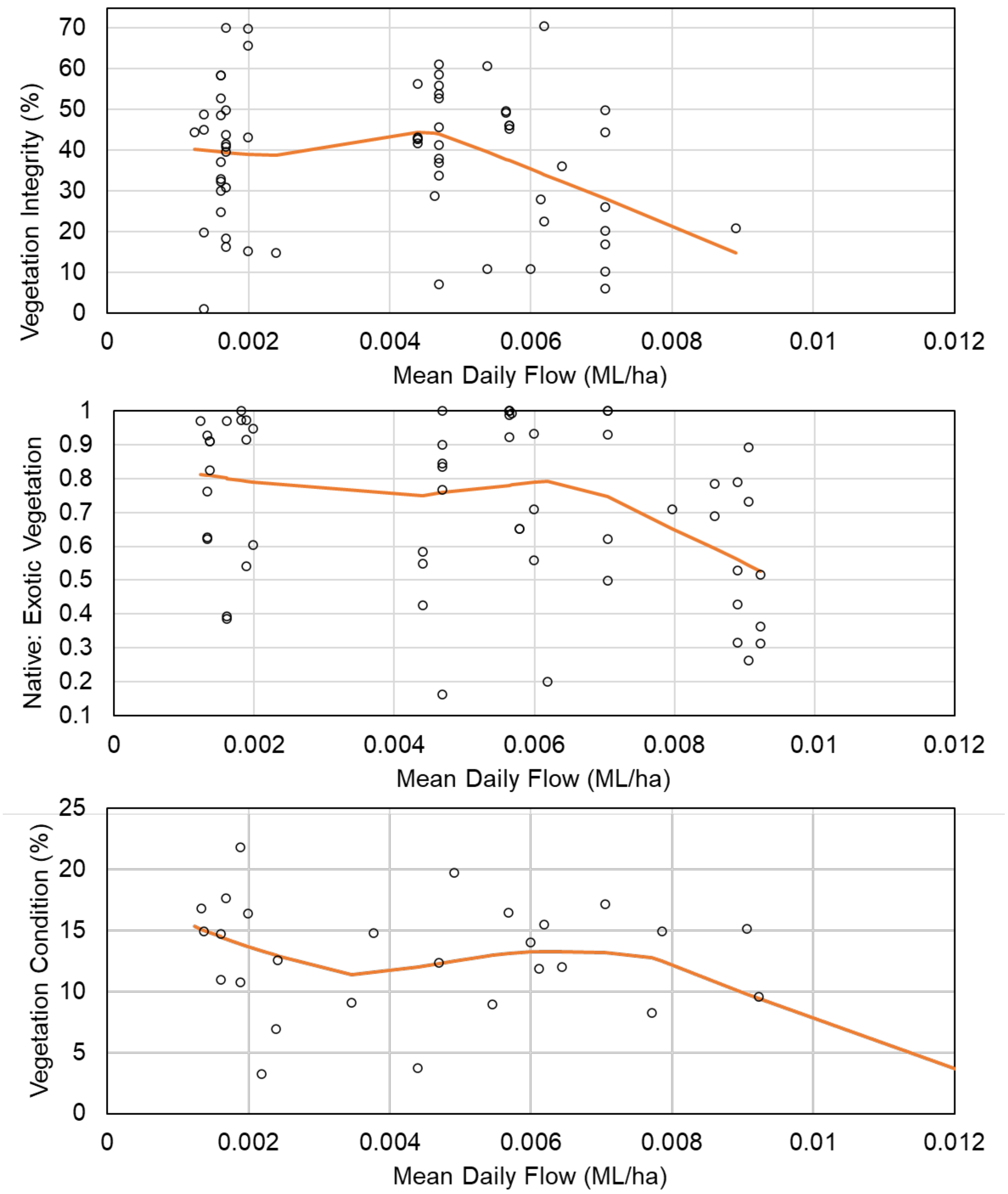

Figure 23 Non-parametric locally weighted smoothing to identify the nature of the relationship (orange line) between MDF and the condition of riparian vegetation habitats

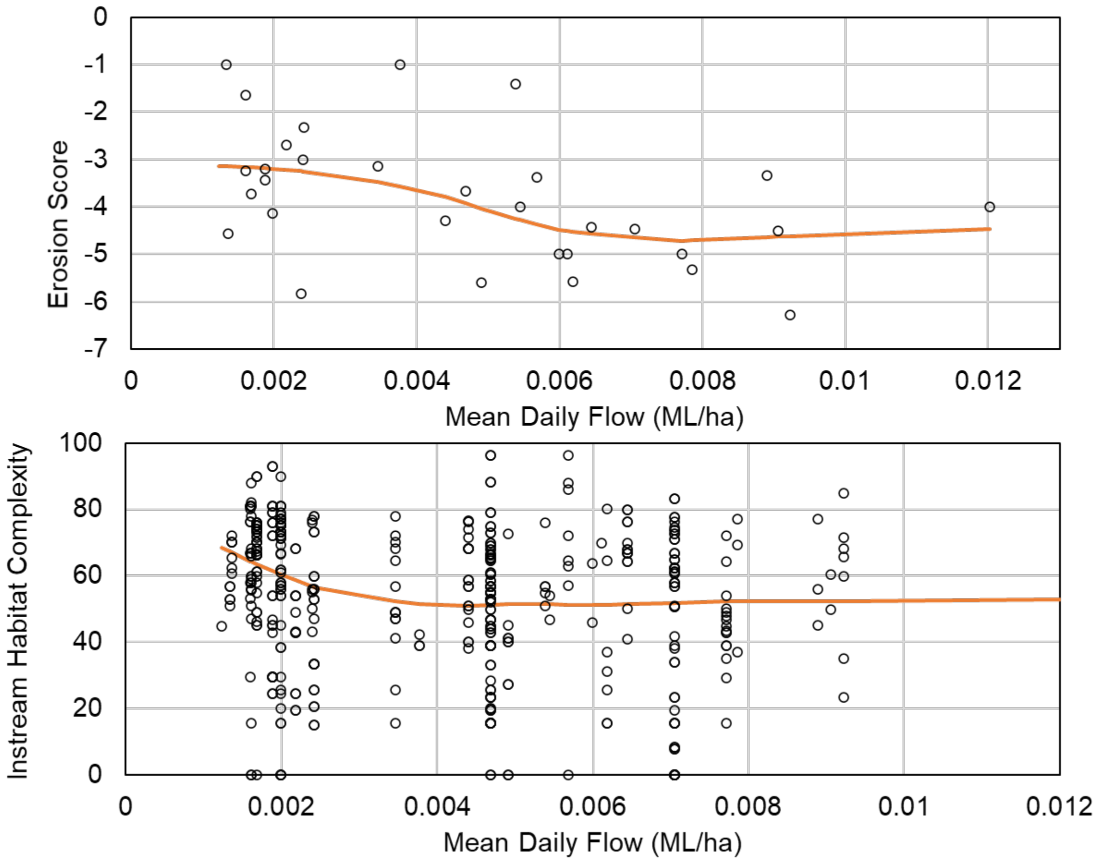

Figure 24 Non-parametric locally weighted smoothing to identify the nature of the relationship (orange line) between MDF and the condition of the stream bank and instream habitat

Table 10 and Table 11 provide the outputs of the ANOVA and Tukey's HSD, which showed that there are significant differences in the condition of stream bank and instream habitats between the groups. There are no significant differences in the condition of riparian vegetation.

Table 10 Outputs of one-way ANOVA with unequal variances used to test differences in the means of the condition of the riparian vegetation, stream bank and instream habitats between the 3 flow groups identified via divisive clustering

		SS	*df*	*MS*	*F*	*p-value*
Vegetation integrity	Between	191.8	2	95.9	0.3	ns* (0.73)
	Within	18,484.8	62	298.1		
	Total	18,676.6	64			
Native: exotic	Between	0.3	2	0.2	2.9	ns* (0.07)
	Within	3.0	54	0.1		
	Total	3.3	56			
Vegetation condition	Between	991.4	2	495.7	2.9	ns* (0.06)
	Within	81,422.8	477	170.7		
	Total	82,414.2	479			
Erosion	Between	73.8	2	36.9	4.1	<0.05
	Within	4,270.2	477	9.0		
	Total	4,344.0	479			
Instream habitat complexity	Between	11,693.2	2	5,846.6	12.1	<0.0001
	Within	229,821.8	477	481.8		
	Total	241,515.0	479			

* not significant

Table 11 Outputs of Tukey's HSD post hoc testing of mean differences in the condition of the stream bank and instream habitats between the 3 flow groups identified via divisive clustering

		BAU vs current	BAU vs tipping	Current vs tipping
Erosion	*Q stat*	3.9	3.1	2
	p-value	<0.05	ns* (0.07)	ns* (0.34)
Instream habitat complexity	*Q stat*	3.2	0.09	6.8
	p-value	ns* (0.06)	ns* (0.90)	<0.01

* not significant

Appendix E – Landscape features

Table 12 provides a summary of the datasets used to define the pressures and inherent landscape features of the Wianamatta–South Creek catchment that are shown in Figure 10, under Section 5.4.

Table 12 Pressures and inherent landscape features of the Wianamatta–South Creek catchment

Attribute	Description	Data source	Relevance
Land use	The NSW Landuse 2017 dataset captures how the landscape in NSW is being used for food production, forestry, nature conservation, infrastructure and urban development. It can be used to monitor changes in the landscape and identify impacts on biodiversity values and individual ecosystems. Land-use information uses the Australian Land Use and Management (ALUM) Classification Version 8 (ABARES 2016). In this study, each ALUM classification was broadly categorised into either 'Agriculture', 'Urban', 'Forest' or 'Not Assessed'.	NSW Landuse 2017 v1.2	Land use is a major factor influencing the health and condition of waterways. A higher prevalence of agricultural or urban land uses is generally correlated with poorer waterway health and condition.
Nominal imperviousness surfaces	Impervious surfaces capture areas that are not permeable to rain and runoff, such as roads and houses. Geoscape Buildings, which contains digital representation of buildings across Australia, was combined with ALUM classifications (ABARES 2016) of Airports (5.7.1), Roads (5.7.2), Railway (5.7.3), and Stormwater (6.4.3) from the NSW Landuse 2017 dataset to create an impervious surfaces dataset.	Geoscape Buildings NSW Landuse 2017 v1.2	Impervious surfaces are a driving force behind changes to catchment hydrology. A greater prevalence of impervious surfaces is associated with flashier hydrology, lower base flows, and increased channel incision.
Soil landscapes	Soil landscapes are areas of land that 'have recognisable and specifiable topographies and soils, that are capable of presentation on maps, and can be described by concise statements'. Six soil landscapes are mapped within the Western Sydney Aerotropolis area: Blacktown (bty), Luddenham (luz), Rickabys Creek (rcz), Picton variant a (pnza), South Creek (scy), Second Ponds Creek (spz).	Soil and Land Resources of the Hawkesbury-Nepean Catchment	Landscapes can be used to distinguish mappable areas of soils because similar causal factors are involved in the formation of both landscapes and soils. Similarly, constraints to rural and urban development of land are related to both landscape and soil limitations (see DPIE 2021c)

Attribute	Description	Data source	Relevance
Lithology	Lithology captures the underlying bedrock and was created by combining Penrith and Wollongong Geological Survey maps to cover the study area.	Penrith 1:100 000 Geological Map Wollongong Port Hacking 1:100 000 Geological Map	Lithology is one factor that influences water chemistry, with changes to area geology being reflected as changes to baseline water chemistry, including hardness, pH, and electrical conductivity.
Hydrogeological landscapes (HGL)	HGLs enable an understanding of how differences in salinity are expressed across the landscape and provide a tool to target a specific combination of land-use activities where they will provide the best salinity management outcomes. The Western Sydney HGLs that cover the Aerotropolis area are: Shale Plains, Upper South Creek, Mt Vernon, Mulgoa HGL, Greendale.	Western Sydney Hydrogeological Landscapes: May 2011 (First Edition)	When used for salinity management, HGLs describe the landscape impacts and hazards of salinity in an HGL unit. They consider risks associated with land salinity, instream salt load, and instream electrical conductivity, as well as the overall salinity hazard posed by the HGL unit (DPIE 2021d)
Water erosion	Water erosion hazard refers to the likelihood of soil detachment and movement under the effects of raindrop impact, initiation of runoff, and flowing water. The mapping is based on an 8-class system with values ranging between 1 and 8 that represent an increasing water erosion hazard.	Land and Soil Capability Mapping for NSW	The amount of water erosion is controlled by the slope gradient and length, erodibility of the soil, and the amount of vegetation cover on the landscape (OEH 2012).
Soil acidification	Soils vary considerably in their natural acidity status and in their buffering capacity to resist changes in pH. The climate imposes an acidification potential on the soil by providing a leaching regime than can drive acidifying processes, especially nitrate leaching, but also by increasing plant growth and the plant related acidifying processes such as nitrogen fixation. The mapping is based on an 8-class system with values ranging between 1 and 8 that represent an increasing soil acidification hazard.	Land and Soil Capability Mapping for NSW	Soil acidification impacts on vegetation include direct impact on biological and plant growth systems, increased presence of some toxic elements, including aluminium at pHCaCl levels below 4, reduction in availability of some plant nutrients. The resulting poor plant growth means increased potential for soil erosion and increased recharge into groundwater systems leading to increased salinity hazard reduced biodiversity.

E.1 Statistical analyses to assess pressure–stressor relationships

This section of Appendix E provides the outputs of the statistical analyses used to assess the relationships between the pressures and the mean daily flow volume (MDF). The MDF was used as a representative surrogate for the spatial variability of all other flow objectives described in Section 5.3 and Appendix C.

Non-parametric locally weighted smoothing (LOESS) was specifically used to identify the relationship between the MDF and the percentage of dominant land uses and percentage imperviousness in the Wianamatta–South Creek catchment. The mean differences between the percentage of dominant land uses and imperviousness of each of the 3 flow groups were assessed via a one-way ANOVA with unequal sample sizes and post hoc Tukey's HSD test. The independent variable was the flow group and the dependent variable the percentage areas of agricultural, urban, native vegetation and imperviousness.

As shown in Figure 25, the highest MDF occur in drainage areas with the greatest percentage of urban land and imperviousness. Lowest MDF occur in drainage areas with the lowest percentage of urban land and imperviousness but greatest percentage of agricultural land. There is a clear inflection point when the MDF is from 0.004–0.006 ML/ha/day.

Table 13 and Table 14 provide the outputs of the ANOVA and Tukey's HSD, which showed that there are significant differences in the percentage of urban and agricultural land and imperviousness between the groups. Both the LOESS and ANOVA showed there are no differences in the percentage of remnant native vegetation (viz. 'forested').

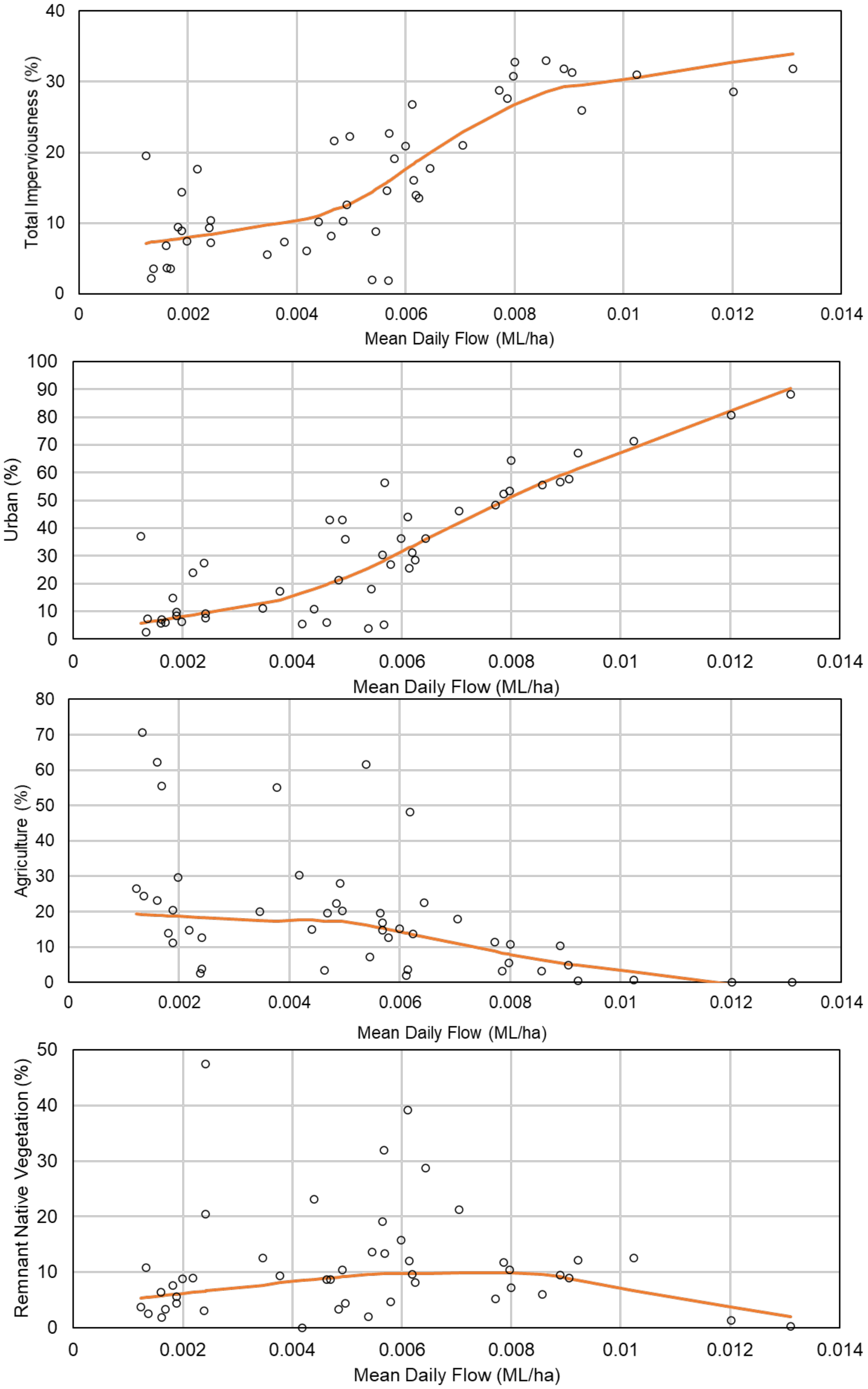

Figure 25 Non-parametric locally weighted smoothing to identify the nature of the relationship (orange line) between MDF and the percentage imperviousness and dominant land use

Table 13 Outputs of one-way ANOVA with unequal variances used to test differences in the means of the percentage of dominant land uses and imperviousness between the 3 flow groups identified via divisive clustering

		SS	*df*	*MS*	*F*	*p-value*
Imperviousness	Between	1,795.1	2	897.6	14.3	<0.0001
	Within	2,753.5	44	62.6		
	Total	4,548.7	46			
Urban	Between	12,069.3	2	6,034.7	21.2	<0.0001
	Within	12,511.4	44	284.3		
	Total	24,580.7	46			
Agriculture	Between	3,332.9	2	1,666.5	6.6	<0.01
	Within	11,114.6	44	252.6		
	Total	14,447.5	46			
Remnant native vegetation	Between	204.4	2	102.2	1.1	ns* (0.35)
	Within	4,231.7	44	96.2		
	Total	4,436.1	46			

* not significant

Table 14 Outputs of Tukey's HSD post hoc testing of mean differences in percentage of dominant land uses and imperviousness of the 3 flow groups identified via divisive clustering

		BAU vs current	BAU vs tipping	Current vs tipping
Impervious	*Q stat*	7.6	5.3	3.8
	p-value	<0.01	<0.01	<0.05
Urban	*Q stat*	9.2	6.5	4.6
	p-value	<0.01	<0.01	<0.01
Agriculture	*Q stat*	5.1	3.4	2.8
	p-value	<0.01	ns* (0.05)	ns* (0.13)

* not significant

Appendix F – Stakeholder feedback on performance criteria

Ahead of the public exhibition of performance criteria in the draft Aerotropolis Precinct Plan, we conducted a series of workshops with state and local governments, industry practitioners and academia, as a requirement for setting objectives under the Risk-based Framework and the Australian Water Quality Guidelines (Commonwealth of Australia 2018).

Table 15 provides a summary of targeted consultation with subject matter experts prior to a broader stakeholder workshop. Table 16 provides a summary of the feedback of the broader workshop, which was held on 19 October 2020 and convened by an independent chair. There were 57 participants of this workshop, with representatives from the following:

- Western Sydney Planning Partnership
- DPIE – Environment, Energy and Science Group
- DPIE – Place Design and Public Spaces
- DPIE – Water
- Department of Primary Industries – Fisheries
- Infrastructure NSW
- NSW Environment Protection Authority
- Greater Sydney Commission
- WaterNSW
- Sydney Water
- Penrith City Council
- Liverpool City Council
- Alluvium Consulting
- CTENVIRONMENTAL
- Aurecon

The purpose of the broader workshop was to seek feedback and endorsement on the performance criteria (objectives) and the stormwater and WSUD strategies for achieving them in the Aerotropolis. The latter strategies were developed by Sydney Water, who was responsible for developing the integrated water cycle management plan for the Aerotropolis. The workshop was designed to support EES in identifying what is needed for them to finalise their advice to Western Sydney Planning Partnership Office for final endorsement and inclusion of the performance criteria in the final Aerotropolis Precinct Plan.

Overall, the participants supported the science that informed the objectives and the objectives themselves; however, they highlighted 4 key issues with delivery:

1. costs for achieving the objectives and ongoing maintenance of infrastructure
2. governance in ongoing management of waterways and stormwater and WSUD infrastructure
3. consideration of impacts of achieving objectives on flood behaviour
4. technical capacity of state and local governments to assess compliance with objectives, and for the urban development industry to provide solutions.

In direct response to this feedback, EHG commissioned a technical guide for stakeholders to demonstrate compliance with the objectives in the most cost-effective manner (DPE 2022d). While the guide does not resolve issues related to funding or governance, it provides a range of WSUD strategies for achieving the performance criteria. The recommended strategy is via regional reticulated stormwater harvesting as it is the most cost effective and achieves the Parkland Vision (DPE 2022c). A staged strategy is also provided to allow time for development of relevant policy and/or legislative settings for regional infrastructure delivery.

Table 15 Feedback arising from targeted consultation with subject matter experts

Subject matter experts	Feedback
DPIE – EES (Science, Economics and Insights Division – Water, Wetlands and Coasts Science Branch) who undertake similar work for estuaries	• Recognised the complexity and challenges • Agreed and supported methods for deriving objectives, and robustness of analysis – recommended that the flow ecology relationship focus on a tipping point • Concern that the WQOs are too lenient – raised an issue that setting objectives that are less stringent upstream compared to downstream is problematic and non-intuitive, but conceded that the soils, geology, other landscape hazards and low flows in the South Creek catchment would lead to this outcome. If feasible (i.e. opportunity to access sites), they recommended that we undertake soil sampling, and extend to leachate analysis to justify the WQOs being proposed
Independent external reviewer (academia) – national expert on urban waterway health management and green infrastructure	• Recognised the complexity and challenges • Agreed and supported methods for deriving objectives, and robustness of analysis • Concern that environmental outcomes will be hampered by who will fund and be the ongoing managers of the infrastructure and ongoing maintenance
Independent external reviewer (industry) – national expert on stormwater and flow modelling, and who provides expert advice to the Independent Planning Assessment Committee	• Agreed and supported how we have used the Sydney Water modelled flows, and in particular how we have accounted for the uncertainty in the modelled data • Identified that cease to flow components are important for Wianamatta–South Creek, and these can be used as a surrogate for baseflows and low spells in absence of better data
DPIE – Water – Water Science	• Raised significant concerns that flow objectives are being developed, because these will have implications for water sharing plans. It was agreed that there is a need to change the terminology to note the distinction • Highlighted that they needed more time to 'digest' the information and assess potential conflicts. It was agreed that DPIE – Water would review this document prior to public release
Infrastructure NSW	• Concerned about the ability of industry to achieve the 0.9 ML/ha/year for 1st–2nd order streams, without significant impact on land availability and costs; however, agreed with approach to limit to these sensitive streams • Indicated that types of flow objectives used in water sharing plans have a different intent to those being used in this study

Table 16 Feedback arising from a large stakeholder workshop held in October 2020

Stakeholder	Feedback
Penrith City Council	• Consideration must be given to how EES's work correlates to tree canopy cover targets, and how WSUD elements (to achieve the objectives) in the public domain can be used most effectively to care for trees and other green infrastructure • Not all council staff were able to attend the early part of the workshop, but council has discussed this work before with the project team in previous consultation • This work is supported in principle but noting that (in achieving the objectives) councils are not responsible for maintaining assets in industrial areas • Reservations are to do with costs (e.g. street trees) for maintenance and ownership (e.g. wetlands in open space) of infrastructure required to achieve objectives • Need clarity on integration of this work with flooding • Overall great work on waterway management but still need to better understand funding (including long-term renewal) and governance issues. Also need to consider cost–benefits, etc.
NSW Environment Protection Authority	• Impacts on flood behaviour need to be considered in regard to the vegetation and the associated tipping points and recommendations for 1st and 2nd order streams • Presentations insightful, lots of information to unpack this issue • Key pieces needed include engagement, with a good communication strategy on Parkland Vision. Needs to be a story about transition, and how we move to this approach to bring everyone along • Costs and practicality and what it means for house prices, buildings and land take. Economic piece is critical to define what are the bottom line costs for achieving the objectives – affordability is important • Adaptive pathway – EPA thought the WSUD scenarios to demonstrate how the objectives could be achieved were 'black and white', i.e. more scenarios are needed • Governance needs to be clarified on how to move to this approach • How can this work be integrated into BASIX? • The work needs to include the role of treated water from the Sydney Water Factory and reuse options as they will compete with some of the solutions discussed today. As well it will also inform the design of the new plant. Needs some discussion and the contribution of the treated water to flow if needed • This is really vital work and discussion – our challenge is the how and who to get this through and integrated. Without it, we cannot get the blue and green corridors with integrity for future despite the high-level objectives in all other plans
Western Sydney Planning Partnership Office	• The Western Sydney Street Design Guidelines include WSUD as a requirement in all local streets. Part of the solution for achieving the objectives should include trees

Stakeholder	Feedback
Infrastructure NSW	• Presentations insightful • Costs for achieving objectives are around 50–70% greater than current costs, plus land take for wetlands at 5% of catchment, street trees, stormwater harvesting, etc. How do we look at implementability? – current WSUD approach hard to construct and maintain but expecting more now • Building capacity for industry – how to get industry to adopt approach and get expertise to show compliance against new objectives • Flooding work needs to be integrated, because there will also be land take of detention basins – need to avoid double up • We are still a way from meeting the outcomes of the Risk-based Framework (OEH 2017) which calls for a 'Strategic Impact Assessment' of any proposed measures to 'assess the feasibility in achieving the options', to ensure that the selected management responses are reasonable, practical and cost effective
WaterNSW	• Warragamba pipeline is at risk of being knocked off anchor block through flood events. There needs to be a balance between flood detention versus water retention issue • Pre and post development flows objectives need to be included in development control plans to manage them • Modelling – assumptions for permeability are critical. How can we make sure that permeability presented today (to achieve objectives) is incorporated into the development control plan?
DPIE – Water	• Interactions with *Water Management Act 2000* need to be considered in context of how solutions to achieve objectives work with floodplain harvesting and existing farm dams • No comment on objectives without understanding the methods on how they were developed. There is other work going on around the state on environmental watering requirements and there needs to be consistency
Sydney Water	• Integration of this work with flood management is underway • Clear about the governance and sustainable funding for infrastructure – there are processes in play and it's important to get that right (e.g. previous work of Infrastructure NSW) • When it comes to development, we need to be clear what we are asking of them to make sure the options are clear to everyone. So, guidance on achieving the objectives needs to be clear • Sydney Water encountered major challenges with land acquisition for stormwater and flooding in Rouse Hill. The planning work will need to understand 'highest and best use' for land to be acquired for public purposes, to achieve the objectives. The importance of land costs needs to be recognised • Development industry are happy to deliver to new approach/differently but need regulatory framework; the biggest issue is that the new approach has to be done from first development, otherwise there is a precedent that is set; applies to funding question; needs the right planning control

Stakeholder	Feedback
Aurecon	• Our consultation with Urban Development Industry Association (UDIA), big developers, are not opposed to healthy waterways and don’t mind spending money but what they don’t like/shy away from is the uncertainty of approvals. Time is money, they need assurance for their approvals. Has to be simple – no harder than what is currently happening, processes need to be seamless • Spending thousands on stormwater management measures that don't achieve what we want (like business-as-usual) is not reasonable, practical and cost effective. Sustainable funding and catchment wide coordination is essential
DPIE – EES	• Western Sydney Planning Partnership need to resolve the relationship between this work and objectives in engineering design guidelines • Funding and governance mechanisms for delivery are critical to achieving the objectives and hence vision for the Western Parkland City • Given development has already started, when finalising this work, there needs to be a consideration of timeline. This work needs to be included as early as possible

Appendix G
Review of water sensitive urban design strategies for Wianamatta–South Creek

Department of Planning and Environment

Review of water sensitive urban design strategies for Wianamatta-South Creek

environment.nsw.gov.au

Cover photo: Wetland and playground at Blacktown Showground. Blacktown City Council

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1. The most insignificant jet

'On 28 August 1826 a truly remarkable public meeting was held in Windsor Courthouse attended by notable local Aboriginal figures of the day. In this remarkable meeting it was resolved 'that the rivers be protected to the most insignificant jet', a poignant resolution still pertinent for the waters of the Wianamatta system.

Water resources have important cultural, spiritual, and practical values for First Peoples. Waterways are crucial for cultural practices and knowledge transfers as part of a healthy, flowing, connected system.

The Cannemegal and Wianamattagal peoples of the Dharug nation still care for the Country of Wianamatta and carry the stories and knowledges of that landscape. Dharug Elders describe Wianamatta as an interconnected system, formed through the Dreaming, this cultural landscape connects from beyond the mountains out to the sea. It is a particularly important place for pregnant women as the place of the mother creek – a female landscape relating to motherhood and creation.

The floodplains of Wianamatta remain a significant place for Aboriginal communities. South, Ropes, Badgerys, and Thompsons Creeks form a major part of the Aboriginal infrastructure which has provided resources such as food, medicine, and recreation over thousands of generations of people. It is imperative to respect these waterways and their dynamic movements, and to learn from their capacity to find the path of least resistance. Allowing one part to become ill through pollution, mismanagement or overuse will cause the whole system to suffer. All the waters must be protected to ensure the health of the whole system – to the most insignificant jet.'

Dr Danièle Hromek is a Budawang woman of the Yuin nation – she has spent some time yarning with the Aboriginal Elders in Wianamatta to help translate cultural values into land use planning

2. About this document

This document describes the feasibility of a range of water sensitive urban design (WSUD) strategies for achieving new stormwater management targets that protect and restore the blue grid in the Wianamatta-South Creek catchment. The new targets are presented as standard planning requirements for stormwater infrastructure in both the Western Sydney Aerotropolis Development Control Plan - Phase 2, and Mamre Rd Precinct Development Control Plan.

The findings of the feasibility assessment are intended to support decisions on developing robust and cost-effective institutional arrangements for urban development in the Wianamatta-South Creek catchment. This document presents optimal WSUD strategies (solutions) for large format industrial and high-density residential typologies, based on comparisons of overall capital, operating, and land costs associated with each of the WSUD strategies.

This document is technical in nature, but should be considered by a wide range of stakeholders involved in land use planning, and managing stormwater and waterways in the Wianamatta-South Creek. These include:

- Policy and planning practitioners (including development assessors) involved in land use planning and policy development
- Infrastructure planners and engineers involved in water management cycle planning
- Proponents and associated consultants involved in the planning, design, delivery and operation of stormwater infrastructure

This document provides background for the NSW Government *Technical guidance for achieving Wianamatta-South Creek stormwater management targets* (DPE, 2022a). It is part of a technical series of documents that have been released by the NSW Government to support precinct planning in Western Sydney, see:

- *Mapping the natural blue grid elements of Wianamatta-South Creek: High ecological value waterways, riparian vegetation communities and other water dependent ecosystems* (DPE, 2022b)
- *Performance criteria for protecting and improving the blue grid in Wianamatta-South Creek: Water quality and flow related objectives for use as environmental standards in land use planning* (DPE, 2022c)
- *Wianamatta-South Creek stormwater management targets* (DPE, 2022d).

3. Background

The Wianamatta-South Creek catchment is part of the Hawkesbury-Nepean River system and lies ~50km west of Sydney. It is the central location for the Western Parkland City, and Sydney's second international airport. Strategic land use planning for the area has been landscape led (WSPP, 2020; DPIE, 2021a), predominantly achieved through the creation of a Blue and Green Infrastructure Framework to provide a range of benefits related to liveability, building resilience to city hazards like urban heat and flooding, and protecting the iconic and/or endangered ecological communities that characterise the area (GSC, 2018a; DPIE 2021a; WSPP, 2021).

This landscape led approach has changed almost all aspects of land use planning for the airport and surrounding precincts that make up the Western Sydney Aerotropolis. This includes changes to planning controls for stormwater infrastructure delivery, which have shifted from long standing post-development load reductions targets to new outcomes-based targets designed to protect and restore the blue grid (see Section 3.1). The targets now include requirements for managing stormwater flow volumes and rates to specifically mitigate risks of stream erosion, riparian and instream habitat loss, and changes to life cycles of flora and fauna (DPE, 2022c). The targets were developed by the NSW Government *via* a risk-based framework (DPE, 2022d), in accordance with the NSW Government policy for managing waterways, the Western City District Plan (GSC, 2018b), Western Sydney Aerotropolis Plan (WSPP, 2020) and State Environmental Planning Policy (Precincts - Western Parkland City) 2021.

The NSW Government 'Risk-based framework for considering waterway health outcomes in strategic land use planning decisions' ('Risk-based Framework', Dela-Cruz *et al*., 2017) outlines a process for developing management targets, in consideration of their feasibility of being achieved. As outlined in Step 4 of the Risk-based Framework, feasibility could include aspects of costs of delivery, benefits achieved, site constraints/characteristics, operational requirements, and/or social considerations.

In this document, we present the results of the feasibility of achieving the new (outcomes-based) stormwater management targets for Wianamatta-South Creek by comparing a range of water sensitive urban design (WSUD) strategies. Feasibility is based on capital, operating and land costs in context of site constraints and the vision set out by the Greater Sydney Commission to deliver a cool parkland city. The site constraints/ characteristics determined the stormwater treatment measures that are viable in the Wianamatta-South Creek catchment. The vision determined the range of WSUD strategies investigated, which themselves were based on consultation with local and state governments, and Sydney Water who delivered integrated water cycle management plans for the Western Sydney Aerotropolis and Mamre Road Precincts (Sydney Water, 2020; Sydney Water, 2021).

3.1 Stormwater management targets

Tables 1 to 4 present the new (outcomes-based) stormwater management targets that need to be achieved at the outlet of a development site during the operational phase i.e. once the site has been developed. A development must demonstrate compliance with both the stormwater quality and quantity (flow) targets.

There are two options for targets provided for stormwater quality and two for stormwater quantity (flow). The two options are intended to provide flexibility in demonstrating compliance with the targets (see DPE 2022a, d), and were a direct request of the water professionals or practitioners who were representing large landowners in Wianamatta-South Creek at the time of this present study.

For stormwater quality targets, most development will likely adopt Option 1, which is based on annual load reduction targets (Table 1). If a development incorporates significant areas of pervious space (e.g. by adopting green rooves), then a proponent may prefer to use Option 2 which is based on allowable loads (Table 2).

Differences between the two options for the stormwater quantity (flow) targets are mainly related to the extent of post-processing of results generated from the industry standard model MUSIC (DPE, 2022a, d). Option 1 allows results to be directly extracted from MUSIC and compared with the targets (Table 3). Option 2 requires flow data to be extracted from MUSIC and a flow duration curve to be developed (Table 4). The proponent is free to select whichever option suits their WSUD strategy best, noting that:

- Option 1 stormwater quantity (flow) targets are based around limiting the mean annual runoff volume (MARV) from a development site as well as ensuring there is suitable low flow regime in the streams.
- Option 2 stormwater quantity (flow) targets are based on preserving key percentiles of a flow duration curve (see DPE 2022d).

Table 1 Operational Phase Stormwater Quality Targets Option 1 – annual load reduction

Parameter	Target - reduction in mean annual load from unmitigated development
Gross Pollutants (anthropogenic litter >5mm and coarse sediment >1mm)	90%
Total Suspended Solids (TSS)	90%
Text Total Phosphorus (TP)	80%
Total Nitrogen (TN)	65%

Table 2 Operational Phase Stormwater Quality Targets Option 2 – allowable loads

Parameter	Target - allowable mean annual load from development
Gross Pollutants (anthropogenic litter >5mm and coarse sediment >1mm)	< 16 kg/ha/y
Total Suspended Solids (TSS)	< 80 kg/ha/y
Text Total Phosphorus (TP)	< 0.3 kg/ha/y
Total Nitrogen (TN)	< 3.5 kg/ha/y

Table 3 Operational Phase Stormwater Quantity (Flow) Targets Option 1 - MARV

Parameter	Target
Mean Annual Runoff Volume (MARV)	≤ 2 ML/ha/y at the point of discharge to the local waterway
90%ile flow	1000 to 5000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5 to 100 L/ha/day at the point of discharge to the local waterway
10%ile flow	0 L/ha/day at the point of discharge to the local waterway

Table 4 Operational Phase Stormwater Quantity (Flow) Targets Option 2 – flow percentiles

Parameter	Target
95%ile flow	3000 to 15000 L/ha/day at the point of discharge to the local waterway
90%ile flow	1000 to 5000 L/ha/day at the point of discharge to the local waterway
75%ile flow	100 to 1000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5 to 100 L/ha/day at the point of discharge to the local waterway
Cease to flow	Cease to flow to be between 10% to 30% of the time

4. Developing WSUD strategies

A total of 16 different WSUD strategies are presented in this document, all demonstrating how the new (outcomes-based) stormwater management targets can be achieved. The WSUD strategies account for the site and development characteristics and associated design principles, reliability of stormwater treatment measures during operation and apply to different scales of delivery (allotment, precinct, regional).

4.1 Site and development characteristics

The precincts of the Western Sydney Aerotropolis and Mamre Rd contain a mix of employment zones of various characters (e.g. town centre and enterprise areas), as well as some medium and high-density residential areas. The greatest portion of the land use will be industrial (large format and strata) and logistics operations, which are characterised by high site coverage of impervious surfaces. Hence, while the vision for the Western Parkland City requires lower impervious cover than 'business as usual', site coverage and imperviousness will still be relatively high for these industrial areas to be commercially viable and provide the envisaged employment opportunities.

Impacts of site coverage and imperviousness on the hydrology are significant, producing much more runoff and mobilising many more pollutants than undeveloped catchments. As shown in a companion study, these impacts have a flow on effect on the ecology of the waterways, riparian corridors and other water dependent ecosystems that make up the blue grid in Wianamatta-South Creek (DPE, 2022c). There is a 'tipping point' at which the ecological health of the blue grid is significantly impacted by flows. The tipping point occurs at a level of imperviousness (~10%), consistent with previous findings for the Greater Sydney Region (Tippler *et al*., 2012) and diagnostic of the urban stream syndrome (Walsh *et al*., 2005; Walsh *et al*., 2012).

Mitigating excess runoff from industrial areas is considered the most challenging aspect of stormwater management in Wianamatta-South Creek because of several compounding factors. The presence of saline and sodic soils (DPIE, 2021b,c) means that stormwater treatment measures like infiltration and permeable paving should not be applied without appropriate soil testing to confirm soil capabilities. Highly variable water demands between allotments in industrial, logistics and agri-business areas/typologies are also a critical consideration when developing WSUD strategies. Predicting allotment water demands (especially for non-potable water) are highly dependent on the activities of a particular tenant. At development planning stages, individual tenants and their type of activities are generally unknown, and therefore predicting lot scale water demands is not feasible in these industrial areas. However, it is feasible to grossly predict water demand at the development precinct scale.

This varying nature of (non-potable) water demands between lots for industrial land use highlight the potential benefit of a regional reticulated stormwater reuse system. This system can deliver harvested stormwater to all allotments in a region to ensure water is supplied to large uses of non-potable water such as a glasshouse horticultural business (compared to a big-box distribution centre). This provides a significant opportunity for conservation of drinking water by allowing all lots to use recycled water for non-potable uses. The supply for the recycled water could be treated wastewater, treated stormwater or a blend of the two sources, depending on the design of the reticulated system.

4.2 WSUD design principles

With consideration of site characteristics and the vision for the Western Parkland City, a set of WSUD design principles to inform the WSUD strategies was developed. Input was sought from key science and operations groups within the NSW Government, particularly those with in-depth local knowledge and data on the soil characteristics for Wianamatta-South Creek (DPIE, 2021b,c) and/or those with responsibilities for guiding waterway management, riparian corridors and/or flood impacts. The following list provides the main WSUD design principles derived from the expert input, and therefore used when selecting stormwater treatment measures for a particular WSUD strategy:

1. Preference for vegetated treatment systems as they provide hydrologic and green infrastructure benefits
2. Infiltration measures (including unlined porous pavements) are unlikely to be feasible because of saline and sodic soils, unless detailed site analysis is done to confirm feasibility
3. Stormwater treatment systems should be arranged in parallel, as much as possible to minimise double treating of stormwater
4. Stormwater harvesting is likely to be a fundamental part of the strategy for protecting waterways. Preference is for a regional reticulated scheme which delivers harvested water to all lots and for all non-potable demands.
5. Irrigation rates are managed to avoid over irrigation and exacerbating saline and sodic soil issues.
6. Stormwater management systems should be lined to minimise infiltration (e.g. engineered clays or synthetic liner).
7. Stormwater treatment and harvesting systems can be located within 1% AEP. They are to be avoided in flood conveyance areas (i.e. 1% AEP floodway and high floodway) and critical flood storage areas unless a flood impact and risk assessment for the development demonstrated that their impacts on flood behaviour and on the community can be managed. Refer to principles set out in an accompanying technical guidance (DPE, 2022a).
8. Stormwater treatments and harvesting storages can be located within the vegetated riparian zone (VRZ), provided the function of the VRZ is preserved (DPI-Office of Water, 2012) and design principle 7 (above) and those set out in our accompanying technical guidance (DPE, 2022a) are satisfied.

Dead trees in low lying areas is an indicator of salinity in the landscape. Rob Muller/DPE

4.3 Stormwater treatment measures

Although there are growing numbers of stormwater treatment measures, a limited number were selected to be suitable for Wianamatta-South Creek catchment based on the WSUD design principles (Section 4.2) and the outcomes of consultation with the Local Governments and stormwater engineers/contractors operating within the catchment. The following table (5) provides a list of stormwater treatment measures, together with an outline of an assumed configuration for each of measure. The measures were considered to be both practical and reliable, and therefore used in the example WSUD strategies presented in this document.

Table 5 Description of stormwater measures adopted in the WSUD strategies

Measure	Description
Green rooves	Roof areas that are covered with soil and vegetation. They act to capture rainwater, promote evaporation, reduce runoff volumes and cool the buildings.
Gross Pollutant Trap (GPT)	GPTs filter litter and debris from stormwater and act to contain oil spills.
Roof water tanks	Tanks that collect roof water that is then pumped to supply indoor uses (e.g. toilet and laundries) and/or outdoor uses (irrigation).
On-site detention	Sunken landscaped areas that provide stormwater storage during infrequent flooding events.
Lot bioretention	Bioretention basins that collect and filter stormwater within a lot, typically targeting roads, carparks and hardstand areas.
Lot wetlands	Constructed wetlands for the purpose of stormwater treatment - treated water commonly pumped to storages for reuse.
Lot storages	Lot storage can be either tanks (e.g. above ground) or open storages (e.g. dam) and are used to supply pumps for reuse systems (e.g. irrigation).
Street bioretention	Bioretention basins located in road verges that collect and filter stormwater from the road, located within the verges (assumed earth batters and no grate covers).
Passively irrigated street trees	Stormwater diverters installed in kerbs to directly direct small amounts of stormwater into soils around street trees for irrigation (not bioretention).
Precinct wetland	Constructed wetlands for the purpose of stormwater treatment - treated water can be directed to storages for reuse, could be located above or below 1% AEP levels (refer to Section 4.2).
Precinct bioretention	Bioretention basins that collect and filter stormwater. They are typically located in public open space, and could be located above or below 1% AEP levels (refer to Section 4.2).
Combined wetland/ bioretention	Wetlands in combination with bioretention, where wetlands treat baseflows and then overflow into bioretention basins during storm events - both share extended detention volumes.
Public open space (POS) storage tank and reuse	Treated water storage in POS can be either tanks (in smaller parks) or open water storage (e.g. lakes or dams).
Regional reuse storage	Treated water storage in open water dams or lakes, could be located above or below 1% AEP levels (within policy and/or legislative requirements).
Reticulated reuse pipe	A dedicated reticulated water pipe to supply recycled stormwater to allotment and open space. Can be combined with recycled wastewater.

4.4 Scales of delivery

Development Control Plans for the Western Sydney Aerotropolis and Mamre Rd Precincts specify that stormwater management systems can be delivered at a range of scales (i.e. allotment, street, estate, or sub-precinct scale) to treat stormwater, integrate with the landscape and maximise evaporative losses to comply with the new (outcomes-based) stormwater management targets.

For this feasibility assessment, three scales of delivery are considered:

- Allotment (on the lot) – WSUD is located entirely within the boundaries of a development site, and compliance with stormwater management targets is demonstrated at an outlet from a development site
- Allotment and Precinct – WSUD is delivered on lots, in streets and at precinct scale (i.e. open space) to enable full development of each lot (up to 85% impervious, as per Development Controls Plans) and still comply with the stormwater management targets
- Regional – WSUD includes a reticulated stormwater reuse system that provides stormwater treatments and storages at precinct or regional scales, and requires a trunk drainage manager

Allotment scale WSUD strategies are presented to reflect smaller scale developments where public open space is not available for stormwater management.

Combined allotment and precinct scale delivery is the strategy presented in the Western Sydney Aerotropolis Stormwater and Water Cycle Management Study (Sydney Water, 2021). It is based on WSUD delivered on lots and in public open spaces (parks), using captured rain and stormwater for irrigation.

Regional and reticulated reuse strategies rely on arrangements for a trunk drainage manager to be implemented. Sydney Water's proposal for Advanced Water Recycling Centre within the Aerotropolis presents an opportunity for regional treatment and reticulated reuse of stormwater. Extensive consultation with Sydney Water and the NSW Government indicated that this specific WSUD strategy was under consideration at the time of this study, and therefore is included in the feasibility assessment.

To support delivery of any future regional WSUD strategy, a staged WSUD strategy is included to allow early development to occur while arrangements for a trunk drainage manager are being developed. This staged WSUD strategy includes:

- 'Interim' solutions that can comply with the targets without trunk drainage manager measures being implemented (typically these include partial development of an area)
- 'Ultimate' solutions that enable interim solutions to transition to final (i.e. full) development that incorporate trunk drainage manager infrastructure such as precinct/ regional treatment and a reticulated stormwater harvesting system.

The above range of scales for delivery (and hence example WSUD strategies) were based on the needs/questions raised by relevant Local and State Governments ahead of the decision to adopt the stormwater management targets for Wianamatta-South Creek. To further support the delivery of the new stormwater targets and WSUD strategies, the NSW Government commissioned the 'Technical guidance for achieving Wianamatta-South Creek stormwater management targets' (DPE, 2022a). This guidance provides schematics and further technical details for WSUD strategies described in this document.

5. WSUD strategies for Large Format Industrial development

WSUD strategies were assessed for Large Format Industrial (LFI) developments, given that this typology makes up the greatest proportion of the land use in the priority release precincts. This typology also represents the greatest challenge in terms of achieving the stormwater management targets. This is because LFI areas are traditionally characterised with large expanses of roof and ground level impervious areas with limited landscape. Hence, if a WSUD strategy that achieves the stormwater management targets can be developed for a LFI typology, it can also be replicated more easily for other typologies with lower intensity land use.

Table 6 provides a range of possible WSUD strategies for achieving the stormwater management targets for LFI typologies. It is not intended as an exhaustive list of strategies, but rather to provide a range of examples to demonstrate possibilities to comply with the stormwater targets.

Some of the WSUD strategies presented in Table 6 do not include streetscape measures such as street trees for stormwater management, but it should be noted that the strategies do not preclude tree canopy coverage targets being met in different ways. This may include passive irrigation of street tree systems (that divert low flows of stormwater to trees) or irrigation from reticulated recycled stormwater. Where streetscape systems are not required to achieve the stormwater management targets, they have not been included in the WSUD strategies (i.e. their function is not related to stormwater management but rather landscape and cooling). This is because converting a street tree or passively irrigated street tree to a stormwater treatment system (i.e. bioretention tree) is an expensive stormwater solution and should only be considered if necessary.

Table 7 shows the sizes of different stormwater treatment measures contributing to each WSUD strategy, along with the impervious coverage. Sizes were determined in MUSIC, using the model assumptions described in the companion study ‘Wianamatta-South Creek stormwater management targets’ (DPE, 2022d). Other key model assumptions such as those adopted for rainwater harvesting, irrigation and water demands are also available in the companion study. Note that other on-site pollution control systems such as gross pollutant traps (GPTs) and oil spill containment systems are not listed but will be required for most allotments.

Table 6 Example WSUD strategies for Large Format Industrial (LFI) development

WSUD Strategy - LFI		Stormwater Infrastructure Requirements								
		Reduced site coverage	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Regional WSUD (maximise below 1% AEP)	Stormwater Quantity Detention	POS stormwater harvesting	Reticulated regional Stormwater Harvesting
A	Current Targets adopted by Local Government		✓	✓		✓		✓		
B1	Lot and streetscape	✓	✓	✓	✓			✓		
B2	Lot, streetscape and local irrigation	✓	✓	✓	✓			✓		
C1-a	Lot, local public open space and regional treatment (above 1% AEP)	✓	✓	✓	✓	✓		✓		
C1-b	Lot, local public open space and regional treatment (above 1% AEP)	✓	✓	✓	✓	✓		✓		
C2-a	Lot, local public open space and regional treatment (below 1% AEP)	✓	✓	✓	✓		✓	✓		
C2-b	Lot, local public open space and regional treatment (below 1% AEP)	✓	✓	✓	✓		✓	✓		
C3-a	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	✓	✓	✓	✓		✓	✓	✓	
C3-b	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	✓	✓	✓	✓		✓	✓	✓	
C4	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)		✓	✓	✓		✓	✓	✓	
D1-a	Lots, regional treatment and reticulated stormwater reuse		✓	✓			✓	✓		✓
D1-b	Lots, regional treatment and reticulated stormwater reuse		✓				✓	✓		✓
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)						✓	✓		✓
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)						✓	✓		✓
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse		✓	✓	✓		✓	✓		✓
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse		✓	✓	✓		✓	✓		✓

*Differences between the ‘a’ and “b” options are different mixes of wetlands and bioretention systems for treatment – as shown in Table 7.

Table 7 Infrastructure sizes and impervious (imperv) cover for Large Format Industrial (LFI) development WSUD strategies.

WSUD Strategy - LFI		Stormwater Treatment Measures												% Open Space		% Imperv	
		Tanks (kL/ha)	Lot Bioretention (m^2/ha)	Street Biorerention (m^2/ha)	Lot/Precint Wetland (m^2/ha)	Regional Wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater Harvesting on lot storage (m3/ha)	Stormwater Harvesting on lot to irrigation (ML/y/ha)	Stormwater Harvesting to POS storage (m^3/ha)	Stormwater Harvesting (local) to POS Irrigation (ML/y/ha)	Regional Stormwater Harvesting Storage (m^3/ha)	Reticulated Regional Stormwater Harvesting (ML/y/ha)	Local	Regional	Lot	Total
A	Current Targets adopted by Local Government	31	42				40							7.4	7.0	85	72
B1	Lot and streetscape	140	10	35	550									0	0	50	48
B2	Lot, streetscape and local irrigation	14	10	35	550			300	0.7					0	0	60	53
C1-a	Lot, local public open space and regional treatment (above 1% AEP)	104	69	25	500									7.4	7.0	70	62
C1-b	Lot, local public open space and regional treatment (above 1% AEP)	47	56	20	600									5.6	30	85	54
C2-a	Lot, local public open space and regional treatment (below 1% AEP)	104	69	25		500								7.4	7.0	70	62
C2-b	Lot, local public open space and regional treatment (below 1% AEP)	47	56	20		600								5.6	30	85	54
C3-a	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	75	69	24		500				200	0.3			7.4	7.0	75	65
C3-b	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	47	60	14		350				200	0.6			6	20	85	62
C4	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	60	69	24		350				200	0.8			7.4	7.0	85	72
D1-a	Lots, regional treatment and reticulated stormwater reuse	55	24			500						300	1.3	7.4	7.0	85	72
D1-b	Lots, regional treatment and reticulated stormwater reuse	14				200	60					300	1.9	7.4	7.0	85	72
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)					375	60					380	1.6	7.4	7.0	85	72
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)					200	60					380	2.0	7.4	7.0	85	72
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse	55	69			300						300	1.4	7.4	7.0	85	72
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse	55	69	24		150	40					300	1.6	7.4	7.0	85	72

Note that Option B has a 0% open space proportion because it considers a development of only allotments and streets (not public open space)

Options B and C, which represent WSUD strategies that include stormwater treatment measures on allotments, in streetscapes and local parks result in reduced impervious coverage in development areas. The extent varies within a range of 50% to the maximum allowable (85%) impervious cover specified in Development Control Plans for the Western Sydney Aerotropolis and Mamre Rd Precincts. The extent depends on the specific type and size of stormwater treatment measure selected. Option C4 for example, provides for 85% impervious cover, incorporates allotment, streetscape and local public open space (POS) stormwater treatment measures but requires that 100% of (15%) pervious spaces are irrigated by allotment and POS reuse systems (which would need to be confirmed with local authorities).

If a regional treatment and reticulated stormwater reuse system is assumed, WSUD strategies can adopt a variety of stormwater measures along with maximum allowed site imperviousness and achieve the stormwater targets (i.e. the D options). Generally, the precinct/regional treatment and reticulated stormwater treatment options rely less on WSUD on allotment and within streets. WSUD infrastructure at the precinct/regional scale is typically less expensive to construct, has more certainty over ongoing maintenance and is less expensive to maintain than distributed small WSUD systems (see Section 7).

Option D3 is presented as an interim or staged approach to meeting the stormwater management targets until such time as a regional WSUD strategy is available that proponents can connect to. At that time, the full development allowance for a site can be delivered.

Rainwater tanks at Bungarribee. Blacktown City Council.

6. WSUD strategies for High Density Residential development

High Density Residential (HDR) developments are characterised by relatively large populations (e.g. 125 people/ hectare) with multi-storey dwellings set amongst landscaped areas. The non-potable water demands of these typologies provide an opportunity to supply harvested stormwater, and the landscaped surrounds offer a potential to integrate water sensitive urban design elements with multiple functions including treatment, harvesting, cooling and amenity improvements. Local parks in high density residential areas also provide opportunities to integrate water into the urban fabric and increase the blue-green network that is central to the vision for the Western Parkland City.

Careful management of stormwater quantity and quantity is still required to ensure the performance criteria (water quality and flow objectives) for protecting and restoring the blue grid are met. Similar to LFI developments, a challenge for HDR developments is intercepting and using sufficient stormwater to limit the quantity of discharges to meet the stormwater flow targets.

A range of possible WSUD strategies are provided in the following tables (Table 8, 9), which apply depending on the scale of development and whether there is a regional stormwater treatment, harvesting and reticulation system. Two WSUD strategies adopt allotment and streetscape measures only, two strategies use local parks in addition to lots and streetscape measures, and two have regional stormwater treatment combined with a reticulated stormwater reuse system as part of the strategy.

Allotment and streetscape strategies rely on green rooves being implemented to reduce site impervious cover (for at least 70% of the roof area). This also improves amenity and would also contribute to green infrastructure, offering other benefits such as urban cooling and increased biodiversity. HDR developments would not be required to implement green rooves for stormwater management purposes where there is regional treatment and reticulated stormwater reuse system. Green rooves may however, still be adopted to achieve the other liveability and amenity objectives for the Western Parkland City.

The performance of green rooves is modelled in MUSIC as reduced impervious cover of the source node. Similar to the work undertaken for LFI developments, all MUSIC model assumptions for this (HDR) work are provided in the companion study (DPE, 2022d).

Table 8 Example WSUD strategies for High Density Residential (HDR) development

WSUD Strategy - HDR		Stormwater Infrastructure Requirements								
		Reduced site coverage (green roof)	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Stormwater harvesting (local)	Stormwater Quantity Detention	Regional WSUD (maximise below 1% AEP)	Reticulated regional Stormwater Harvesting
A	Current Targets adopted by Local Government					✓		✓		
B1	Lot (wetlands) and streetscape	✓	✓	✓	✓			✓		
B2	Lot (bioretention) and streetscape	✓	✓	✓	✓			✓		
C1	Lot, streetscape and public open space wetland and reuse		✓	✓	✓	✓	✓	✓		
C2	Lot, streetscape and public open space bioretention and reuse		✓	✓	✓	✓	✓	✓		
D1	Lot, street and regional treatment and reticulated stormwater reuse			✓	✓			✓	✓	✓
D2	Regional treatment (bioretention) and reticulated stormwater reuse							✓	✓	✓

Table 9 Infrastructure sizes and impervious (imperv) cover for High Density Residential (HDR) development WSUD strategies

WSUD Strategy - HDR		Stormwater Treatment Measures													% Open Space		% Imperv	
		Green roof (m^2/ha)	Tanks (kL/ha)	Lot Bioretention (m2/ha)	Street Bioretention (m^2/ha)	Lot/Precint Wetland (m^2/ha)	Regional Wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater Harvesting on lot (m^3/ha)	Stormwater Harvesting on lot to irrigation	Stormwater Harvesting to POS (m3/ha)	Stormwater Harvesting (local) to POS	Reticulated Regional Stormwater Harvesting	Reticulated Regional Stormwater Harvesting	Local	Regional	Lot	Total
A	Current Targets adopted by Local Government							80							10	5	70	62
B1	Lot (wetlands) and streetscape	2600	94		41	100			52	0.2					10	5	32	41
B2	Lot (bioretention) and streetscape	2200	94	200	55				52	0.3					10	5	32	41
C1	Lot, streetscape and public open space wetland and reuse		125	5	9	400					60	0.2			10	5	70	62
C2	Lot, streetscape and public open space bioretention and reuse		125	5		150		30			60	0.3			10	5	70	62
D1	Lot, street and regional treatment and reticulated stormwater reuse			5	13		500						200	1.2	10	5	70	62
D2	Regional treatment (bioretention) and reticulated stormwater reuse						150	30					200	1.6	10	5	70	62

7. Costs of delivering WSUD strategies

Costs for delivering the WSUD strategies are based on:

- CAPEX – capital (expenditure) infrastructure costs to construct the stormwater treatment measures, including restoration and stabilisation works within waterway and riparian corridors
- OPEX – operating (expenditure) and maintenance costs for stormwater treatment and harvesting measures
- Land (take) costs associated with the installation of stormwater treatment and harvesting measures
- Recoverable costs that would apply to the regional treatment and reticulated reuse strategy (e.g. from recycled stormwater sales).

Costs have not been attributed to any entity but are a statement of the costs involved across the development life. The purpose of providing cost estimates is to enable a systematic and clear comparison between different strategies. Cost estimates do not include (co-)beneficial costs of protecting and restoring the blue grid, as the decision to deliver the Western Parkland City *via* a landscape led approach is well established in the Western City District Plan, Western Sydney Aerotropolis Plan and associated Western Sydney Aerotropolis Precinct Plan. It is worth noting however, that previous economic valuation studies show the net benefits of protecting and restoring the natural blue grid is over $1 billion (Bennett *et al*., 2015; INSW 2019). These net benefits include those for communities within the Wianamatta-South Creek catchment (e.g. bass fishing, riparian vegetation habitat for birds) and those for communities downstream in the Nepean River and out towards the ocean (e.g. swimming, no infestation of water weeds).

7.1 Cost assumptions

The stormwater treatment measures considered, and their capital cost unit rates are presented in Table 10. The unit rates relate to the wetted footprint of a stormwater treatment measure and these cover all associated costs (including access tracks, batter treatments) except for land costs. The rates have been estimated by using the most recent adopted cost rates by several local authorities, recent industry installations/construction including within Western Sydney and industry best practice guidelines (Melbourne Water, 2013; eWater, 2021; Sydney Water, 2021). The unit costs rates were also confirmed with the independent reviewers of this work, who represent local water and stormwater (engineer) practitioners and professionals from the urban development industry.

Land (take) costs associated with the installation of each stormwater treatment measure is based on the total area needed to construct, access and maintain an asset (not just the wetted footprint). Total land required is assumed to be double the area of the wetted footprint.

Land costs associated with a reduction in impervious area (i.e. reduction in development yield) are also included at the rate identified as ‘Land and opportunity above 1% AEP’ in Table 10. It is assumed that this land would otherwise be developed if it were not required to comply with the new stormwater management targets. Also shown in Table 10 are the cost rates that were assumed for areas below and above a 1% AEP flood level to recognise different land values.

Table 10 CAPEX unit rates assumed for different components of the WSUD strategies

Stormwater Treatment Measure	Unit	CAPEX
WSUD COSTS		
Rainwater tanks	kL	$1,000
Green rooves	m^2	$150
Allotment bioretention	m^2	$1,000
Streetscape bioretention* (or 'biopod') - excludes normal tree costs	m^2	$1,350
Passively irrigated trees - excludes tree costs	each	$300
Precinct/Regional bioretention (above 200m2)	m^2	$500
Wetland (>2000m^2)	m^2	$175
Local stormwater reuse system (e.g. in POS including above ground storages)	ML/y supplied	$100,000
Reticulated stormwater harvesting (SWH) reuse system (including open storages)	ML/y supplied	$30,000
Reticulation pipe network	ha of development	$25,000
Waterway Rehabilitation Costs - full waterway	ha of development	$64,600
Waterway Rehabilitation Costs - part waterway	ha of development	$36,500
LAND COSTS		
Land below 1% AEP	m^2	$90
Land and opportunity above 1% AEP	m^2	$600

* Streetscape bioretention costs do not cover hard edges and grated covers but are assumed to be located in verges with vegetated batters

Streetscape bioretention systems in Table 10 are systems that are constructed in verges with vegetated batters (and can include street trees). These differ from streetscape bioretention systems in more space constrained areas that incorporate vertical sides, structural soils or permanent covers around trees, which are not included because they are much more expensive and generally are not required for greenfield installations.

Passively irrigated street trees are shown as a comparison with streetscape bioretention. The costs per tree include the 'plumbing' (kerb diverter, transfer pipe and sump) but not the cost of the tree or soil.

Reticulation pipe network costs are included as a stormwater cost in the regional treatment and reticulated reuse scheme (Option D) strategies. It is noted that a reticulated pipe may be installed as part of a recycled wastewater network separately, and therefore costs for the pipe may not necessarily be incurred. The pipe costs are however, included here for completeness of a WSUD strategy in the event there is no recycled wastewater system or there is a separate reticulated stormwater reuse network.

Rehabilitation costs for the waterways and riparian corridors were adopted from the Western Sydney Aerotropolis Riparian Corridors Assessment (Sydney Water, 2021), which is largely based on the costs provided for the Western Sydney Place Infrastructure Compact (GSC, 2020). The 'full waterway' works relate to restoration and stabilisation associated with BAU stormwater management, where the hydrologic regime is significantly altered and would not preserve the ecological values of Wianamatta-South Creek. The 'part' waterway works are mainly associated with riparian plantings and some minor armouring, and assume that the flow targets are already being met (resulting in less impact on streams).

Costs for green rooves only account for the 'stormwater components' such as soil, vegetation and drainage pipes. They do not include the building costs such as structural elements.

Land costs for developable land (above 1% AEP) were estimated from Atlas Urban Economics (2020), and those for flood prone land (i.e. below 1% AEP) were estimated from the work of Frontier Economics (2021). It is recognised that property prices are volatile and are subject to change with market forces, however, these estimates provide a realistic interpretation of the impact of required land for stormwater measures on landowners at the time of writing and should be considered as relative.

As indicated above, the footprint of the total land required for stormwater infrastructure is assumed to be double the wetted footprint of a stormwater system (harvesting storages are assumed to be two metres deep). Total land costs are a sum of the footprints required for stormwater treatment systems (excluding allotment and street measures because WSUD systems are integrated without requiring additional land), harvesting storage systems as well as reduced yield on the development site (i.e. any decrease in impervious area compared to a base case of 72% imperviousness for the total development area).

Note that the costs in Table 10 focus on stormwater treatment measures that manage flows, nutrients and sediments. They do not include costs for on lot spill control systems, oil separators or gross pollutant traps (GPT). Costs for GPTs are excluded as there is such a wide range of proprietary products available with hugely varying treatment performances, and few with industry endorsed performance criteria.

Table 11 OPEX unit rates assumed for different components of the WSUD strategies

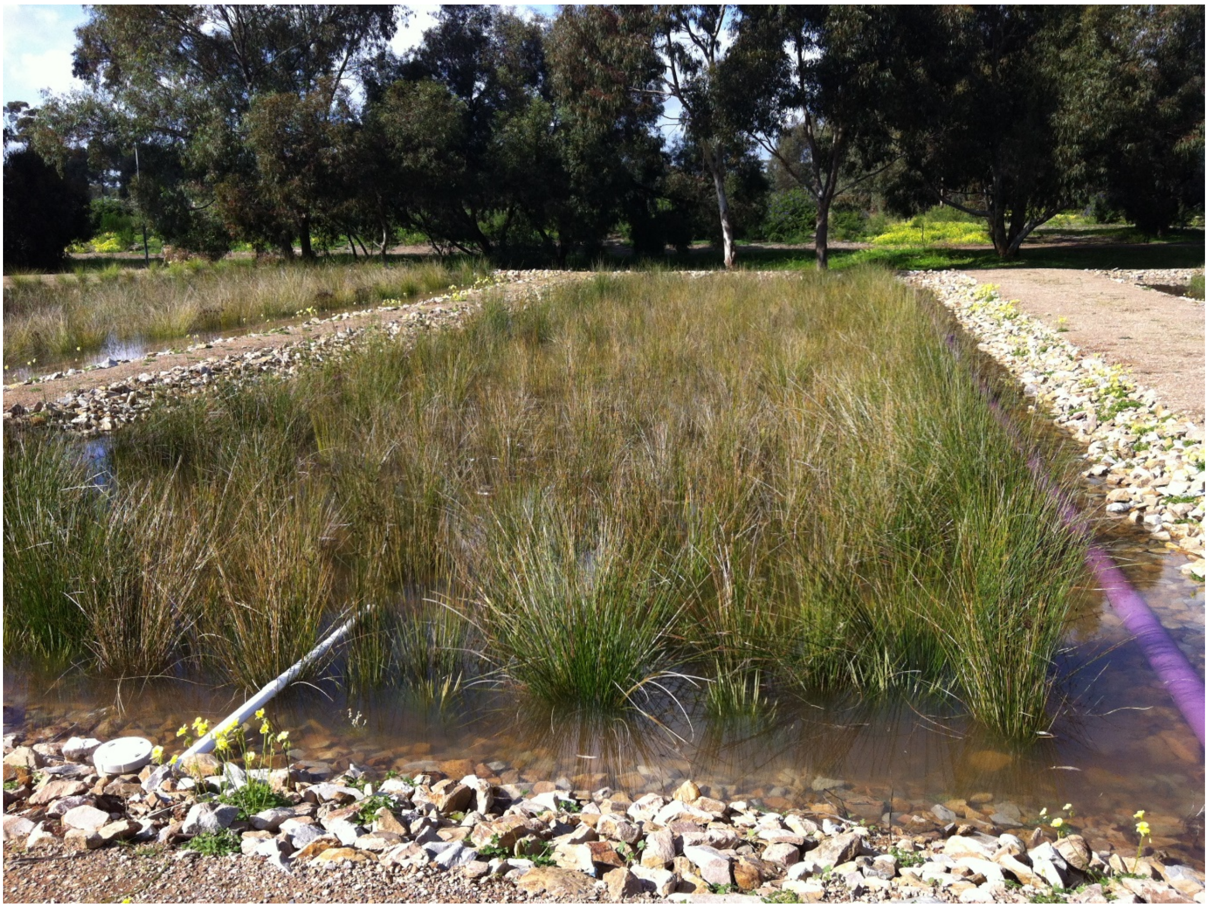
Stormwater Treatment Measure	Unit	Annual Costs
WSUD COSTS		
Rainwater tanks	KL/y	\$10
Allotment bioretention	m^2/y	\$5
Streetscape bioretention (or 'biopod') - excludes normal tree costs	m^2/y	\$50
Precinct/Regional bioretention (above 200m^2)	m^2/y	\$3
Wetland (>2000m2)	m^2/y	\$2
Local stormwater reuse system (e.g. in POS including above ground storages)	ML/y	\$2,250
Reticulated stormwater harvesting reuse system (including storages)	ML/y	\$1,250
WATER REUSE REVENUE		
Sold water	KL	\$2.20

The operating costs shown in Table 11 are based on operating stormwater systems in Australia from commercial (in confidence) projects undertaken by the document authors (Design Flow Consulting Pty Ltd) and then cross checked with rates quoted in industry best practice guidelines (Melbourne Water, 2013; eWater, 2021; Sydney Water, 2021). The unit rates are expressed as dollar figures per unit (as opposed to percentages of CAPEX) to enable direct derivation of operating costs from the scale of the stormwater treatment measures. Operating costs for stormwater harvesting schemes have been derived from a review of operating costs for local scale schemes (e.g. 5-20 ML/year) and then dividing by a typical scale for an oval irrigation scheme (i.e. 10ML/year).

Costs to operate reticulated stormwater harvesting schemes have been based on the City of Salisbury (South Australia) scheme because it is of similar scale to that proposed (by Sydney Water) for Wianamatta-South Creek. The costs reported by previous studies (e.g. Dillon *et al*., 2013; Radcliffe *et al*., 2017) have been factored up (approximately doubled) to account for uncertainties and because it is unlikely to be a managed aquifer scheme.

Stormwater reuse revenue rates were estimated from discussions with City of Salisbury. The unit rates are conservative because the configuration of a reticulated stormwater reuse scheme in Wianamatta-South Creek is unknown.

The photograph below shows a bioretention system in the City of Salisbury at a site (Unity Park) that harvests more than 600ML of stormwater each year for reuse.



Salisbury Water harvesting bioretention system (Unity Park). Design Flow Consulting

7.2 Cost comparisons

Using the unit rates shown in Table 10 and Table 11, cost estimates are calculated for each strategy using the infrastructure sizes outlined in Table 7 (LFI) and Table 9 (HDR). Note that Option A does not achieve the stormwater management targets and will result in waterway degradation and is only included for information and transparency. Example layouts of selected WSUD strategies are illustrated in the companion study (DPE, 2022a) to demonstrate how the stormwater infrastructure may interact with other elements of a development.

It is quite evident from the plots (e.g. Figures 1, 2) that regional treatment and reticulated stormwater reuse strategies (i.e. Option D) represent the most cost-effective approach for delivering the stormwater management targets. Connecting harvested stormwater to high water users *via* a reticulated stormwater reuse scheme is the most cost-effective method of losing excess stormwater to protect the waterways and achieving the Western Parkland City vision, with the added benefit of conserving potable water for potable uses.

The benefit of the regional treatment and reticulated reuse strategy is emphasised further when land costs (Figure 2) are considered in comparison. The cost of land associated with the reduced imperviousness is significant in Options B and C (except Option C4).

Option C4 (i.e. using lot, local POS and regional treatment within the 1% AEP area) is also shown as a potentially viable option in Figure 2. However, it is worth noting this option requires 100% of the pervious area of allotments and 100% of POS pervious areas to be irrigated (i.e. to create a sufficiently large irrigation demand). The viability and ongoing commitment to such an extensive irrigation scheme would need to be thoroughly investigated and agreed upon with a local authority for POS and conditioned as part of approval for private allotments.

Operational costs are presented in Tables 14 and 15, and show the benefit of revenue of the sale of harvested stormwater in the reticulated stormwater schemes (Option D). In fact, this revenue outweighs the operational costs for several of the D Options for LFI development and Option D2 for the HDR development.

Table 12 Capital cost estimates of WSUD and land for Large Format Industrial (LFI) developments (* POS denotes public open space)

WSUD Strategy - HDR		Stormwater Treatment Measures										Land Costs			
		Tanks ($/ha)	Lot Bioretention ($/ha)	Street Bioretention ($/ha)	Regional Wetland ($/ha)	Regional bioretention ($/ha)	Stormwater harvesting on lot ($/ha)	Stormwater harvesting for POS ($/ha)	Regional harvesting & reticulation ($/ha)	Waterway rehabilitation ($/ha)	WSUD COST TOTAL ($/ha)	Above 1% AEP ($/ha)	Below 1% AEP ($/ha)	TOTAL LAND COST ($/ha)	WSUD + LAND TOTAL ($/ha)
A	Current Targets adopted by Local Government	$31,000	$42,000			$20,000				$64,600	$157,600	$48,000		$48,000	$205,600
B1	Lot and streetscape	$140,000	$10,200	$47,250	$96,250					$36,500	$330,200	$1,440,000		$1,440,000	$1,770,200
B2	Lot, streetscape and local irrigation	$14,000	$10,200	$47,250	$96,250		$70,000			$36,500	$274,200	$1,140,000		$1,140,000	$1,414,200
C1-a	Lot, local POS and regional treatment (above 1% AEP)	$103,700	$69,300	$33,075	$87,500					$36,500	$330,075	$1,200,000		$1,200,000	$1,530,075
C1-b	Lot, local POS* and regional treatment (above 1% AEP)	$47,000	$55,800	$26,595	$105,000					$36,500	$270,895	$1,800,000		$1,800,000	$2,070,895
C2-a	Lot, local POS and regional treatment (below 1% AEP)	$103,700	$69,300	$33,750	$87,500					$36,500	$330,750	$600,000	$90,000	$690,000	$1,020,750
C2-b	Lot, local POS and regional treatment (below 1% AEP)	$47,000	$55,800	$26,595	$105,000					$36,500	$270,895	$1,080,000	$108,000	$1,188,000	$1,458,895
C3-a	Lot, local POS and regional treatment and POS irrigation (below 1% AEP)	$75,000	$69,300	$32,940	$87,500			$30,000		$36,500	$331,240	$420,000	$108,000	$528,000	$859,240
C3-b	Lot, local POS and regional treatment and POS irrigation (below 1% AEP)	$47,000	$59,600	$18,900	$61,250			$60,000		$36,500	$283,250	$600,000	$81,000	$681,000	$964,250
C4	Lot, local POS and regional treatment and POS irrigation (below 1% AEP)	$60,000	$69,300	$32,940	$61,250			$76,000		$36,500	$335,990		$81,000	$81,000	$416,990
D1-a	Lots, regional treatment and reticulated stormwater reuse	$55,300	$24,300		$87,500				$64,600	$36,500	$268,200		$117,000	$117,000	$385,200
D1-b	Lots, regional treatment and reticulated stormwater reuse	$14,000			$35,000	$30,000			$80,500	$36,500	$196,000		$73,800	$73,800	$269,800
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)				$65,625	$30,000			$73,000	$36,500	$205,125		$112,500	$112,500	$317,625
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)				$35,000	$30,000			$84,100	$36,500	$185,600		$81,000	$81,000	$266,600
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse	$55,300	$69,300		$52,500				$66,700	$36,500	$280,300		$81,000	$81,000	$361,300
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse	$55,300	$69,300	$32,940	$26,250	$20,000			$71,500	$36,500	$311,790		$61,200	$61,200	$372,990

Table 13 Capital cost estimates of WSUD and land for High Density Residential (HDR) development WSUD strategies. (* POS denotes public open space).

WSUD Strategy - HDR		Stormwater Treatment Measures												Land Costs			
		Green Roof ($/ha)	Tanks ($/ha)	Lot Bioretention ($/ha)	Lot Wetland ($/ha)	Street Bioretention ($/ha)	Regional Wetland ($/ha)	Regional bioretention ($/ha)	Stormwater harvesting on lot ($/ha)	Stormwater harvesting for POS ($/ha)	Regional harvesting & reticulation ($/ha)	Waterway rehabilitation ($/ha)	WSUD COST TOTAL ($/ha)	Above 1% AEP ($/ha)	Below 1% AEP ($/ha)	TOTAL LAND COST ($/ha)	WSUD + LAND TOTAL ($/ha)
A	Current Targets adopted by Local Government							$40,000				$64,600	$104,600	$96,000		$96,000	$200,600
B1	Lot (wetlands) and streetscape	$390,000	$94,000		$30,000	$55,350			$52,000			$36,500	$657,850				$657,850
B2	Lot (bioretention) and streetscape	$330,000	$94,000	$200,000		$73,575			$52,000			$36,500	$786,075				$786,075
C1	Lot, streetscape and POS* wetland & reuse		$125,000	$5,000		$12,150	$70,000			$22,000		$36,500	$270,650	$516,000		$516,000	$786,650
C2	Lot, streetscape and POS bioretention and reuse		$125,000	$5,000			$26,250	$15,000		$27,000		$36,500	$234,750	$252,000		$252,000	$486,750
D1	Lot, street & regional treatment and reticulated stormwater reuse			$5,000		$16,875	$87,500				$61,000	$36,500	$206,875		$108,000	$108,000	$314,875
D2	Regional treatment (bioretention) and reticulated stormwater reuse						$26,250	$15,000			$73,000	$36,500	$150,750		$50,400	$50,400	$201,150

Table 14 Operating cost estimates of WSUD for Large Format Industrial (LFI) developments. (* POS denotes public open space).

WSUD Strategy - LFI		**Maintenance Costs ($/ha/year)**										
		Tanks	Lot bioretention	Street bioretention	Wetland	Regional bioretention	Stormwater harvesting for lot irrigation	Stormwater Harvesting for POS irrigation	Reticulated regional stormwater harvesting	TOTAL ($//ha/year)	Water sales ($/ha/year)	NET TOTAL ($/ha/year)
A	Current Targets adopted by Local Government	$310	$210			$120				$640		$640
B1	Lot and streetscape	$1,400	$51	$1,750	$1,100					$4,301		$4,301
B2	Lot, streetscape and local irrigation	$140	$51	$1,750	$1,100		$1,575			$4,616		$4,616
C1-a	Lot, local public open space and regional treatment (above 1% AEP)	$1,037	$347	$1,225	$1,000					$3,609		$3,609
C1-b	Lot, local public open space and regional treatment (above 1% AEP)	$470	$279	$985	$1,200					$2,934		$2,934
C2-a	Lot, local public open space and regional treatment (below 1% AEP)	$1,037	$347	$1,250	$1,000					$3,634		$3,634
C2-b	Lot, local public open space and regional treatment (below 1% AEP)	$470	$279	$985	$1,200					$2,934		$2,934
C3-a	Lot, local public open space and regional treatment & POS* irrigation (below 1% AEP)	$750	$347	$1,220	$1,000			$675		$3,992		$3,992
C3-b	Lot, local public open space and regional treatment & POS irrigation (below 1% AEP)	$470	$298	$700	$700			$1,350		$3,518		$3,518
C4	Lot, local public open space and regional treatment & POS irrigation (below 1% AEP)	$600	$347	$1,220	$700			$1,710		$4,577		$4,577
D1-a	Lots, regional treatment and reticulated stormwater reuse	$553	$122		$1,000				$1,650	$3,325	-$2,904	$421
D1-b	Lots, regional treatment and reticulated stormwater reuse	$140			$400	$180			$2,313	$3,033	-$4,070	-$1,038
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)				$750	$180			$2,000	$2,930	-$3,520	-$590
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)				$400	$180			$2,463	$3,043	-$4,334	-$1,292
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse	$553	$347		$600				$1,738	$3,237	-$3,058	$179
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse	$553	$347	$1,220	$300	$120			$1,938	$4,477	-$3,410	$1,067

Table 15 Operating cost estimates of WSUD for High Density Residential (HDR) development WSUD strategies. (* POS denotes public open space).

WSUD Strategy - HDR		Maintenance Costs ($/ha/y)										
		Tanks	Lot bioretention	Street bioretention	Wetland	Regional bioretention	Stormwater harvesting for lot irrigation	Stormwater Harvesting for POS irrigation	Reticulated regional stormwater harvesting	TOTAL ($/ha/year)	Water sales ($/ha/y)	NET TOTAL ($/ha/y)
A	Current Targets adopted by Local Government					$240				$240		$240
B1	Lot (wetlands) and streetscape	$940		$2,050	$200		$405			$3,595		$3,595
B2	Lot (bioretention) and streetscape	$940	$1,000	$2,725			$698			$5,363		$5,363
C1	Lot, streetscape and POS wetland & reuse	$1,250	$25	$450	$800			$495		$3,020		$3,020
C2	Lot, streetscape and POS bioretention & reuse	$1,250	$25		$300	$90		$608		$2,273		$2,273
D1	Lot, street & regional treatment and reticulated stormwater reuse		$25	$625	$1,000				$1,500	$3,150	-$2,640	$510
D2	Regional treatment (bioretention) and reticulated stormwater reuse				$300	$90			$2,000	$2,390	-$3,520	-$1,130

Note that operating for green rooves are assumed to be included with landscape maintenance (not included here)

Figure 1 shows plots of the CAPEX for the LFI development WSUD strategies, and Figure 2 includes the OPEX and land costs. OPEX represents the net present value by assuming a 35y life cycle and 2% discount rate. The distinct differences among the approaches are evident, in particular, the land costs associated with reducing the site coverage in Options B and C.

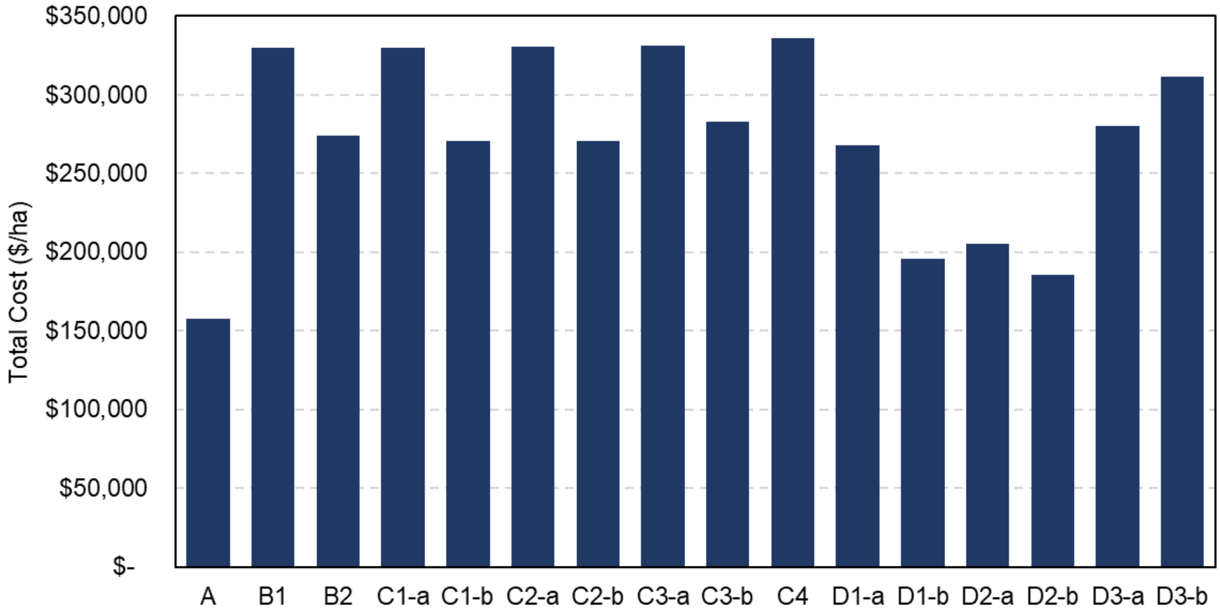


Figure 1 Capital (CAPEX) cost of WSUD strategies for Large Formal Industrial development

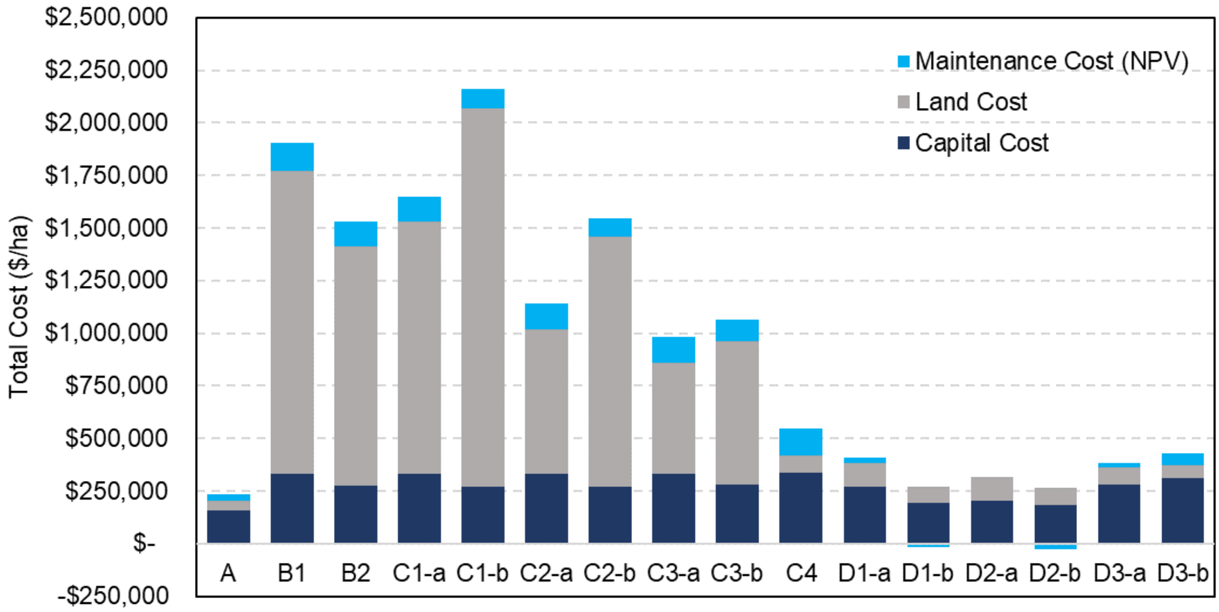


Figure 2 Capital (CAPEX), maintenance (OPEX) and land costs of WSUD strategies for Large Formal Industrial development

Figure 3 shows plots of the CAPEX for the HDR development WSUD strategies, and Figure 4 includes the OPEX and land costs. Note there are no land costs associated with Option B1 and B2 because green rooves are adopted, and therefore the lots can be fully developed. The plots show that Option D has the lowest combined costs, noting that Option A does not meet the stormwater management targets and will not protect and restore the blue grid.

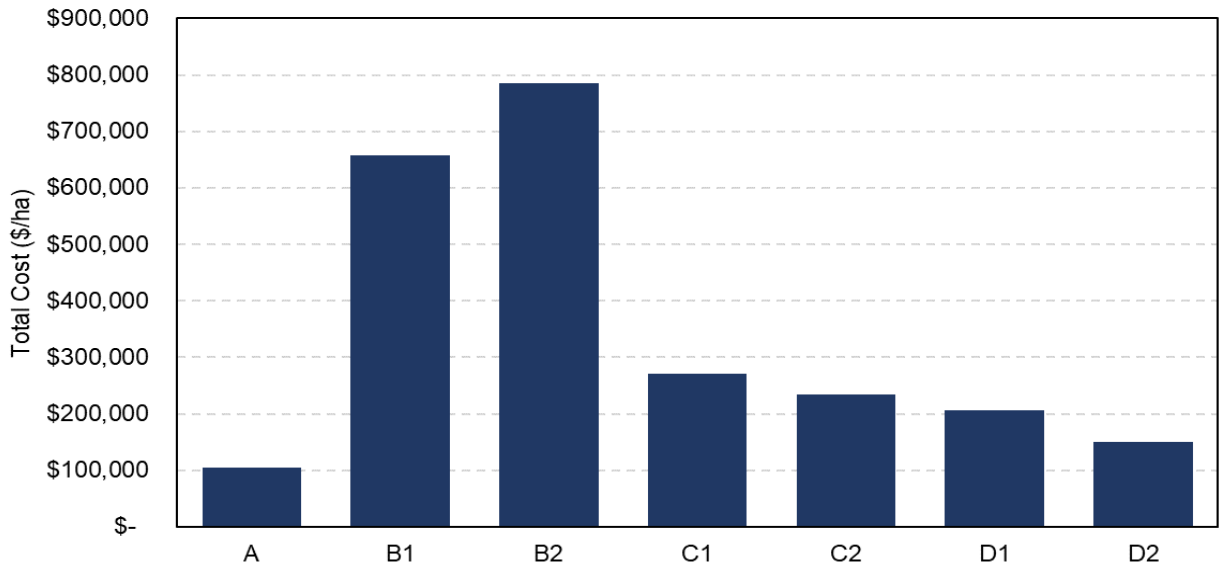


Figure 3 Capital (CAPEX) cost of WSUD strategies for High Density Residential development

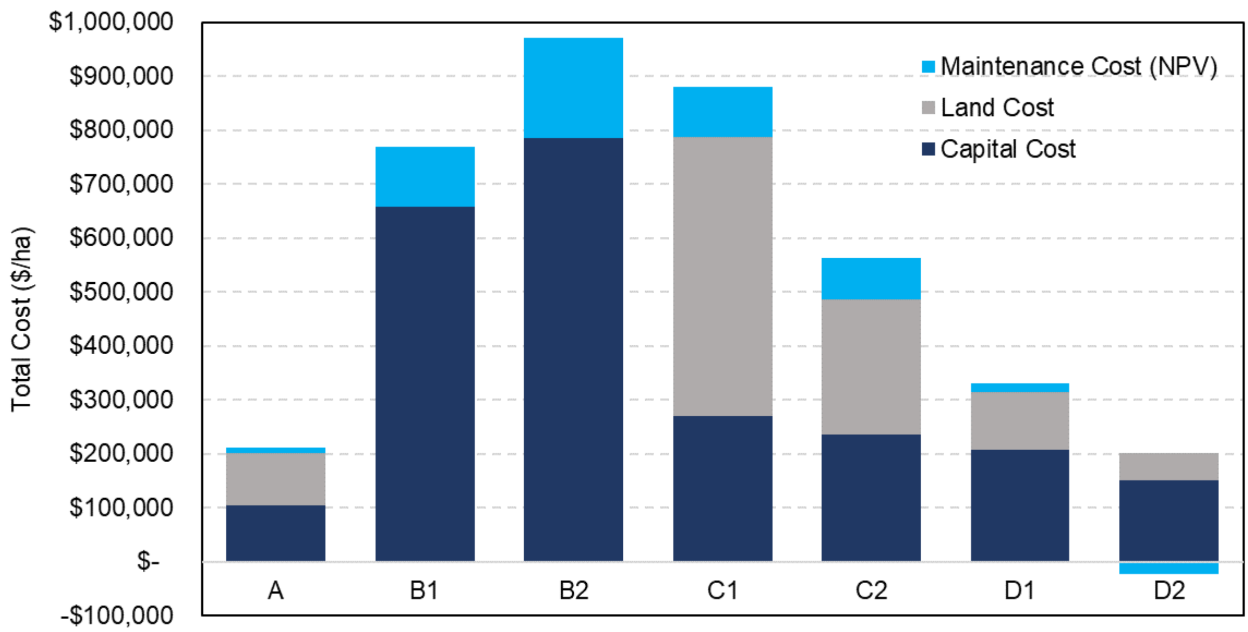


Figure 4 Capital (CAPEX), maintenance (OPEX) and land costs of WSUD strategies for High Density Residential development

7.3 Operational risks

Tables 16 and 17 describe some of the operation and management risks associated with the different WSUD strategies. The risks relate to implementation and operation of the WSUD systems discussed in this document and the resulting potential impact to the blue grid. It is noted again that land uses will also have other on-lot measures, such as GPTs and oil capture systems (particularly for LFI land uses), however, these do not relate to comparing between the stormwater schemes discussed here.

In general, the more WSUD assets that are used, particularly in private ownership, the higher the risk for the long-term delivery of stormwater management outcomes. A strategy which relies on many distributed/decentralised WSUD assets will require all proponents to design and deliver the WSUD infrastructure, and then owners to manage the assets effectively. This includes a need for auditing and compliance checks of the WSUD assets. WSUD strategies that have fewer assets and a defined owner (e.g. a Trunk Drainage Manger) are considered to have less long-term risks of failure and consequential negative impacts on the blue grid. Indeed, the qualitative assessment of risks shown in Tables 16 and 17 is consistent with the lowest cost strategies that incorporate a Trunk Drainage Manger to operate a regional treatment and reticulated stormwater reuse system that is plumbed throughout the development areas to all allotments.

Human health risks associated with any stormwater reuse scheme are important considerations for the design and operation of the system. It is assumed that any stormwater reuse scheme in a public domain would follow the requirements of the Australian Stormwater Recycling Guidelines (NRMMC *et al.*, 2009) which outline requirements to adequately manage health risks. A similar conclusion could be drawn when assessing human health risks among between schemes – that is, fewer (larger) systems with defined owners and operators present fewer risks than many distributed/decentralised systems.

Table 16 **R**isks of impacting the blue grid as a result of operation and maintenance requirements for Large Format Industrial developments. The blue grid is made of waterways, riparian corridors and other water dependent ecosystems

WSUD Strategy - LFI		Stormwater Infrastructure Requirements									Risk	Description of Risk
		Reduced site coverage	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Regional WSUD (maximise below 1% AEP)	On-site Stormwater Quantity Detention	POS stormwater harvesting	Reticulated regional Stormwater Harvesting		
A	A. Current Targets adopted by Local Government		✓	✓		✓		✓			HIGH	Performance criteria (water quality and flow objectives) for blue grid not met, resulting in negative impacts
B1	Lot and streetscape	✓	✓	✓	✓	✓		✓			HIGH	Relies on allotment WSUD requiring comprehensive compliance and regulation, and maintenance of distributed street bioretention
B2	Lot, streetscape and local irrigation	✓	✓	✓	✓	✓		✓			HIGH	Relies on allotment WSUD requiring comprehensive compliance and regulation, and maintenance of distributed street bioretention
C1-a, b	Lot, local public open space and regional treatment (above 1% AEP)	✓	✓	✓	✓	✓		✓			HIGH	Relies on allotment WSUD requiring comprehensive compliance and regulation, and maintenance of distributed street bioretention and local stormwater harvesting scheme
C2-a, b	Lot, local public open space and regional treatment (below 1% AEP)	✓	✓	✓	✓		✓	✓			HIGH	Relies on allotment WSUD requiring comprehensive compliance and regulation, and maintenance of distributed street bioretention and local stormwater harvesting scheme
C3-a, b	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	✓	✓	✓	✓		✓	✓	✓		HIGH	Relies on allotment WSUD, and maintenance of distributed street bioretention and POS reuse schemes
C4	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)		✓	✓	✓		✓	✓	✓		HIGH	Less reliant on allotment measures and lot harvesting, but relies on and maintenance of streetscape bioretention, public open space reuse systems and very high proportions of irrigated area
D1-a	Lots, regional treatment and reticulated stormwater reuse		✓	✓			✓	✓		✓	LOW	Minimal allotment WSUD, no streetscape WSUD, Trunk Drainage Manager for regional systems and reticulated reuse
D1-b	Lots, regional treatment and reticulated stormwater reuse		✓				✓	✓		✓	LOW	Tanks on allotments, no streetscape WSUD, Trunk Drainage Manager for regional systems and reticulated reuse
D2-a, b	Regional treatment and reticulated stormwater reuse (no tanks)		✓				✓	✓		✓	LOW	No allotment or streetscape WSUD, Trunk Drainage Manager for regional systems and reticulated reuse
D3-a, b	Lots and streetscape with regional treatment and reticulated stormwater reuse		✓	✓	✓		✓	✓		✓	LOW - MODERATE	Relies on some allotment and streetscape WSUD, Trunk Drainage Manager for regional systems and reticulated reuse

Table 17 Example WSUD strategies for High Density Residential (HDR) development

WSUD Strategy - HDR		Stormwater Infrastructure Requirements									Risk	Description of Risk
		Reduced site coverage (green roof)	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Stormwater harvesting (local)	On-site Stormwater Quantity Detention	Regional WSUD (maximise below 1% AEP)	Reticulated regional Stormwater Harvesting		
A	Current Targets adopted by Local Government		✓	✓	✓	✓		✓			HIGH	Performance criteria (water quality and flow objectives) for blue grid not met, resulting in negative impacts
B1	Lot (wetlands) and streetscape	✓	✓	✓	✓			✓			HIGH	Relies on allotment WSUD (including reuse) requiring comprehensive compliance and regulation and maintenance of distributed street bioretention
B2	Lot (bioretention) and streetscape	✓	✓	✓	✓			✓			HIGH	Relies on allotment WSUD (including reuse) requiring comprehensive compliance and regulation and maintenance of distributed street bioretention
C1	Lot, streetscape and public open space wetland & reuse		✓	✓	✓	✓	✓	✓			HIGH	Relies on allotment WSUD, distributed street bioretention and maintenance of local public open space reuse schemes
C2	Lot, streetscape and public open space bioretention and reuse		✓	✓	✓	✓	✓	✓			HIGH	Relies on allotment WSUD, distributed street bioretention and maintenance of local public open space reuse schemes
D1	Lot, street and regional treatment and reticulated stormwater reuse			✓	✓			✓	✓	✓	LOW - MODERATE	Relies on some allotment and streetscape WSUD, Trunk Drainage Manager for regional systems and reticulated reuse
D2	Regional treatment (bioretention) and reticulated stormwater reuse							✓	✓	✓	LOW	No allotment or streetscape WSUD, Trunk Drainage Manager for regional systems and reticulated reuse

8. Case study – regional WSUD strategy

To illustrate the potential implementation of a WSUD strategy in the Wianamatta-South Creek catchment, a hypothetical case study was developed for the Mamre Road Precinct. The case study assumes that a regional treatment and reticulated stormwater reuse scheme is implemented (i.e. Option D). The case study provides a high-level concept layout for required treatment systems and reuse storages distributed across the precinct, for illustrative purposes only.

The approach makes use of the multifunctional intention of the Blue and Green Infrastructure Framework along Wianamatta-South Creek and Ropes Creeks (i.e. outside significant vegetation areas). The stormwater treatment measures are located within the 1% AEP flood extents, while ensuring that flood behaviour is not compromised (see Floodplain Development Manual, and principles in our technical guide – DPE, 2022a) .

8.1 Site description

The Mamre Road Precinct and approximate stormwater catchment is shown in Figure 5. The precinct site has a ridge running roughly north-south, meaning that stormwater will flow either westwards into Wianamatta-South Creek or eastwards into Ropes Creek.

The dominant typology in the Mamre Road Precinct is Large Formal Industrial development. The MUSIC model assumptions relating to this typology are outlined in our companion study (DPE 2022a), and were adopted for the case study. The most significant characteristic of the assumptions is the 85% impervious cover in the allotments, consistent with the Mamre Rd Precinct Development Control Plan.

8.2 Proposed treatment and reuse system description

The WSUD strategy adopted for the case study is based on the Option D1-b for Large Format Industrial area (Table 6), and water demand and irrigation rates from DPE (2022a). This WSUD strategy assumes:

- Tanks on individual allotments to capture 50% of roof areas and supply water for toilet flushing (14KL tanks with 375L/day demands per hectare of development)
- Regional wetland systems that are 2% of the catchment areas, with a small rate of treated flow released to meet environmental flow needs of the waterways
- Regional bioretention systems at 0.6% of the catchment area that share extended detention with the wetland system
- The regional treatment systems are located in public open space (managed by a trunk drainage manager) and in the 1%AEP area where possible
- Treated water from the treatment system is directed to a storage, as part of a broader stormwater harvesting scheme
- The regional water storage systems are sized to be 300m^3 per hectare and have a constant daily demand of 6.25 KL/ day per hectare, as part of a regional reticulated reuse system.

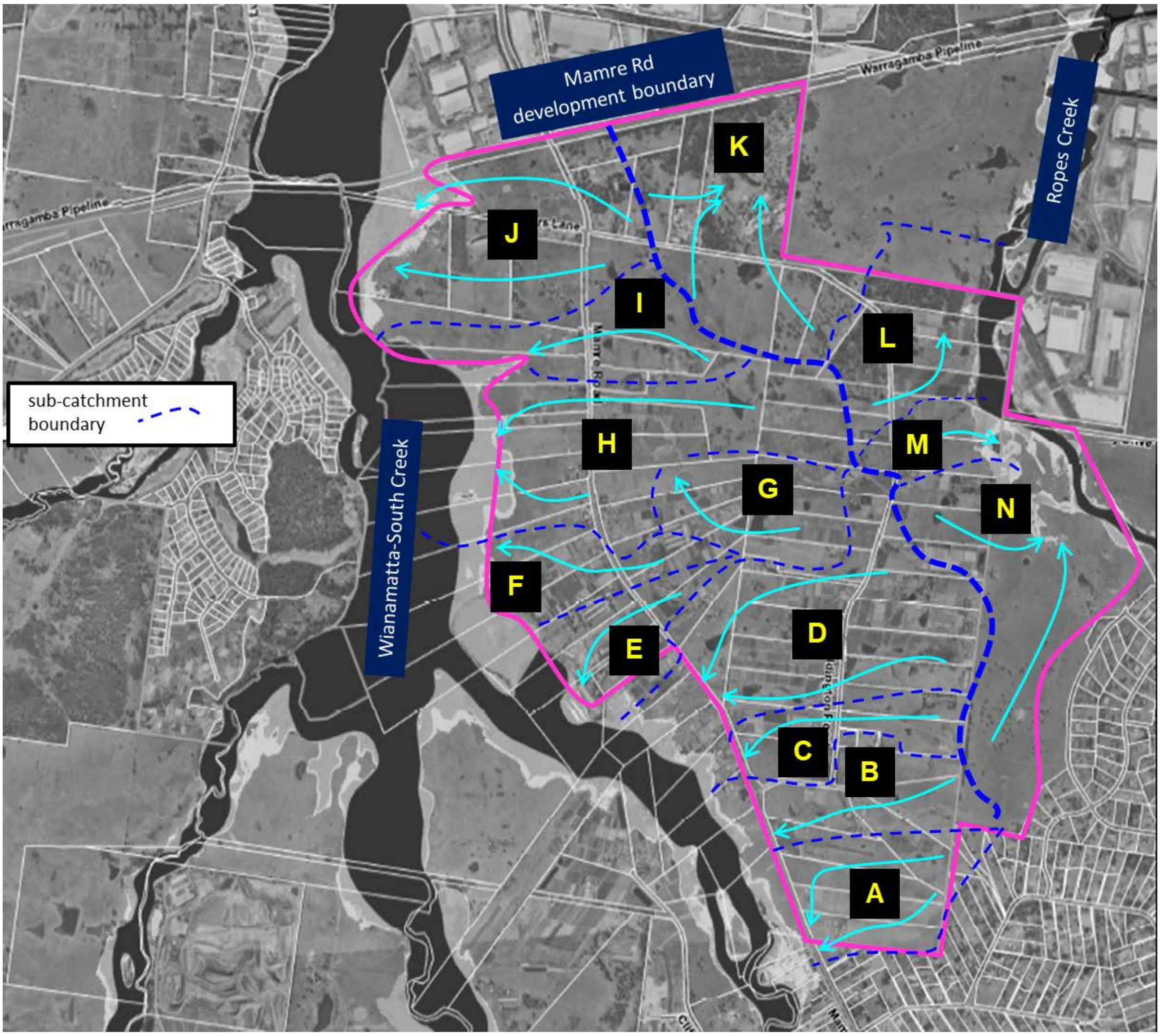


Figure 5 Capital (CAPEX), maintenance (OPEX) and land costs of WSUD strategies for High Density Residential development

The intent is that the treatment systems and storages are located within the 1% AEP areas if there is sufficient available space. Another design approach is to limit the sub-catchment areas to each treatment system to approximately 150 hectares so that the size of the systems are not too large and the risk of damage caused from spills is spread such that if one treatment system is off-line it will not significantly affect the overall treatment and reuse system. This approach results in some treatment systems being located above the 1% AEP in the development area.

In addition to the above requirements, each lot would be required to meet on-site detention requirements as well as gross pollutant capture and possibly oil spill containment, depending on the land use type.

Table 18 provides a list of sub-catchments and sizes of respective stormwater treatment measures.

Table 18 Sub-catchments making up the Mamre Road Precinct, and sizes of respective stormwater treatment measures

Sub-catchment	Area (ha)	Wetland (m^2)	Bioretention (m^2)
A	100	20,000	6,000
B	50	10,000	3,000
C	40	8,000	2,400
D	160	32,000	9,600
E	35	7,000	2,100
F	50	10,000	3,000
G	90	18,000	5,400
H	120	24,000	7,200
I	50	10,000	3,000
J	115	23,000	6,900
K	100	20,000	6,000
L	25	5,000	1,500
M	30	6,000	1,800
N	100	20,000	6,000
TOTAL	1,065	213,000	63,900

The storages have been consolidated to have one storage in the west (Wianamatta-South Creek – 243ML) and one in the east (Ropes Creek – 77ML). Treated stormwater would be pumped or gravity fed from the treatment systems to these storages that would then connect to a broader reuse scheme and potentially be combined with treated wastewater. This means that each storage in this example would not require its own treatment plant as it would transfer flows to separate storages (and treatment plant) as part of a broader scheme.

An indicative layout of the regional treatment and reuse storages is shown in Figure 6. It shows how the majority of the treatment and storage systems are located along the edge of the development and are within the 1% AEP areas.

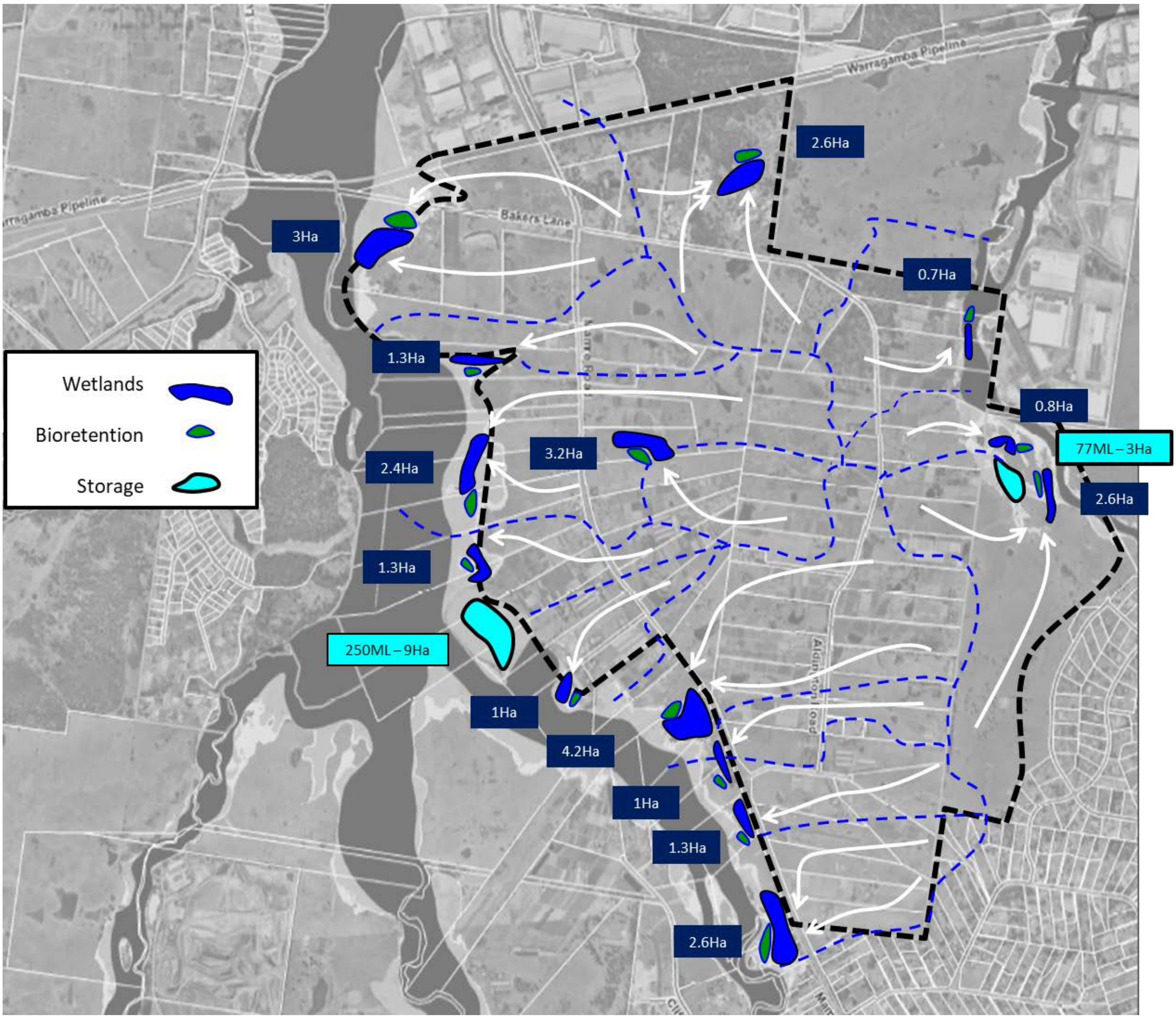


Figure 6 Indicative layout for the case study showing the sub-catchments, treatments and reuse storages

8.3 System performance

The system performance of the above WSUD strategy was modelled and analysed using the calibrated MUSIC file and post processing excel spreadsheet provided with our companion study (i.e. technical guide - DPE, 2022a). Specifically, the model is used to generate daily flows, and the spreadsheet to develop flow-duration curves and assess compliance with the targets. Tables 19 and 20 were directly produced from the spreadsheet. They show the modelled results of stormwater quality and quantity, compared against the respective targets. These results indicate that the WSUD strategy achieves both targets. Figure 7 shows the flow duration curve, which was also directly produced from the spreadsheet.

Table 19 Modelled stormwater quality compared against target

Water Quality Targets Alternative 1			
Parameter	Result	Comply	Target
TSS	94	Yes	>90% load reduction
TP	85	Yes	>80% load reduction
TN	74	Yes	>65% load reduction

Table 20 Modelled stormwater quantity (flow) compared against target

Flow Targets Alternative 1			
Parameter	Result	Comply	Target
95%ile	13196	Yes	3000 to 15000 L/ha/day
90%ile	1769	Yes	1000 to 5000 L/ha/day
75%ile	916	Yes	100 to 1000 L/ha/day
50%ile	32	Yes	5 to 100 L/ha/day
Cease to Flow	12%	No	10-30%

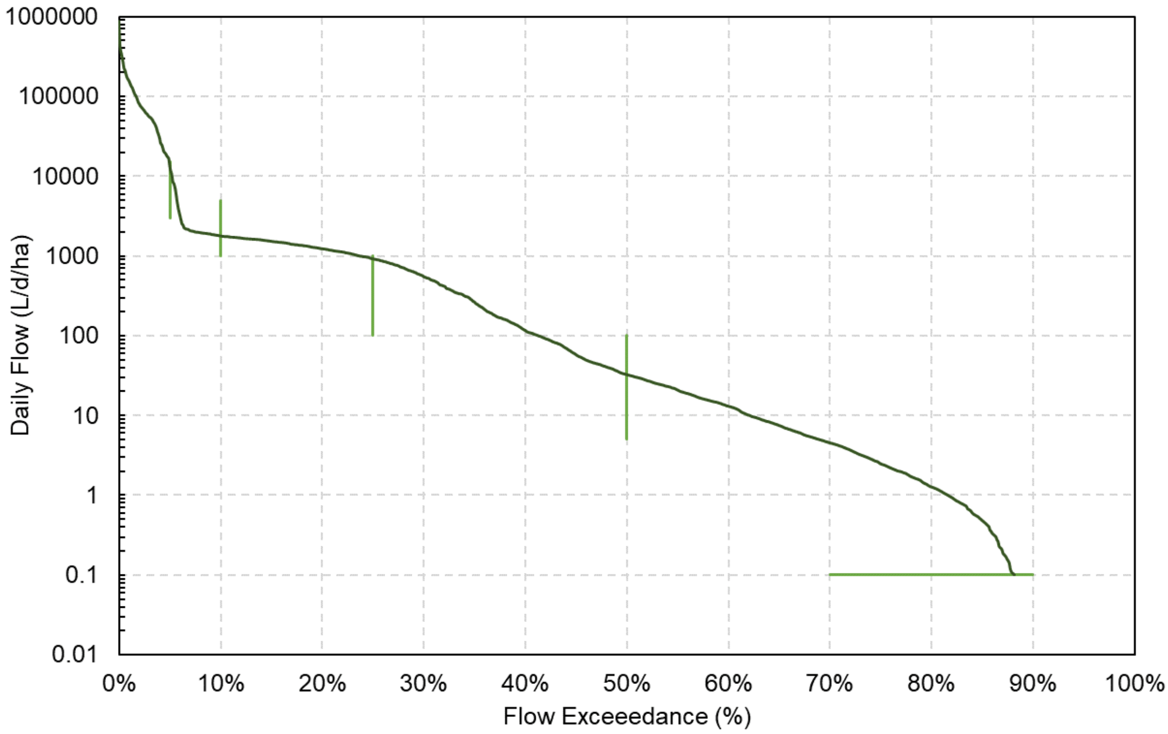


Figure 7 Flow duration curve for proposed WSUD Strategy

Overall, the modelling results indicate the following water balance estimates:

- 4,800 ML/year of runoff is generated
- 135 ML/year is used for toilet flushing
- 645 ML/year is lost to evaporation from wetlands, bioretention and storages
- 25 ML/year is lost to seepage
- 1,785 is used through the reticulated stormwater reuse system
- 2,210 ML/year is released back to Wianamatta-South Creek.

It is also worth noting that while approximately 1,800ML/year will be reused through the reticulated stormwater reuse system, this could be increased to up to 2,400ML/year if further demands are found outside of the case study area or larger storages were used. In the current scenario the storages overflow approximately 600 ML/year to the waterways which could be reduced if the storages were made larger or if there were more demands on the reuse system.

8.4 WSUD cost estimates

The costs for this WSUD strategy were estimated using the unit rates shown Table 10. Construction cost estimates are presented in Table 21 for the type and scale of infrastructure needed to meet the targets.

Table 22 presents an estimate of the land costs associated with the WSUD infrastructure. The land required was estimated by doubling the water surface area to account for other land requirements such as batters, bunds and access tracks. The water storages were assumed to have an average depth of 2m.

Land costs are estimated for infrastructure located above and below the 1% AEP as it will have different values, as indicated in Table 10.

Table 21 Cost estimates for the stormwater treatment measures

Stormwater Treatment Measure	Unit	Rate	Quantity	Costs ($M*)
Rainwater tanks	kL	1,000	14,910	14.9
Regional wetlands	m^2	175	213,000	37.3
Regional bioretention	m^2	500	63,900	32.0
Reuse storage and treatment	ML	30,000	1,800	54.0
Reticulation	ha	25,000	1,065	26.6
Waterway rehabilitation	ha	36,500	1,065	38.9
		TOTAL CAPEX	$M	204
		CAPEX PER HA	$/ha	191,204

*$M denotes million

Table 22 Estimated land (take) costs associated with the installation of stormwater treatment measures

Land take area	Wetted Area (m^2)	Total Area Required (m^2)	Rate ($\$/m^2$)	Costs ($M*)
Treatment areas below 1% AEP	253,500	507,000	90	45.6
Treatment areas above 1% AEP	23,400	46,800	600	28.1
Storage areas below 1% AEP	319,500	319,500	90	28.8
		TOTAL LAND COST	$M	102
		LAND COST PER HA	$/Ha	96,211

*$M denotes million

Operation costs for the WSUD are shown in Table 23. The costs to operate and maintain the stormwater treatment and reuse systems is approximately $2,800 per hectare each year. This cost is outweighed by the revenue from stormwater sales so that the net operation costs are a revenue of approximately $900 per hectare each year, equivalent to $940,000 per year for the total case study area.

Table 23 Estimated operation costs and stormwater sales revenue

Stormwater Treatment Measure	Unit	Rate	Quantity	Costs ($/y)
Rainwater tanks	$/kL	10	14,910	149,100
Regional wetlands	$\$/m^2/y$	2	213,000	426,000
Regional bioretention	$\$/m^2/y$	3	63,900	191,700
Reuse storage and treatment	$/ML/y	1,250	1,800	2,250,000
Stormwater reuse sales	$/ML/y	-2,200	1,800	-3,960,000
		TOTAL OPEX	$/y	-943,200
		OPEX PER HA	$/ha/y	-886

8.5 Case study outcomes

This case study indicates that a combined cost of WSUD infrastructure and waterway rehabilitation is $191,000 per hectare if a regional treatment and reticulated reuse system is implemented. This cost includes $14,000 per hectare for on allotment rainwater tanks with the remainder of the costs being subdivision scale works. This is very similar to the rates presented for Option D1-b (Table 12).

The treatment and storage systems would require approximately 87 hectares of land and costs associated with land acquisition equate approximately to an additional $96,000 per hectare. This rate is higher than Option D1-b ($76,000/ha) because some of the treatment systems are in areas above 1% AEP which have significantly higher land costs (Option D1-b assumed all areas were below the 1% AEP).

The overall WSUD and land capital cost of $276,000 per hectare. Revenue from harvested stormwater sales is estimated to exceed annual operation costs providing a revenue of approximately $900 per hectare per year.

The success of a regional treatment and reticulation system relies on available land for infrastructure and this will need to be carefully planned and implemented through precinct/master planning.

9. Conclusion

The work presented in this document has focussed on a range of WSUD strategies to achieve new (outcome-based) stormwater management targets for the Wianamatta-South Creek catchment. The new stormwater management targets are inclusive of flow volumes and flow rates, consistent with best practice to protect the waterways and other components of the blue grid that help deliver the vision for the Western Parkland City.

This work shows that a variety of WSUD strategies are available depending on the scale and typologies proposed. The strategies considered include allotment, streetscape and public open space treatment and reuse systems. Significantly, the feasibility assessment shows that if stormwater treatment measures are restricted to allotments and streetscapes only, then a reduced level of imperviousness on the allotment (compared to typical development) is required to meet the stormwater management targets. This translates into reduced development yield unless stormwater treatment measures such as green rooves can be adopted. The overall cost impacts of the reduced development yields (land costs) significantly determine/effect the total costs of the different WSUD strategies, compared to the cost of the stormwater treatment measure (CAPEX and OPEX).

It is clear from the feasibility assessment that the most cost effective WSUD strategy incorporates a regional approach to treatment and a reticulated stormwater reuse system that provides non-potable water to all allotments. This approach enables full development yield (up to 85% impervious coverage) to be achieved as well as achieving the stormwater management targets.

The most critical component to achieve the stormwater management targets is to intercept and divert stormwater from receiving waterways. This can generally be done through either generating less runoff, promoting evapotranspiration and/or with a reuse system, especially given that infiltration is generally limited because of a high salinity risk of the soils in the area.

WSUD strategies that incorporate a reticulated stormwater reuse system enable treated stormwater to be delivered to all allotments so that the high demands for non-potable water can be met with recycled stormwater. Another advantage of this approach is an ability to recover costs through the sale of the reused stormwater. This system requires a trunk drainage manager to plan, construct, manage and administer the system.

The hypothetical case study for the Mamre Road Precinct demonstrates if a regional treatment and reticulated reuse system is implemented, the cost of WSUD infrastructure is in the order of $191,000 per hectare. The treatment and storage systems would require approximately 87 hectares of land and costs associated with land acquisition equate approximately to an additional $96,000 per hectare. The case study includes reticulated stormwater reuse system and the revenue from harvested stormwater sales is estimated to exceed annual operation costs providing a revenue of approximately $900 per hectare each year.

The overall findings of this work demonstrates that financially viable solutions to achieve the stormwater targets can be developed if a trunk drainage manager is established. The findings form Step 4 of the NSW Government Risk-based Framework (Dela-Cruz *et al*., 2017), and will assist decisions on institutional arrangements for development and delivery of water infrastructure in the Wianamatta-South Creek catchment.

10. Acknowledgements

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- Design Flow Consulting Pty Ltd – Robin Allison and Shaun Leinster who undertook the feasibility assessment, including extensive consultation with stakeholders, developing WSUD strategies, MUSIC modelling and associated life cycle costings, and preparing the draft versions of this document
- Environment and Heritage Group of DPE – Marnie Stewart, Susan Harrison, Trish Harrup and Jocelyn Dela-Cruz who were involved in extensive consultation with stakeholders, including responding to industry queries and state significant development submissions. Jocelyn was responsible for the overall management and delivery of the project, and helped with finalising the document
- Fluvial Consulting – Richard MacManus who was instrumental in strategically aligning the findings of this work with related state initiatives for regional infrastructure delivery for the Western Parkland City.

The project team are grateful to Peter Mehl, Director at J. Wyndam Prince who reviewed the MUSIC modelling, WSUD strategies and the draft versions of the document to ensure the feasibility assessment was practical and locally specific to the catchment. Chris Avis from Infrastructure & Development Consulting (idc), and Mark Liebman from the Sustainability Workshop, also reviewed this document and provided key inputs to some of the modelling assumptions and strategies.

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Appendix H
NSW Government Announcement of Sydney Water's Appointment

Western Sydney Aerotropolis Stormwater

On 25 March 2022 the NSW Government appointed Sydney Water as the Regional Stormwater Authority for stormwater in the Western Sydney Aerotropolis, including the Mamre Road Precinct.

This means Sydney Water will be responsible for delivering, managing and maintaining the Aerotropolis stormwater network as well as the drinking water, wastewater and recycled water networks.

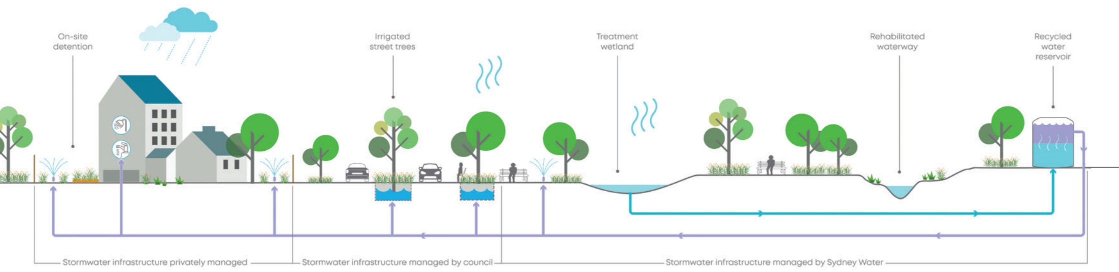
Our plan is for stormwater to flow into natural water channels and wetlands instead of relying on buried concrete pipes or drains. The stormwater will then be collected in wetlands for harvesting, treatment and reuse as recycled water for irrigation of parks, flushing of toilets and a cooler and greener Western Parkland City.

What we've done so far

Sydney Water developed a draft Aerotropolis Stormwater Management Framework and a draft Scheme Plan for Mamre Road precinct. The Framework proposes guiding principles for Sydney Water, in partnership with local councils, Department of Planning and Environment, and developers to manage trunk drainage in the Aerotropolis and Mamre Road precincts.

The Framework and Scheme Plan were open to consultation from June to July 2022. Feedback from landowners, councils and the development industry will help us refine the approach to managing drainage in the Aerotropolis, as detailed in the Framework.

Integrated stormwater harvesting and recycled wastewater concept



A simpler solution for managing stormwater

Simpler on-lot stormwater design and modelling

Centralised infrastructure off-lot

More efficient and productive developments

Resilient parklands which contribute to value

What's next?

Feedback received on the Draft Framework and Scheme Plan will be considered towards finalising detailed design plans for the Mamre Road Precinct. This process will also be carried out to develop the Scheme Plan for the Aerotropolis initial precincts.

Sydney Water will engage with landowners and industry stakeholders on the Aerotropolis Scheme Plan between late 2022 and early 2023.

Sydney Water will continue to work with the NSW Department of Planning and Environment and local councils on acquisition planning and time frames for Aerotropolis stormwater.

For more information on acquisition please visit **nsw.gov.au/housing-and-property/property-acquisition**

For more information

Sydneywatertalk.com.au/aerostormwater

1800 645 466

aerostormwater@sydneywater.com.au

Interpreter Service 13 14 50
(Arabic, Chinese, Greek, Italian, Korean, Vietnamese)

Appendix I

Sydney Water Letter re. Stormwater Servicing in Mamre Road Precinct

15 March 2023

[redacted]

Reference: Case [redacted]

Stormwater Servicing in Mamre Road Precinct

Dear [redacted]

As you are aware, Sydney Water was appointed as the Regional Stormwater Authority by the NSW Government in March 2022 to provide stormwater servicing for the Mamre Road Precinct, in addition to responsibility for the drinking water, wastewater and recycled water networks.

Since March 2022, we have been developing a service offering to meet the NSW Government's Waterway Health Targets for Wianamatta South Creek and to drain the new urban areas efficiently and safely. Stormwater will flow into natural water channels and wetlands where it is harvested, treated, and combined with a recycled water network for irrigation of parks, trees, flushing of toilets and other industrial uses. This approach was identified and specified by the NSW Government and aligns with the vision for the Western Parkland City by delivering:

- A cooler, greener Western Parkland City with healthy waterways
- A sustainable water supply independent of climate or rainfall without using water from Warrangamba Dam
- Alignment with First Nations cultural values and Recognising Country guidelines by using the most natural and non-intrusive approach to waterways
- Community expectations for contemporary urban planning and environmental protection
- More land for development, that otherwise would have housed water infrastructure
- Servicing that supports growth of surrounding industrial precincts.

Sydney WATER

Stormwater and recycled water infrastructure will be delivered over the next 20 years to align with development of the Mamre Road Precinct. The stormwater scheme plan for this precinct is available on the Sydney Water Talk website.
A Development Servicing Plan that outlines an Integrated Stormwater and Recycled Water Infrastructure Contribution (Infrastructure Contribution) is being finalised. Supporting documentation including detail of the Infrastructure Contribution will be exhibited later this year in line with the requirements of the Independent Pricing and Regulatory Tribunal (IPART). We encourage you to provide feedback when this occurs. Compensatory and offsetting mechanisms to reduce the cost (such as works in kind) will also be detailed at this time.

Sydney Water is aware that development in the Mamre Road Precinct is occurring now. To support this development, Sydney Water can accept a bond to secure payment for the Infrastructure Contribution which will allow for an s73 Compliance Certificate to be obtained. This process is similar to our existing Bonding of Works arrangements. Payment of the Infrastructure Contribution will be required once the Development Servicing Plan is registered, and before the bond can be released.

We currently estimate that the Integrated Stormwater and Recycled Water Infrastructure Contribution for the Mamre Road Precinct is $1,300,000.00 per hectare of developable land. This estimate is based on the requirements set out in the State Environment Planning Policy, *Land Acquisition (Just Terms Compensation) Act 1991*, *State Owned Corporations Act 1989* and the *Sydney Water Act 1994*.

Sydney Water is committed to working with the development industry and government partners to reduce this cost. We invite you to attend an Industry Session in April 2023 to identify efficiencies and better ways of working together.

Please do not hesitate to contact your Account Manager, [redacted]

Yours sincerely

[redacted]

Appendix J
SGS Economics Peer Review

Draft Mamre Road Precinct Capacity to Pay Analysis

NSW Department of Planning and Environment

28 | 08 | 2023

SGS Economics and Planning Pty Ltd
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1.1 Background

SGS has been commissioned by the Department of Planning and Environment (DPE) to undertake a capacity to pay analysis of potential stormwater charges within the Mamre Road Precinct.

The Mamre Road Precinct is a peri-urban, greenfield industrial area, which was previously zoned and used as agricultural land, and which was rezoned to accommodate industrial uses in June 2020 under the *State Environmental Planning Policy (Western Sydney Employment Area) 2009* (WSEA SEPP).

Since the rezoning, there has been significant activity in the precinct in terms of market transactions, and development applications, indicating high levels of demand in the area.

Required supporting infrastructure for the precinct is being provided through the following state and local contributions plans:

- The Western Sydney Aerotropolis Special Infrastructure Contribution (drafted 2020, implemented 2022)
- The Penrith City Council Mamre Road Precinct Development Contributions Plan (drafted 2020, implemented 2022)

Sydney Water is proposing a Stormwater and Recycled Water Development Servicing Plan (DSP) for the Mamre Road Precinct. A DSP is a plan which considers the future requirements and costs of water infrastructure in a given catchment, in order to reflect the relative cost of the required infrastructure for that area. The proposed contribution for the Stormwater and Recycled Water DSP is $1,300,000 per hectare of net developable area (NDA). This is henceforth referred to as the proposed *stormwater charge* and is the primary subject of the capacity to pay analysis.

Separately, Sydney Water is currently consulting on wider DSPs and associated contributions for potable (drinking) and wastewater infrastructure across its service area[1]. These are referred to as proposed *DSP contributions*.

Key dates for the Mamre Road Precinct

A timeline of key dates in the strategic identification and rezoning of the Mamre Road Precinct from rural to industrial land is provided in **Table 1** below.

TABLE 1: KEY DATES FOR THE MAMRE ROAD PRECINCT

Date/s	Milestone / decision / event
August - September 2014	Draft SEPP amendment released providing for the expansion of the Western Sydney Employment Area, including Mamre Road Precinct for the first time
August 2018	Draft Western Sydney Aerotropolis Plan placed on public exhibition (including Mamre Road Precinct)
18 November - 20 December 2019	Public exhibition of draft rezoning package
11 June 2020	Rezoning package finalised. **Land rezoned**

[1] Sydney Water 2023, Infrastructure Contributions, via https://www.sydneywatertalk.com.au/infrastructure-contributions

September 2020	Western Sydney Aerotropolis Plan finalised
10 November - 17 December 2020	Mamre Road Precinct Draft Development Control Plan (DCP) on exhibition
26 February 2021	Draft Aerotropolis Special Infrastructure Contributions Plan (SIC) on exhibition
19 November 2021	Mamre Road Precinct Development Control Plan (DCP) finalised
9 December 2021 – 27 January 2022	Draft Mamre Road Precinct Development Contributions Plan (LIC / s.94) exhibited by Penrith City Council
9 March 2022	Aerotropolis SIC comes into effect – Determination signed by Minister for Planning
25 March 2022	NSW Government announced the appointment of Sydney Water as the trunk drainage authority for stormwater in the Western Sydney Aerotropolis, including the Mamre Road Precinct.
28 March 2022	Mamre Road Precinct Development Contributions Plan adopted by Penrith City Council
4 April 2022	Mamre Road Precinct Development Contributions Plan comes into effect
7 June 2022 – 31 July 2022	Draft Stormwater Scheme Plan exhibited by Sydney Water
21 December 2022	Stormwater Scheme Plan finalised by Sydney Water

Source: DPE 2023

Review of materials and documents

This section summarises the materials that served as quantitative and qualitative context to SGS's development of one component of key factors, inputs, and assumptions in the technical capacity-to-pay analysis.

Given the multiplicity of stakeholders and organisational involvement related to development and infrastructure provision in the Mamre Road Precinct, SGS was tasked with reviewing materials and documents to:

- Identify relevant key factors, inputs and assumptions that should be considered in establishing key factors, inputs, and assumptions in SGS's technical methodology.
- Identify any departures from the inputs and assumptions used in previously-completed capacity-to-pay analyses, such as that which was undertaken for the Aerotropolis SIC
- Qualitatively acknowledge strategic considerations related to the development of the proposed Sydney Water Stormwater Charge
- Identify any limitations to the incorporation of key factors, inputs, assumptions or the suggestion of economic or community benefit articulated in background studies and documents
- Provide a high-level review of the landowners' group response and analysis of the proposed stormwater charge

SGS was provided with the following background documents and materials to be reviewed for purposes described above. These documents were shared in confidence.

Western Sydney Aerotropolis Special Infrastructure Contributions Analysis (October 2020)

The SIC feasibility study covered the entire Aerotropolis precinct, but did not include specific outputs identifying a tolerable level of SIC for the Mamre Road Precinct. It concluded that the "capacity for development to pay a SIC would be adversely affected" if both the then-proposed s7.11 of $700,000 per hectare of Net Developable Area (NDA) and the SIC were implemented together.

The study also identified that, given the fact that landowners had been engaged in market transactions which included VPA negotiations around $200,000 per hectare of net developable area, that this would be a tolerable level for the SIC. The study utilised the following parameters for feasibility thresholds: a range of 16-18% (where less than 16% was not feasible, and greater than 18% feasible) for industrial development. It also identified similar (but slightly higher) hurdle rates for commercial and residential land use developments. It was not clear, however, how the development margins and IRR thresholds were estimated.

Since the SIC feasibility work was completed, the SIC was implemented in March 2022 at a rate of $200,000 per hectare of NDA. The Penrith City Council Mamre Road Precinct Development Contributions Plan was also implemented in April 2022 with a rate of $599,225 per hectare of NDA. Both charges are subject to indexation.

Landowners' Group Feasibility Analysis (Atlas Economics, June 2023)

SGS was provided the outputs of Atlas Economics report to the landowners group for review. SGS has summarised key inputs and assumptions of that analysis (as represented by the June 2023 report) in the following Table 2. This summary illustrates where and to what extent many of the key inputs and assumptions differ or are similar. It should be noted that, among the material differences, Atlas analysed a prototype on a 10 hectare site. Whereas SGS tested prototypes on a 5- and 15-hectare site given the possibility that acquired land (lot acquisitions were generally approximately 10 hectares each) within the precinct could be assembled under different ownership structures and developed in a wider variety of different formats of scale.

TABLE 2: COMPARISON OF FEASIBILITY ASSUMPTIONS

Input or assumption	Atlas assumption	SGS assumption	Impact
Net developable area of site	85%	90.5% (large format) 98% (small format)	Lower NDA increases land costs relative to realisable values
FSR (of NDA)	0.575:1	0.54:1	Higher FSR increases realisable value as larger buildings can be realised
Construction time	22 months	28 months (large format) 18 months (small format)	Longer construction times increase costs of finance
Net face rent per sqm	$185	$190	Higher face rents increase realisable value
Capitalisation rate	4.75%	5.15%	Lower capitalisation rates increase realisable value
Marketing and legal costs	0.25% of gross realisable value (each)	Marketing at 1.5% of GRV Legal at 0.5% of hard costs	
Sales commission	1.5% of GRV	2.0% of GRV	
Cost of land (per sqm gross site area)	$575	$450 (large site) $550 (small site)	
Legal and due diligence fees	0.5% of land cost	N/A	
Construction costs	$1,150 per sqm of GFA	$994 per sqm of GFA	
Estate servicing	$200 per sqm of gross site area	$85 per sqm of gross site area for servicing $76 per sqm for demolition and site preparation	
Professional fees	8.5% of hard costs	10% of hard costs (including project management)	
Contingency	5% of hard costs	10% of hard costs	
Holding costs	Land tax, council, and water rates	N/A	
DSP charges	$50,000/ha NDA	$376,771/ha NDA (large format) $373,871/ha NDA (small format)	
7.11 charges	$668,893/ ha NDA, 20% offset against WIK	$599,010 (unindexed, no offsets)	
Finance costs	Land purchased with equity, 5.5% interest	LTV of 60%, 8% interest	
Hurdle rates	16% to 18%	18.25% to 18.50%	Higher hurdle rates effectively act as a higher 'cost' of development.

Source: SGS Economics and Planning 2023 using Atlas Economics 2023

Table 3 provides a closer comparison of the two sets of assumptions used in the estimation of development costs and realisable value. As such, this highlights that while assumptions used in both analyses are similar, there are some variations between a few key variables:

- Atlas applied a higher land cost, particularly by comparison to SGS's large format prototype
- SGS's hard construction costs are lower, but SGS's soft costs are higher
- Atlas's analysis assumed higher net realisable values due to lower yields, while SGS's analysis assumed slightly higher net face rents with higher yields

Further differences emerge when comparing the tested array of charges by scenario. For the analysis overleaf, the included fees and charges were the **7.11 contributions, the SIC, and the DSP charges.** That is, the proposed stormwater charges were excluded from analysis of the overall development costs. However, it should also be noted that SGS's methodology for estimating the proposed DSP charges was informed by Sydney Water's methodology for calculating per-equivalent tenements (discussed in **Table 10** on page 11).

- Total development costs per square metre of land and per square metre of gross floor area were very similar between the Atlas' analysis, and the SGS analysis for the large format site. Within the SGS analysis, total development costs per square metre of GFA were approximately 12% lower for the small site when compared with the large site.
- Net realisable value per square metre of gross floor area was higher under Atlas assumptions, generally driven by the lower capitalisation rate adopted.

TABLE 3: COMPARISON OF REALISABLE VALUE AND DEVELOPMENT COST ASSUMPTIONS

	Atlas assumptions (per sqm)	SGS assumptions (per sqm, large format)	SGS assumptions (per sqm, small format)
Realisable Values			
Net face rent per square metre of GFA	$185	$190	$190
Capitalisation rate	4.75%	5.15%	5.15%
Net realisable value per square metre of GFA (net of vacancy and sales commission)	$3,892	$3,543	$3,543
Development Costs			
Total development costs per square metre of GFA	$2,136	$2,131	$1,886
Total development costs per square metre of site	$1,044	$1,041	$998

Source: SGS Economics and Planning 2023 using Atlas Economics 2023

Review and identification of relevant infrastructure charges

Sydney Water is proposing to implement three types of infrastructure contributions for new development to pay for new infrastructure required to support growth. These are:

- **Potable water DSP** – $5,311 per equivalent tenement
- **Wastewater DSP** – $21,276 per equivalent tenement
- **Stormwater charge** – This proposed fee is the subject of this analysis and is proposed at $1,300,000 per net developable hectare

The first two of these charges have been calculated and are currently on exhibition. Based on review of the background information provided to SGS, it is understood they are intended to be introduced from 1 July 2024 at 25% of the total contributions, 50% from 1 July 2025, and 100% from 1 July 2026[2]. The applicable Development Servicing Plans (DSP) for the Mamre Road Precinct are, for the potable water charges and wastewater charges respectively, the Greater Sydney Drinking Water Plan and the Nepean River Wastewater Plan.

1.2 Technical approach, inputs and assumptions

SGS applies a standard residual land value (RLV) feasibility modelling approach. Along with land acquisition costs, development costs, related fees and charges, as well as an appropriate risk-adjusted return, a supportable stormwater charge is estimated by referencing a benchmark risk-adjusted development margin (calibrated as discussed with Table 12 on page 12) against each prototype's estimated development margin. Where an excess development margin exists, a supportable stormwater charge is calculated on the basis of each square metre of NDA of site.

Inputs and assumptions

This section summarises SGS inputs and assumptions used in the capacity-to-pay analysis. The methodology as described above requires identification of the following components:

- **Site characteristics** – built form outcomes of proposed development typologies and potential required works to support the site.
- **Development costs** – including hard costs (e.g., building), soft costs (e.g., professional fees, legal, financing, contingency, etc.), planning fees and charges (e.g., stamp duty, GST, SSDA fees), infrastructure contribution charges (e.g., Section 7.11/7.12, SIC, Sydney Water potable water and wastewater DSP charges, and the proposed Sydney Water stormwater charge.
- **Realisable values** – a method to derive the end value of the proposed development, considering rental and a suitable capitalisation rate.
- **Development margin and risk** – an estimate of the minimum margin a developer would seek in developing such a project that is adjusted for the various risks associated with such development (e.g., timing, land cost, construction cost, market, environment, etc.).

[2] Sydney Water 2023, Infrastructure Contributions, via https://www.sydneywatertalk.com.au/infrastructure-contributions

Development prototypes and site characteristics

The Mamre Road Precinct has approximately 100 large lots making up close to 1,000ha (including areas with environmental conservation zoning and flood affectations). The median size of lots was 10ha in 2020. The Precinct was rezoned to industrial uses in June 2020. The FSR for warehouse typologies which have been approved in the Precinct or are currently on exhibition is generally around 0.5:1.

Two theoretical sites have been modelled for this analysis: a small site (5ha) and a large site (15ha). The small site is intended to theoretically provide for one warehouse of approximately 25,000 square metres, and the large site is intended to model a more significant master planned precinct.

These two prototypes were selected following analysis of State Significant Development Applications (SSDAs) which have been submitted within the Mamre Road Precinct and which, in aggregate, were considered indicative of development in the precinct, considering the existing planning controls for the area. This analysis accordingly sought to understand an approximate proportion of net developable area (NDA) of proposals in the area, as well as the built form outcomes being proposed for development in the area. This revealed the following trends within the master plans for the precinct:

TABLE 4: DEVELOPMENT TRENDS IN THE MAMRE ROAD PRECINCT

Parameter	Upper range	Lower range
Lot size	72ha	32ha
Total road reserves	9%	6%
Total stormwater and environmental reserves	9%	3%
Net developable area	90%	81%
Net developable area excl. environmental and stormwater reserves	94%	91%
Size of individual warehouse	77,880 sqm	14,500 sqm
FSR of individual warehouse site	0.68	0.42

Source: SGS Economics & Planning, 2023, various sources.

The trends found within **Table 4** informed the development of the two prototypes for capacity to pay testing as shown in **Table 5**. For both prototypes, the existing state of the site is assumed to be a greenfield, agricultural typology.

TABLE 5: DEVELOPMENT PROTOTYPE CHARACTERISTICS

Parameter	Large format	Small format
Lot size	15ha (150,000 sqm)	5ha (50,000 sqm)
Net developable area	90.5%	98.0%
FSR	0.54	0.54
Gross floor area	73,305 sqm	26,460

Source: SGS Economics & Planning, 2023

Development costs

Development costs were estimated for each prototype. Construction costing information and assumptions from Rawlinsons Construction Cost Guide (2023) and benchmarked rates from other projects within the Mamre Road Precinct (specifically, QS reports on other SSDAs). Soft costs used are industry standard costs, calibrated to the particular project typology and assumed site characteristics. All costs were reviewed by M3 Property.

Development charges and infrastructure contributions were sourced from Council and the State Government.

Hard costs

The first category of development costs identified are referred to as hard costs. As noted previously, SGS utilised the Rawlinsons Construction Cost Guide (2023) and inputs and assumptions developed through analysis of Quantity Surveyor (QS) reports submitted for SSDAs within the Mamre Road Precinct. A summary of these hard costs inferred from Rawlinsons and QS information is provided in **Table 6** below.

The QS reports covered the period of 2020 and 2021. They were used to understand the costs for works specific to the Mamre Road Precinct. These costs related to the specific features of the site, such as the required cut and fill for the existing topography, as well as the cost of infrastructure installation and reticulation. Infrastructure installation is closely linked to the specific site conditions (influencing the cost of installation) and local requirements (determining what sort of infrastructure is required, for instance in the key area of stormwater provision). These reports accordingly have been cross referenced, where possible, to the construction cost estimates provided by Rawlinsons, which by their nature are not site-specific. A key challenge of using these costs in tandem is in the divergence of definitions and costs which is evident in this review.

TABLE 6: HARD COSTS REVIEWED IN MODELLING

Cost		Per	Source
Demolition and site preparation	$76	m^2 of site	QS analysis
Warehouse construction	$927	m^2 of warehouse GFA	Rawlinsons
External pavements	$94	m^2 (assumed at half of warehouse sites not occupied by warehouse)	Rawlinsons
External landscaping	$40	m^2 (assumed at half of warehouse sites not occupied by warehouse)	QS analysis
Site costs comprising infrastructure reticulation	$85	m^2 of site	QS analysis
Site costs comprising road construction	$17	m^2 of site	QS analysis
Cost of stormwater infrastructure	$10	m^2 of site	QS analysis – note this was a small sample size

Source: SGS Economics & Planning Rawlinsons Construction Cost Guide, and various sources, 2023

A discussion of how costs were apportioned to sites is provided in **Table 7** below.

TABLE 7: HARD COST APPORTIONMENT BY PROTOTYPE

Cost	Large format	Small format	Notes
Demolition and site preparation	100%	100%	Demolition, earthworks, and construction are assumed to be consistent for all sites.
Building works, including external costs	100%	100%	
Site costs comprising infrastructure reticulation	100%	25%	Infrastructure reticulation along internal roads is not required for smaller sites. The assumption is made that only one average-sized warehouse will be developed on the site, and that driveway access will be available directly from a suitable road. 25% of these anticipated costs are, however, still assumed for small sites, to provide for connections to trunk services.
Site costs comprising road construction	25%	0%	Road construction costs are not considered to be relevant for small sites, as they are assumed to have an existing frontage with road access. For large sites, circulation is broadly assumed to be provided for within the 7.11 plan. However, for the large format prototype, there are portions of internal roads which are only for the use of the development – this is conservatively assumed at 25%.

Source: SGS Economics & Planning, 2023

Soft costs

The second category of development costs identified are referred to as soft costs. Inputs for such estimated costs are summarised in **Table 8** and represent industry standard assumptions (and reviewed by M3 Property) regarding professional fees, project management, general contractors, marketing, legal, financing, contingency, etc.

TABLE 8: DEVELOPMENT SOFT COSTS

Soft Cost	Model Input
Professional Fees	8.5% of hard costs
Project Management	1.5% of hard costs
Marketing & Advertising	1.5% of gross realisable value
Legal Fees	0.5% of hard costs
Financing	Estimated via formula related to current conventional debt borrowing costs, and estimated construction period (months). Conventional debt is currently estimated at a rate of 8.00% at an LTV of 60%, with a construction period of 28 months for the large format site, and 18 months for the small format site.
Contingency	10.0% of hard costs and selected other costs
Land Acquisition Fee	0.5% of residual land value
Sales Commission	2.0% of gross realisable value

Source: SGS Economics & Planning, 2023

Statutory Planning Fees and Charges

The third category of development costs in the modelling includes planning fees and charges, as described below in **Table 9**. In addition to the fees and charges identified in the table, the **Stormwater contribution of $1,300,000 per net developable hectare** was the variable being tested for this analysis.

TABLE 9: STATUTORY FEES AND CHARGES

Fee or charge	Assumption used, source
Stamp duty	From NSW Revenue
Application fees	SSDA application fees as per Schedule 4, Part 5 of the Environmental Planning and Assessment Regulation 2021
7.11 Contribution	$599,225 per Net Developable area Penrith City Council
Special Infrastructure Contribution	$210,733 per Net Developable area DPE
Sydney Water Nepean River Wastewater Plan (DSP)	$21,276 per equivalent tenement
Sydney Water Greater Sydney Drinking Water Plan (DSP)	$5,311 per equivalent tenement

Source: SGS Economics & Planning, 2023

Table 10 below indicates the total DSP charges per net developable area (NDA) on a per-hectare basis for each prototype. SGS worked with Sydney Water to understand and replicate the calculation of per-equivalent tenement. As such, the use of potable water and wastewater for each site was calculated according to the relevant Development Servicing Plan using assumptions for light or general industrial usage where applicable.

TABLE 10: DSP CHARGES PER HECTARE OF NET DEVELOPABLE AREA

Prototype	Potable Water DSP charge (per hectare)	Wastewater DSP charge (per hectare)
Large format (15 hectare)	$37,896	$338,875
Small format (5 hectare)	$34,996	$338,875

Source: SGS Economics & Planning, 2023

Realisable Values

Industry development sales evidence was compiled to determine core inputs regarding realisable values for each prototype. The compilation of such sales evidence included industrial sales and rental evidence for the Mamre Road Precinct, the surrounding area, and the Aerotropolis. Nearby industrial areas of Erskine Park, Kemps Creek, and Eastern Creek demonstrate recent industrial development which can be understood to inform future realisable values.

The data gathered provided SGS and M3 Property with sufficient evidence to identify a range of realisable value inputs appropriate for the two prototypes, including net face rents per square metre and yield rates, as shown in **Table 11**. A vacancy rate assumption was also made to reach a realisable value for future development. Sources for this sales evidence included: Corelogic, realcommercial.com, commercialrealestate.com, and industry reports.

TABLE 11: REALISABLE VALUE INPUTS

	Large format	Small format
Net face rent (per m^2)	$190	$190
Vacancy rate	2%	2%
Cap rate	5.15%	5.15%
Realisable value (per m^2)	$3,615.53	$3,615.53

Source: SGS Economics & Planning, M3 Property, 2023.

Margin and hurdle rate

To understand the development's capacity to pay in the subject area, SGS has determined the likely hurdle rate required. In development feasibility, a *hurdle rate* is the minimum acceptable level of profitability that a development must achieve to be considered feasible. It is used as a benchmark that will enable the analysis to answer the key objectives of this study. A rate of return is a percentage value that expresses the net profit from an investment over a given period of time.

Hurdle rates consider a variety of factors, including the cost of capital and risks to the project. The hurdle rate is calculated by subtracting the Consumer Prince Index (CPI) from the Standard Business Rate of Return to understand the return over and above inflation. This value is then added to all other possible risks, expressed as percentages. This combined hurdle rate is accordingly calibrated to the current development market and the Mamre Road Precinct.

TABLE 12: RISK-ADJUSTED RETURN (HURDLE RATE) ESTIMATE

	Component	Value	Estimation Technique	Source
A	Inflation (CPI)	4.00%		ABS [Note 1]
B	Riskless Rate of Return	3.70%		RBA [Note 2]
C	Standard Business Rate of Return	10.00%		ASX [Note 3,4]
D	Risk Premium - Timing	1.20%	Increased construction period	in model
E	Risk Premium - Land cost	2.62% – 3.11%	Increase to EUV	in model
F	Risk Premium - Construction cost	1.91% - 2.27%	Increase to construction costs	in model
G	Risk Premium – Market	3.94% - 7.93%	Decrease to GRV factor	in model
H	Risk Premium - Environmental	1.00%		qualitative
I	Risk Premium - Approvals	1.00%		qualitative
J	Hurdle Rate (above inflation)	18.25% - 18.50%		

[Note 1] https://www.abs.gov.au/statistics/economy/price-indexes-and-inflation/consumer-price-index-australia/mar-quarter-2023
[Note 2] https://www.rba.gov.au/chart-pack/interest-rates.html
[Note 3] https://www.marketindex.com.au/statistics
[Note 4] https://topforeignstocks.com/2017/06/14/the-historical-average-annual-returns-of-australian-stock-market-since-1900/

Source: SGS Economics & Planning, M3 Property, 2023.

Existing Use Values

Existing use values applied to the analysis are provided in **Table 13** and were estimated on a per square metre basis, considering sales evidence gathered by M3 property in the study area. For the purposes of this analysis, it is assumed that the whole site is usable and not affected by water courses or easements.

It is assumed that the price of acquisition is higher for the small format site, and lower for the small format site, considering macro trends seen in the sales evidence. The values used in the modelling were reviewed with M3 Property as modelling progressed.

TABLE 13: EXISTING USE VALUE INPUTS

Prototype		Land Value (per sqm)
Small format prototype	High estimation	$550
Large format prototype	Low estimation	$450

Source: SGS Economics & Planning, M3 Property, 2023.

Scenarios

SGS understands that some of the fees and charges associated with development the Mamre Road Precinct are proposed to change over time. To understand the aggregate impact of these charges, scenario testing was carried out by varying the scale of charges to understand the incremental impact that certain extent of charges is likely to have on the development margin pre- and post-effective date of the proposed Sydney Water stormwater charge. As such, the scenarios are defined by variations in the following key variables:

- **GRV escalation** – representing a core scenario (representative of a point in time when slightly higher supportable net face rents are possible)
- **Sydney Water DSP charges** – representing the two DSP charges related to potable water and wastewater
- **SIC** – representing the current Aerotropolis Special Infrastructure Contribution

There has been no escalation of costs associated with the analysis for scenarios which represent future states of fees – only the identified changes in fees. Across all of the following scenarios summarised in **Table 14**, SGS provides a supportable stormwater charge, only if the excess development margin is greater than zero (when the estimated margin exceeds the hurdle rate).

- **Scenario A** – this scenario represents the SIC at 50% of the full proposed charge and the proposed DSP charges at 25%.
- **Scenario B** – this scenario represents the SIC at 100%, and the proposed DSP charges at 100%. As such, the results of A and B may be contrasted to identify the impact of the potable and wastewater charges, as well as the SIC at 100%, to the development margin.
- **Scenario C** – this scenario represents the same DSP and SIC charge assumptions as Scenario B, but increases the potential GRV by 5% to reflect the potential for escalated net effective rents above those factored in the base cases (Scenarios A and B).

TABLE 14: SCENARIOS USED IN MODELLING

Scenario	A	B	C
Description	BAU GRV, **25% DSPs**, 50% SIC	BAU GRV, **100% DSPs**, 100% SIC	**Esc'd GRV**, **100% DSPs**, 100% SIC
GRV escalation	0%	0%	5%
Sydney Water DSPs (potable & wastewater)	25%	100%	100%
SIC	50%	100%	100%

Source: SGS Economics & Planning, 2023

1.3 Findings and considerations

The following section details the findings of the capacity-to-pay feasibility modelling. The discussion outlines the findings related to the two evaluated prototypes from Scenario A through Scenario C:

- Large format site (15 hectares)
- Small format site (5 hectares)

Each table accompanying the findings of the large and small format prototypes outlines key characteristics and outputs, including:

- Net revenues
- Total development costs (TDC)
- Margin (estimated net revenues less TDC less EUV)
- Hurdle rate (as established by the risk-adjusted premiums methodology)
- Excess margin (the difference between the margin and the hurdle rate, if positive)
- Supportable stormwater charge

Furthermore, the findings also provide an estimation of the supportable stormwater charge on the basis of the following two critical development margin inputs:

- Target hurdle rate, as estimated by SGS to be 18.25% to 18.50%. This hurdle rate is considered the business-as-usual hurdle rate, reflecting anticipated risks related to construction cost, market, timing, and land and holding costs. From this perspective, the findings yield a lower-bound supportable stormwater charge.
- Baseline hurdle rate, identified also by Atlas as a minimum threshold for risk-adjusted return at 16%. This hurdle rate is considered the borderline between infeasible and feasible, which, by contrast to the target hurdle rate, could be described as a condition in which some of the above-mentioned risks (construction cost, market, timing, land holding costs) might be mitigated and thus reduced. From this perspective, the findings yield an upper-bound supportable stormwater charge.

Large format prototype

This section provides the capacity-to-pay outputs for the large format development prototype, illustrated in **Table 15**. The findings of the analysis demonstrate the following across the scenarios:

- **Scenario A** – with a hurdle rate at 18.25%, the development margin with the 25% DSP charges is estimated at approximately 15.6% leaving no excess margin to support a stormwater charge. The impact of the 25% DSP charges is approximately 0.5% on the margin.
- **Scenario B** – with a hurdle rate at 18.50%, the development margin with the 100% DSP charges is estimated at approximately 13.6% leaving no excess margin to support a stormwater charge. The impact of the 100% DSP charges is approximately 2.0% on the margin.
- **Scenario C** – with a hurdle rate at 18.50%, the development margin with 5% escalated GRV assumptions and 100% DSP charges is estimated at approximately 17.4% leaving no excess margin to support a stormwater charge. The impact of the 100% DSP charges is approximately 1.9%.

TABLE 15: DEVELOPMENT OUTCOMES WITHOUT PROPOSED STORMWATER CHARGE – CALCULATED HURDLE (LARGE FORMAT)

Scenario	A	B	C
Description	BAU GRV, **25% DSPs**, 50% SIC	BAU GRV, **100% DSPs**, 100% SIC	**Esc'd GRV**, **100% DSPs**, 100% SIC
Net Revenues	$259,735,984	$259,735,984	$272,722,783
TDC	$151,636,797	$156,903,150	$157,849,066
Margin	$40,599,187	$35,332,834	$47,373,717
Margin as % of Net Revenues	15.63%	13.60%	17.37%
Hurdle Rate	18.25%	18.50%	18.50%
Margin (at hurdle)	$47,401,817	$48,051,157	$50,453,715
Excess Margin (if ≥ Hurdle)	n/a	n/a	n/a
NDA	135,750 sqm	135,750 sqm	135,750 sqm
Supportable Charge (per ha NDA)	n/a	n/a	n/a

Source: SGS Economics & Planning, 2023

Shown in **Table 16**, with a minimum hurdle rate threshold of 16%, a supportable stormwater charge of approximately $275,000 per hectare of NDA is estimated for Scenario C, in which GRV is escalated by 5%.

TABLE 16: DEVELOPMENT OUTCOMES WITHOUT PROPOSED STORMWATER CHARGE – 16% HURDLE (LARGE FORMAT)

Scenario	A	B	C
Description	BAU GRV, **25% DSPs**, 50% SIC	BAU GRV, **100% DSPs**, 100% SIC	Esc'd GRV, **100% DSPs**, 100% SIC
Net Revenues	$259,735,984	$259,735,984	$272,722,783
TDC	$151,636,797	$156,903,150	$157,849,066
Margin	$40,599,187	$35,332,834	$47,373,717
Margin as % of Net Revenues	15.63%	13.60%	17.37%
Hurdle Rate	16.00%	16.00%	16.00%
Margin (at hurdle)	$41,557,757	$41,557,757	$43,635,645
Excess Margin (if ≥ Hurdle)	n/a	n/a	$3,738,072
NDA	135,750 sqm	135,750 sqm	135,750 sqm
Supportable Charge (per ha NDA)	n/a	n/a	$275,364

Source: SGS Economics & Planning, 2023

Small format prototype

This section provides the capacity-to-pay outputs for the large format development prototype, illustrated in **Table 17**. The findings of the analysis demonstrate the following across the scenarios:

- **Scenario A** – with a hurdle rate at 18.25%, the development margin with the 25% DSP charges is estimated at approximately 19.4% leaving an excess margin of approximately $1.0 million or approximately $218,000 per hectare. The impact on the margin compared to Scenario A is approximately 0.5%.
- **Scenario B** – with a hurdle rate at 18.50%, the development margin with the 100% DSP charges is estimated at approximately 17.4% leaving no excess margin to support a stormwater charge. The impact of the 100% DSP charges is approximately 2.0% on the margin.
- **Scenario C** – with a hurdle rate at 18.50%, the development margin with 5% escalated GRV assumptions and 100% DSP charges is estimated at approximately 21.0% leaving an excess margin of approximately $2.5 million and a supportable stormwater charge of approximately $514,000 per hectare. The impact of the 100% DSP charges is approximately 1.9%.

TABLE 17: DEVELOPMENT OUTCOMES WITHOUT PROPOSED STORMWATER CHARGE – CALCULATED HURDLE (SMALL FORMAT)

Scenario	A	B	C
Description	BAU GRV, **25% DSPs**, 50% SIC	BAU GRV, **100% DSPs**, 100% SIC	Esc'd GRV, **100% DSPs**, 100% SIC
Net Revenues	$93,753,689	$93,753,689	$98,441,373

TDC	$48,073,426	$49,963,698	$50,211,380
Margin	$18,180,262	$16,289,990	$20,729,993
Margin as % of Net Revenues	19.39%	17.38%	21.06%
Hurdle Rate	18.25%	18.50%	18.50%
Margin (at hurdle)	$17,110,048	$17,344,432	$18,211,654
Excess Margin (if ≥ Hurdle)	$1,070,214	n/a	$2,518,339
NDA	49,000 sqm	49,000 sqm	49,000 sqm
Supportable Charge (per ha NDA)	$218,411	n/a	$513,947

Source: SGS Economics & Planning, 2023

Shown in **Table 18**, with a minimum hurdle rate threshold of 16%, a supportable stormwater charge of ranging between approximately $263,000 (Scenario B) and slightly more than $1,000,000 per hectare of NDA (Scenario C).

TABLE 18: DEVELOPMENT OUTCOMES WITHOUT PROPOSED STORMWATER CHARGE – 16% HURDLE (SMALL FORMAT)

Scenario	A	B	C
Description	BAU GRV, **25% DSPs**, 50% SIC	BAU GRV, **100% DSPs**, 100% SIC	**Esc'd GRV**, **100% DSPs**, 100% SIC
Net Revenues	$93,753,689	$93,753,689	$98,441,373
TDC	$48,073,426	$49,963,698	$50,211,380
Margin	$18,180,262	$16,289,990	$20,729,993
Margin as % of Net Revenues	19.39%	17.38%	22.92%
Hurdle Rate	16.00%	16.00%	16.00%
Margin (at hurdle)	$15,000,590	$15,000,590	$15,750,620
Excess Margin (if ≥ Hurdle)	$3,179,672	$1,289,400	$4,979,373
NDA	49,000 sqm	49,000 sqm	49,000 sqm
Supportable Charge (per ha NDA)	$648,913	$263,143	$1,016,199

Source: SGS Economics & Planning, 2023

Direct estimation of stormwater charge impact

The following **Table 19** and **Table 20** summarise the findings of the capacity-to-pay modelling outputs when incorporating 100% of the proposed stormwater charge into each scenario and prototype.

- There is no scenario modelled producing a sufficient development margin.
- The 5% escalation of the GRV assumption in Scenario C has a positive impact on the margin, but not by a sufficient amount to achieve the established hurdle rate.

TABLE 19: DEVELOPMENT OUTCOMES WITH PROPOSED STORMWATER CHARGE (LARGE FORMAT)

Scenario	A	B	C
Net Revenues	$259,735,984	$259,735,984	$272,722,783
TDC	$169,284,297	$174,550,650	$170,381,896
Margin	$22,951,687	$17,685,334	$34,840,887
Margin as % of Net Revenues	8.84%	6.81%	12.78%
Hurdle Rate	18.25%	18.50%	18.50%
Impact on margin	6.79%	6.79%	6.47%

Source: SGS Economics & Planning, 2023

TABLE 20: DEVELOPMENT OUTCOMES WITH PROPOSED STORMWATER CHARGE (SMALL FORMAT)

Scenario	A	B	C
Net Revenues	$93,753,689	$93,753,689	$98,441,373
TDC	$54,443,426	$56,333,698	$56,581,380
Margin	$11,810,262	$9,919,990	$14,359,993
Margin as % of Net Revenues	12.60%	10.58%	14.59%
Hurdle Rate	18.25%	18.50%	18.50%
Impact on margin	6.79%	6.79%	6.47%

Source: SGS Economics & Planning, 2023

Analytical assumptions and limitations

There are a variety of limitations to development feasibility modelling. The Reserve Bank of Australia and other central banks around the world continue adjusting their target cash rates in response to macroeconomic conditions including high rates of inflation.

For the assessment of development costs, not only can inflationary pressures on construction materials and labour costs impact feasibility, but the cost of conventional debt for commercial loans, such as those used in financing development projects, can also be impacted by higher commercial lending rates. For the assessment of realisable values, as well, the impact of the higher cash rate can increase yield and capitalisation rates, as investors demand higher returns from investment.

These considerations imply downside risks associated with both construction costs and realisable values. And while this assessment has modelled the impact of potential downside risks (in establishing a benchmark hurdle rate), there is still a risk that conditions change to a greater extent than were contemplated in the modelling.

There are, however, a variety of factors and conditions in which development feasibility and the supportability of the proposed stormwater charge could be **improved** under the following conditions:

- Actual NDA is higher than modelled.
- EUV assumptions are lower than modelled.
- Construction costs are lower than modelled.
- Supportable net face rents are higher than those modelled.

Feasibility and the supportability of the proposed stormwater charge could be **negatively impacted** under any one or combination of the following conditions:

- Actual NDA is lower than modelled.
- EUV assumptions are higher than modelled.
- Construction costs are higher than modelled.
- Supportable net face rents are lower than those modelled.

Disclaimer: The modelling in this study has been undertaken to test the capacity to pay for a proposed stormwater charge.

Inputs and assumptions relevant to development costs and realisable values for each prototype, such as site dimensions, GFA, site work, hard and soft costs, financing, as well as supportable net face rents, vacancy, and yield have been informed and reviewed by a Certified Valuation Firm (M3 Property) with an understanding of the redevelopment potentials for each site identified.

To the extent that redevelopment was proceeding, actual costings from individual contractors and professionals would need to be obtained to provide further refinement of these costs and realisable value potentials. In such an event, inputs and assumptions may materially differ from those modelled in this study.

Appendix K

MLOG Letter of Upper Limit on Stormwater DSP Charge

The Hon Rose Jackson MLC

Minister for Water
Minister for Housing
Minister for Homelessness
Minister for Mental Health
Minister for Youth
Minister for the North Coast Water
Level 15, 52 Martin Place
Sydney 2000

By Email: office@jackson.minister.nsw.gov.au

Dear Minister Jackson,

Mamre Road Regional Stormwater DSP and Interim Measures

Firstly, thank you for the commitment to work with industry on an a It was extremely encouraging to see you take such decisive action on the proposed Sydney Water bonding amount, and we look forward to continuing to engage productively. I am writing today to provide further background and suggested next steps.

In June 2020, the then Minister for Planning announced the rezoning of 850 hectares of industrial land at Mamre Road, Kemps Creek, to deliver 17,000 jobs, as the priority precinct for the Aerotropolis due to the dwindling industrial land supply pipeline in Sydney.

Sydney has a critical industrial land supply shortage, with the vacancy rate approximately 0.2%, the lowest of any global city and less than one year of supply left. This land shortage has significantly impacted affordability and availability of new development options for occupiers forcing them to increasingly favour investment in other states out of necessity.

Today, development has commenced on four estates, with Agreements for Lease with major national and global businesses over approximately ~200 hectares, equating to approximately 3,000 construction and 4,500 operational jobs. Occupiers have major concerns about the time delays for approvals and potential impact on their business operations as well as the potential cost increases associated with the Sydney Water regional stormwater scheme.

At the time of adoption of the Mamre Road DCP in November 2021, new stormwater controls were imposed for the Mamre Road precinct which are a ‘step change’ from what has typically been adopted. In consultation with NSW Department of Planning and Environment (DPE), the Mamre Road Landowners Group (MLOG) supported application of these controls on the basis that:

1. A regional stormwater scheme would be adopted to achieve the new stormwater controls;
2. The cost of this scheme would not be more than $30 per sqm; and
3. NSW DPE would work with the landowners to ensure abortive interim stormwater management works would not be required prior to adoption of the regional scheme.

In March 2023, Sydney Water announced a $1.3 million per hectare Bond for the Mamre Road Precinct. Since this announcement the Mamre Road Landowners Group (MLOG) have been working with The Department of Planning and Environment (DPE), Penrith Council (PCC) and Sydney Water to identify a solution to allow development to proceed, in a cost effective way prior to delivery of the regional stormwater scheme without the need for abortive costs or land sterilisation.

SGS (engaged by DPE) and Atlas Economics (engaged by MLOG) have both completed a Capacity to Pay analysis, confirming development within the precinct can only accommodate $30/m2 or $300,000 per hectare in DSP charges

It should be noted that the current Sydney Water Mamre Road Precinct stormwater scheme and Mamre Road Precinct DCP requires some stormwater elements to be delivered by land owners within each development estate (***On-lot Costs***) whereas other stormwater elements are to be delivered by Sydney Water as part of the regional stormwater scheme (***DSP Contributions***).

The *On-lot Costs* for each development within the Mamre Road Precinct consist of the delivery of estate detention basins, trunk drainage channels, passively irrigated street trees and rainwater tanks (which are required in advance of regional scheme) and total approximately $93.8/m2 or $938,000m/2 per Ha of net developable area. Inclusion of a DSP contribution of $130/m2 or $1.3 million per Ha would result in a total cost industry to comply with the stormwater targets to $223.8/m2 or $2.238 million per Ha of net developable area

In addition, the NSW Government's current interim requirement results in only 60% of the site able to be developed with remaining land to be sterilised and used as large basins or irrigation. The Sydney Water timeline to complete the regional stormwater system is relatively unknown, however it is anticipated to be delivered in 5+ years. This creates significant cost and feasibility impacts in sterilising land and abortive costs, which has not been factored into any Capacity to Pay Analysis and renders most sites unfeasible to purchase/develop. If an affordable solution is not found quickly, it will result in development halting in the Mamre Road Precinct and Aerotropolis as a whole

On the 18 October 2023, UDIA received a letter from Sydney Water confirming its intention to work with industry to investigate some cost saving options to reduce the DSP, however in order to progress a solution we believe this next round of consultation should involve:

- Sydney Water to provide sufficient transparency regarding all precinct stormwater design, costing and other scheme inputs that form the DSP cost
- NSW Government (DPE, Treasury, Council and Environment and Heritage Group (EHG)) fully investigate all cost saving options not related to the design of construction of the regional stormwater system, including land tax, section 7.11 overlap, RE1 land reallocation and a review of the environmental targets
- NSW Government support of an interim solution, that allows development to proceed in advance of the regional system, with no abortive costs or land sterilisation

To assist with ensuring the most effective DSP charge is implemented in a timely manner, we have provided a table below outlining key potential regional stormwater scheme opportunities to be jointly explored by all parties

Item	Potential Regional Stormwater Scheme savings items
1	Inclusion of flood prone land (~225ha) within modelling as undeveloped to offset developable area impacts
2	Works In Kind, including cost savings assuming the majority of works will be constructed by industry at a lower cost to Sydney Water
3	Earthworks Export, review of spoil export costs and looking at disposal sites that will minimise costs
4	Irrigation of non developable areas
5	Rainwater Tanks,utilise Smart Storage technology to enable Real-Time Control of capture and release of stormwater from developer delivered estate basins throughout the entire Aerotropolis to ensure peak discharge rates are met and instream routing flows do no exceed relevant tipping point / erosive flow requirements based on specific watercourse requirements.
6	Water Balancing to generate efficiency in the regional system
7	Water Quality on development lots
8	Location of Basins and acquisition of flood affected land only
9	Catchment Areas – optimisation of the regional scheme
10	Bio-retention street trees
11	Removal of recycled water component of the system
12	Removal of GPTs
13	OPEX and calculation of maintenance costs. Cost of OPEX to be levied as part of customer rates
14	Land Values and adoption of market rates
15	Local contributions RE1 Land 28.2ha of RE1 is to be acquired along the Wianamatta-South Creek
16	Land tax exemption (between 11.5% -20% of total cost)
17	Reduce land escalation rates in the SW model
18	Review Waterway Health Targets, adopting lessons learnt from the Melbourne Water approach, which set water quantity targets and flow percentiles corresponding to the receiving watercourse and level of historic degradation due to urbanisation

Next steps

MLOG understands its obligations to contribute to infrastructure that is required to service land, protects the environment and enables the delivery of a new world-class employment precinct. To finalise a reasonable DSP, MLOG has agreed it can accept a DSP bonding amount of $500,000/ha and would request the following actions be undertaken:

- NSW Government to work through each cost saving initiatives with sufficient transparency with Sydney Water, with the intention to finalise a DSP back to $30/m2 or $300,000/ha in line with the Capacity To Pay Analysis.
- NSW Government commitment to determining an interim solution (similar to that proposed by Industry) that allows development within the Mamre Road Precinct to progress without abortive works or any land sterilisation.

- Fortnightly workshop meetings to be established between MLOG and senior representatives from DPE, Sydney Water, Treasury and the Ministers Office.
- NSW Government provides commitment to review timeframes for the gradual re-introduction of revised Sewer and Water DSP charges within the Mamre Road Precinct..
- In line with the above actions, the MLOG would also request for the NSW Government to finalise a position on an economically viable DSP and interim solution **by December 2023**

Please find attached a Presentation which provides more background and possible solutions.

MLOG is committed to continue working with NSW Government to resolve these critical matters for Mamre Road Precinct and Wianammata-South Creek and appreciates your input.

[redacted] is managing this issue on our behalf and will be in contact with your office to arrange a meeting.

Regards,

[redacted]

Signed on behalf of the Mamre Road Precinct Land Owners Group, including Altis, Mirvac, Frasers, ISPT,Aliro, Dexus, Fife Capital, Stockland, ESR, GPT and Gibb Group.

24 October 2023

The Hon. Rose Jackson
Minister for Water, Housing, Homelessness, Mental Health, Youth, North Coast
52 Martin Place
Sydney 2000
By email: office@jackson.minister.nsw.gov.au

Dear Minister

Mamre Road Regional Stormwater DSP/Bond and Interim Measures

In June 2020 the then Minister for Planning rezoned 850 hectares of industrial land at Mamre Road, Kemps Creek, to deliver 17,000 jobs as the priority precinct for Aerotropolis. This sought to respond to the dwindling industrial land supply pipeline in Sydney. The first State Significant DAs were submitted by the end of that year and a Development Control Plan (DCP), Special Infrastructure Contribution and Section 7.11 Local Contributions were finalised over the next 18 months. Five months after the adoption of this DCP the Department of Planning's Water division presented a regional stormwater treatment and reuse system to industry with a forecast developer charge of $287,000/ha.

In mid-2022 it was announced that Sydney Water would be directed to prepare a Regional Stormwater Scheme based on the Wianamatta South Creek Water Quality Guideline 2020. In March 2023 Sydney Water asked UDIA for assistance to find affordable solutions as they announced a $1.3 million a hectare Bond for Mamre Road, which was a huge surprise and an unprecedented infrastructure charge. I have led a cross government working group over the last six months with several areas of the Department of Planning and Environment (DPE), Sydney Water, Penrith City Council (PCC) and Mamre Road developers (MLOG) and we have not, as yet been able to progress an affordable RSWS solution.

Industry has made numerous submissions to government about the capacity to deliver these unprecedented Water Quality standards and MLOG has provided evidence analysing the Melbourne Water's appropriately scaled solution which has industry support. As you are aware we have made limited progress with this to date, towards an affordable permanent solution and an interim solution which does not sterilise land nor introduce abortive costs. We are grateful that you and Minister Scully have recognised the need to provide strong direction to get a reasonable bond on the table now so projects under construction can be completed and occupied and urgent work to finish a final business case which is fit for purpose and as efficient as possible.

Below are the key outstanding issues stemming from our discussions to date with Sydney Water and DPE which I believe need resolution:

- Sydney Water have on a number of occasions mentioned comparable stormwater schemes cost in the real of $700k/ha. We do not believe this is accurate as it compares Stormwater costs and On-Lot costs to the proposed Regional Stormwater costs only. MLOG note that the On-Lot costs at Mamre Road are >$900k, plus the Regional Stormwater cost which is a total closer to $2M/ha with the recent feedback from Sydney Water on the Bond. That is why industry and DPE capacity to pay work both show only $300k/ha as an affordable Stormwater charge. MLOG supports the need for a Regional Stormwater solution for Wianamatta South Creek and has worked hard to bring forward savings/solutions for the proposed Sydney Water Scheme, working with AT&L Engineers to put forward costed design solutions. We believe there are numerous opportunities to resolve the gap from the Bond to final design. These are outlined in more detail in the attached proposal from MLOG and we strongly recommend that Sydney Water is required to directly consider each identified potential saving in the final business case.

- We have identified potential solutions to the overall cost, which includes that we cannot see the nexus in the S7.11 Local Contributions for the RE1 Land being charged to Industrial Zoned Land and this charge should not be levied.

- The current environmental controls only allow ~60% of the sites to be able to be developed before a regional stormwater solution is available, with the remainder to form large basins and irrigation in order to comply with the current stormwater engineering targets. The current Sydney Water timeline to complete the regional system is relatively unknown, however it is expected to be +5 years. This creates significant abortive cost and feasibility impacts, not to mention that the outcome on the ground is unworkable. Large detention basins would be excavated to receive water until the Regional Stormwater scheme is complete. We are told that the water is not wanted in the waterway, so it would have to be removed and basins refilled for the development to be completed. This is clearly completely impracticable and provides no certainty for industry to complete development and no costs have been allocated in the capacity to pay analysis.

UDIA believes that a more BAU approach for the interim solution is needed, with the opportunity for government to utilise large water tanks which industry is building to achieve GreenStar ratings and together with the scope for the overall development in the Catchment able to reach 13%, will defer any impact on the waterway for many years.

Industry is seeking your support to deliver a whole of government solution for an affordable Regional Stormwater scheme ~$300,000/ha net developable area, to ensure Sydney remains open for industrial development. The solution needs to eliminate costly interim works and land sterilisation, deliver the full development yield announced and include the option for works-in-kind delivered by industry as development is completed and offset against contribution charges.

Attached is a proposal from MLOG providing more detail on the way to move forward. UDIA is willing to continue working with government and MLOG to resolve this crucial enabling infrastructure for Wianammata-South Creek at Mamre Road and then Aerotropolis. We look forward to your response and to arrange a meeting please contact [redacted]

Yours sincerely,

[redacted]

UDIA NSW

Attached: MLOG Developers Stormwater bond proposal – 24 October 2023

CC: The Hon. Daniel Mookhey MLC, Treasurer
The Hon. Paul Scully MP Minister for Planning
The Hon. Rose Jackson MLC Minister for Water

Appendix L
AT&L Rooftop Irrigation Results

Appendix M
Technical guidance for achieving Wianamatta–South Creek stormwater management targets

Department of Planning and Environment

Technical guidance for achieving Wianamatta–South Creek stormwater management targets

environment.nsw.gov.au

Cover photo: Wetland at Blacktown Showground. Blacktown City Council

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Role of this guide

The NSW Government has set construction and operational phase stormwater management targets to achieve waterway health objectives for protecting and restoring the blue grid in the Wianamatta–South Creek catchment. The blue grid is made up of waterways, riparian vegetation communities, wetlands, and other water dependent ecosystems.

The role of this guide is to support:

- approval and consent authorities in the assessment of state significant development (SSD), state significant infrastructure (SSI), development applications and modification applications
- the Minister in determining whether to approve Master Plans that are proposed to apply to specified land to which Chapter 4 of the State Environmental Planning Policy (Precincts – Western Parkland City) 2021 applies
- *any* practitioner, applicant or proponent involved in planning, design, approval, delivery and operation of water sensitive urban design (WSUD) strategies to achieve the stormwater management targets.

The guide provides specific direction on what modelling to undertake, assumptions to make and which data to use to demonstrate that the stormwater management targets are being achieved. It provides information on how to access a calibrated MUSIC[1] model file with source nodes suitable for use in the Wianamatta–South Creek catchment.

The guide outlines WSUD design considerations in the context of the vision for the Western Parkland City, landscape constraints such as salinity and sodicity hazards, and interactions with the floodplain. Example WSUD strategies that achieve the stormwater management targets are also provided in this guide for large format industrial (LFI), high density residential (HDR) and low density residential (LDR) typologies.

How to use this guide

This guide has 4 chapters, plus appendices and a glossary, as outlined in Table 1.

Table 1 Structure of this guide

Chapter	Description
Chapter 1 – Stormwater management targets	Outlines the construction and operational phase stormwater management targets required to achieve waterway health objectives
Chapter 2 – Achieving stormwater management targets	Guidance on what modelling to undertake, assumptions to make and which data to use to demonstrate that the targets are being achieved Information on a modelling toolkit that contains a calibrated MUSIC model and post-processing spreadsheet, which were developed to support proponents in demonstrating compliance with the targets A range of considerations to support existing lodgement requirements / submissions

[1] MUSIC (Model for Urban Stormwater Improvement Conceptualisation) is an industry standard and widely used tool for developing WSUD strategies.

Chapter	Description
Chapter 3 – WSUD design considerations	A range of design considerations for WSUD infrastructure in the Wianamatta–South Creek catchment with reference to other guidelines to ensure best contemporary practice
Chapter 4 – Example WSUD strategies	A range of example WSUD strategies that suit different typologies. These include strategies for different scales of development as well as an interim strategy, which demonstrates how partial development can achieve the targets until the site is fully developed and connected to a regional stormwater system
Appendix A – MUSIC model parameters	Sets out acceptable parameters to use for specific elements of a MUSIC model, including the appropriate climate data
Appendix B – Water demand data	A consistent set of water demand data for use in performance modelling to demonstrate compliance with the operational phase stormwater quality and quantity targets
Acknowledgements	Details about the preparation of this guide
Glossary	Explanations of specialised terms used in this guide
References	Documents cited in this guide
More information	Links to online resources

Relationship to other documents

Further guidance on the design of stormwater treatment systems and WSUD strategies for developments in the Wianamatta–South Creek catchment includes:

- *Managing Urban Stormwater: Soils and Construction* – Blue Book (NSW Government 2004)
- *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks: Stormwater harvesting and reuse* (NRMC, EPHC and NHMRC 2009)
- *Penrith City Council Water Sensitive Urban Design (WSUD) Policy* (PCC 2013)
- *Penrith City Council WSUD Technical Guidelines* (PCC 2015)
- *Blacktown City Council Developers Toolkit for Water Sensitive Urban Design (WSUD)* (BCC 2022)
- *Blacktown City Council WSUD developer handbook MUSIC modelling and design guide* 2020 (BCC 2020)
- *Blacktown City Council Water sensitive urban design (WSUD) standard drawings* (BCC 2017)
- *Liverpool City Council Water Sensitive Urban Design (WSUD) guideline* (LCC 2015).

Background and other supporting information for this guide is available from:

- *Mapping the natural blue grid elements of Wianamatta–South Creek: High ecological value waterways, riparian vegetation communities and other water dependent ecosystems* (DPE 2022b)
- *Performance criteria for protecting and improving the blue grid in Wianamatta–South Creek: Water quality and flow related objectives for use as environmental standards in land use planning* (DPE 2022c)
- *Wianamatta–South Creek stormwater management targets* (DPE 2022d)
- *Review of water sensitive urban design strategies for Wianamatta–South Creek* (DPE 2022e)
- *Urban salinity management in the Western Sydney Aerotropolis area* (DPIE 2021c)
- *Soil and land resource mapping for the Western Sydney Aerotropolis area* (DPIE 2021d).

Chapter 1 – Stormwater management targets

The Wianamatta–South Creek catchment is part of the Hawkesbury–Nepean River system and lies approximately 50 km west of Sydney. It is the central location for the Western Parkland City, and Sydney's second international airport. Strategic land-use planning for the area has been landscape led (DPE 2022a; DPIE 2021e), predominantly achieved through the creation of a Blue–Green Infrastructure Framework to provide a range of benefits related to liveability, building resilience to city hazards like urban heat and flooding, and protecting the iconic and/or endangered ecological communities and waterways that characterise the area (GSC 2018; DPIE 2021e; DPE 2022a).

This landscape led approach has changed almost all aspects of land-use planning for the airport and surrounding precincts that make up the Western Sydney Aerotropolis. This includes changes to planning controls for stormwater infrastructure delivery, which have shifted from long standing post development stormwater load reductions targets to the new outcomes-based targets outlined in this guide. The new targets are designed to achieve ambient water quality and flow related objectives (viz. waterway health objectives) for protecting and restoring the waterways and water-dependent ecosystems making up the blue grid.

The targets are provided to strengthen provisions for controlling sediment during the construction phase of development, and for compliance at the outlet of a development site during the operational phase (i.e. once the site has been developed).

Construction phase targets

Construction phase stormwater quality targets apply to development sites >2,500 m^2 (Table 2). The targets were designed to strengthen existing requirements in the Managing Urban Stormwater: Soils and Construction (the Blue Book), in particular with regard to treating a minimum volume of annual runoff from a construction site.

It is ideal for independent audits to be undertaken by a Certified Professional in Erosion and Sediment Control (CPESC) to certify that the management of the site complies with these targets, or where not in compliance, specific advice is provided to the proponent to achieve compliance.

Table 2 Construction phase stormwater quality targets

Parameter	Target (reduction in mean annual load from unmitigated development)
Total suspended solids (TSS) and pH	All exposed areas greater than 2,500 m^2 are to be provided with sediment controls that are designed, implemented and maintained to a standard that would achieve treatment of at least 80% of the average annual runoff volume of the contributing catchment (i.e. 80% hydrological effectiveness) to 50 mg/L TSS or less, and pH in the range (6.5–8.5) No release of coarse sediment is permitted for any construction or building site Sites less than 2,500 m^2 are required to comply with the requirements of the Blue Book

Parameter	Target (reduction in mean annual load from unmitigated development)
Oil, litter and waste contaminants	No release of oil, litter or waste contaminants
Stabilisation	Prior to completion of works for the development, and prior to removal of sediment controls, all site surfaces are to be effectively stabilised including all drainage systems An effectively stabilised surface is defined as one that does not or is not likely to result in visible evidence of soil loss caused by sheet, rill or gully erosion or lead to sedimentation and water contamination

Operational phase targets

For the operational phase targets there are 2 options available for stormwater quality and 2 for stormwater quantity (flow). The choice of 2 options is intended to provide flexibility in demonstrating compliance with the targets.

> One option each for stormwater quality and stormwater quantity must be achieved to demonstrate compliance.

For stormwater quality targets, most development will likely adopt Option 1, which is based on annual load reduction targets (Table 3). If a development incorporates significant areas of pervious space (e.g. by adopting green roofs), then a proponent may prefer to use Option 2, which is based on allowable loads (Table 4).

Differences between the 2 options for the stormwater quantity (flow) targets are mainly related to the extent of post-processing of results generated from the industry standard model MUSIC. Option 1 allows results to be directly extracted from MUSIC and compared with the targets (Table 5). Option 2 requires flow data to be extracted from MUSIC and a flow duration curve to be developed (Table 6). The proponent is free to select whichever option suits their WSUD strategy best, noting that:

- Option 1 stormwater quantity (flow) targets are based around limiting the mean annual runoff volume (MARV) from a development site as well as ensuring there is a suitable low flow regime in the streams.
- Option 2 stormwater quantity (flow) targets are based on preserving key percentiles of a flow duration curve.
- Compliance with the flow percentiles is demonstrated when the stormwater volume discharges at the outlet of a development site is between the upper and lower bands/ranges specified for the flow percentile

Table 3 Operational phase stormwater quality targets Option 1 – annual load reduction

Parameter	Target – reduction in mean annual load from unmitigated development
Gross pollutants (anthropogenic litter >5 mm and coarse sediment >1 mm)	90%
Total suspended solids (TSS)	90%
Total phosphorus (TP)	80%
Total nitrogen (TN)	65%

Table 4 Operational phase stormwater quality targets Option 2 – allowable loads

Parameter	Target – allowable mean annual load from development
Gross pollutants (anthropogenic litter >5 mm and coarse sediment >1 mm)	<16 kg/ha/y
Total suspended solids (TSS)	<80 kg/ha/y
Total phosphorus (TP)	<0.3 kg/ha/y
Total nitrogen (TN)	<3.5 kg/ha/y

Table 5 Operational phase stormwater quantity (flow) targets Option 1 – MARV

Parameter	Target
Mean annual runoff volume (MARV)	≤2 ML/ha/y at the point of discharge to the local waterway
90%ile flow	1,000–5,000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5–100 L/ha/day at the point of discharge to the local waterway
10%ile flow	0 L/ha/day at the point of discharge to the local waterway

Table 6 Operational phase stormwater quantity (flow) targets Option 2 – flow percentiles

Parameter	Target
95%ile flow	3,000–15,000 L/ha/day at the point of discharge to the local waterway
90%ile flow	1,000–5,000 L/ha/day at the point of discharge to the local waterway
75%ile flow	100–1,000 L/ha/day at the point of discharge to the local waterway
50%ile flow	5–100 L/ha/day at the point of discharge to the local waterway
Cease to flow	Cease to flow to be between 10% and 30% of the time

Chapter 2 – Achieving stormwater management targets

This chapter provides guidance on technical modelling requirements to demonstrate that the operational phase stormwater targets (Table 3 to Table 6) are being achieved, including what assumptions to make and which data to use. The technical modelling requirements apply, irrespective of the scale of delivery of WSUD infrastructure; that is, lot, streetscape, precinct or regional scale. Examples of the application of the technical modelling requirements at varying scales of delivery are provided in Chapter 4 of this guide.

The general approach to demonstrating the targets are achieved is to:

a. establish which stormwater quality and quantity target options (1 or 2) will be used – refer to Table 3 to Table 6 in Chapter 1 of this guide
b. devise WSUD strategies that will meet the stormwater quality and quantity targets:
    i. follow technical modelling requirements and WSUD design considerations to demonstrate the performance of the WSUD strategies. These requirements and considerations are specified in this guide, in the section titled 'Technical modelling (MUSIC) requirements' and Chapter 3 'WSUD design considerations', respectively
    ii. refer to examples of WSUD strategies in Chapter 4 of this guide
c. establish management arrangements for WSUD strategies to demonstrate long-term operation
d. compile lodgement requirements (see respective section in this chapter) for submission to relevant approval or consent authority.

The example WSUD strategies in Chapter 4 of this guide include an interim solution to allow development to commence while planning for a regional stormwater system is undertaken. The interim solution includes:

- *interim* WSUD strategies that can comply with the stormwater quality and quantity targets in the absence of the regional stormwater system – typically these include partial development of an area
- *ultimate/final* WSUD strategies that enable the interim solutions to transition to full development that incorporates the regional stormwater system, such as reticulated stormwater harvesting and regional treatment.

Technical modelling (MUSIC) requirements

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) is required for developments to demonstrate how the targets are achieved. MUSIC modelling should follow the specifications provided in this guide, and for parameters outside the scope of this guide, follow the recommendations of the relevant documents of local council's in Wianamatta (see the 'Relationship to other documents' section of this guide).

Appendix A provides ranges of acceptable parameters to use for specific elements of a MUSIC model, including the appropriate climate data. Further guidance on WSUD strategies and how to model them is presented in Chapter 4 of this guide. A MUSIC file that contains the climate data and source node parameters is part of a MUSIC modelling toolkit to support this guide. A spreadsheet for post-processing daily modelled flow data to generate and assess whether the flows from the site of development achieves the stormwater quantity (flow) targets is also available in the toolkit.

MUSIC modelling toolkit

The 'MUSIC modelling toolkit for Wianamatta–South Creek' is available from the NSW Government Sharing and Enabling Environmental Data (SEED) portal. Refer to the 'More information' section below for a link to the toolkit.

Presenting MUSIC results

The results of the MUSIC modelling should be compared to the operational phase stormwater management targets (Table 3 to Table 6) to demonstrate they have been achieved.

Stormwater quality targets (% load removed) can be directly extracted from the 'treatment train effectiveness' statistics in MUSIC models from the most downstream node, and expressed as either annual load reductions or allowable loads.

Accordance with stormwater quantity (flow) targets can be demonstrated in 2 ways depending on which targets are adopted (Table 5, Table 6).

For Option 1, (MARV; Table 5) mean annual runoff volumes and selected flow percentiles can be extracted directly from MUSIC (Statistics/Flow-weighted Daily Mean). Note that the results presented in MUSIC are in m^3/s and therefore need to be converted to ML/ha/day or L/ha/day to compare with the target values.

Option 2 (flow percentiles; Table 6) requires daily flow data to be extracted from MUSIC (Export/Flow-daily timestep) at the most downstream node. These data are then plotted in a flow duration curve to compare with the target values. The post-processing spreadsheet contained in the MUSIC modelling toolkit was developed to support this option. Accordance is shown with the stormwater quantity (flow) targets by presenting the flow rates for different flow duration percentages and comparing to the ranges of the targets, either in tables or plots. Examples of how to present this data are provided in Chapter 4.

Supporting information for applications

This section of the guide provides supporting information to assist applicants to demonstrate how they achieve the stormwater management targets.

Pre-lodgement

Prior to lodging SSD, SSI or development applications, it is recommended that an applicant or proponent meet with the relevant approval or consent authority to confirm the stormwater management targets and acceptable WSUD strategies and devices.

An optimal approach would be for the applicant or proponent to undertake a preliminary site assessment and provide a range of baseline information to inform pre-lodgement discussions and/or be included in scoping reports. These could include, but are not limited to:

- natural attributes such as existing environmental values of the site and its surrounding area including waterways or wetlands, native vegetation, native flora and fauna and its habitat, biodiversity corridors, waterway corridors/buffers and other natural features. Natural attributes proposed to be either retained, enhanced or removed should be clearly identified
- stormwater drainage characteristics such as the site's existing topography, stormwater drainage within and downstream of the development site. Existing and proposed discharge points should be identified

- geology and soils to support evaluations in identifying soil types, erosivity, hydraulic conductivity, presence of sodic or saline soils, presence of rock and general groundwater details. If this is not available, the default assumption for the Wianamatta–South Creek catchment is that the soils are saline and sodic
- the proposed approach for achieving the stormwater targets should be provided along with a summary of the likely WSUD strategy for the site. Performance modelling is not required at this stage
- presence of lakes or dams to inform whether they will be retained or decommissioned. Note that if a new lake or dam is proposed, the design objectives should be described (i.e. amenity or stormwater harvesting) and the proposed ownership of the lake outlined.

Development applications (local and state government)

SSD, SSI or development applications should ensure the stormwater management targets are achieved as outlined in an Erosion and Sediment Control Plan (ESCP) for the construction phase, and in a Water and Stormwater Management Plan for the operational phase.

Concept development applications should demonstrate that the concept plan, Stage 1 and subsequent stages of development can achieve the stormwater management targets set out in this guide (Table 3 to Table 6).

Erosion and Sediment Control Plan

An ESCP would generally include the following information to demonstrate the construction phase stormwater quality targets (Table 2) are achieved. A conceptual ESCP would be required for an area of disturbance less than 2,500 m^2. A more detailed plan is generally required to demonstrate compliance with targets for areas greater than 2,500 m^2.

The detailed plan would:

- be developed and certified by a Certified Professional in Erosion and Sediment Control (CPESC) or a qualified and experienced civil engineer with at least 5 years' experience in the development of site-specific soil and water management plans
- illustrate appropriate controls, that when implemented will achieve the construction phase stormwater quality targets in Table 2
- be prepared in accordance with the Blue Book (NSW Government 2004)
- be prepared in accordance with the WSUD design considerations set out in Chapter 3 of this guide (especially WSUD measures)
- provide conceptual designs that include the site, catchment and key features of the ESCP on scaled drawings.

The scope of each ESCP is dependent on the scale of disturbance and site characteristics with larger-scale construction requiring more detail.

Water and Stormwater Management Plan

A Water and Stormwater Management Plan should demonstrate how the operational phase stormwater quality and flow targets are achieved for the development site. To ensure the plan is implementable it would typically be prepared and certified by a suitably qualified engineer with at least 5 years' experience in modelling, design and supervision of WSUD systems, and describe the site, development, water use and WSUD strategy.

The plans are generally concise yet present all the information outlined in Table 7 to demonstrate how the targets can be achieved. The plan focuses on a particular site and its attributes and is not required to reproduce general information from other WSUD guidelines such as descriptions of treatment systems.

Table 7 Information to include in a Water and Stormwater Management Plan

Section / item	Contents
Site description	• Location of site • Plan of waterways and habitat (scaled) and summary of what is to be preserved • Receiving waterways and waterway buffers • Existing wetlands, native vegetation, native flora and fauna and its habitats, biodiversity corridors • Existing catchment and drainage plan (scaled) • Sub-catchments with areas • Contours • Drainage and discharge locations to waterways • Geology and soils (with plans as required)
Proposed development	Plan of development (scaled) with land use or land type split shown (roof, ground level impervious, pervious, road, open space, drainage and WSUD) Estimate of water demand and sources including the use of alternative water sources such as stormwater and recycled water
Stormwater targets	Summary of stormwater targets that apply
WSUD strategy	Details of the proposed WSUD strategy for the development including drawings, tables and relevant descriptions of the following: • catchment and drainage plan showing sub-catchment extents, areas of roof, ground level impervious/pervious and associated drainage systems (i.e. kerb, surface drainage pits, pipes, etc.), WSUD measure locations, stormwater quantity management systems and drainage connection or outlet locations for WSUD measures • details of connections to any relevant regional stormwater and recycled water systems • WSUD system details including type, purpose, location and size • conceptual design of each WSUD measure with sufficient detail to confirm its feasibility; typically including area, surface levels, inflow and outflow levels, batters and a conceptual earthworks plan in 3D form to show how it relates to the development • plan views and cross-sections showing levels and functional details for each WSUD system • staging plan to illustrate how each WSUD measure will be delivered with the development stages to ensure compliance with the operational phase stormwater targets • details of any interim WSUD strategy if the regional stormwater system cannot be implemented initially, to ensure the operational phase stormwater management targets are achieved at all times
Performance assessment	MUSIC modelling: • MUSIC assumptions (for any that are different from this guide) • catchment assumptions (land use or land type split and % impervious) • stormwater quality performance (% removal) • stormwater flow performance for all discharge locations • stormwater quantity modelling • pre and post development flows/levels
Maintenance and operations	Draft operation and maintenance manual for assets, submitted in support of development applications to outline maintenance requirements / commitments

Post development application (local and state government) approval

The documentation should include drawings and plans prepared by qualified professionals, specifically:

- **Erosion and Sediment Control Plan**

Detailed ESCPs and drawings should demonstrate the construction approach and timing so that the construction phase stormwater quality targets (Table 2) are met. Plans should be prepared in accordance with the Blue Book (NSW Government 2004), and with the WSUD design considerations set out in Chapter 3 of this guide (especially WSUD design on waterfront land). The ESCP should be prepared and certified by a CPESC or a qualified and experienced civil engineer with at least 5 years' experience in the development of site-specific soil and water management plans.

- **Water and Stormwater Management Plan**

Detailed Water and Stormwater Management Plans and drawings should demonstrate the construction approach and timing so that the operational phase stormwater quality and quantity targets (Table 3 to Table 6) are met by:

- being completed and certified by a **suitably qualified engineer** with at least 5 years' experience in WSUD design
- **updating the Water and Stormwater Management Plan** – the Water and Stormwater Management Plan should be updated if the WSUD strategy has changed as part of detailed design (e.g. changes in catchments, treatment systems, sizes)
- providing **engineering drawings** that document the WSUD measures. WSUD drawings are clearly identified in a drawing set and are of sufficient detail and resolution to support a detailed appraisal and tender issue. They would include annotated drawings for all WSUD elements including plan views, cross-sections and long sections. The designs would occur in accordance with the WSUD design considerations set out in Chapter 3 of this guide and with the section titled 'Relationship to other documents'
- providing **landscape drawings** to document planting and hardscape details of the WSUD measures. These would include topsoil requirements, planting details of surface and all batters and embankments (species, zones and densities), planting schedule, mulching details, hardscape details including maintenance access, finishes and notes
- providing completed **checklists and certification** for the proposed WSUD measures based on those prepared by Local Government Authorities as listed in the section titled 'Relationship to other documents'. Other best practice checklists should also be consulted; for example, *Water Sensitive Urban Design Technical Design Guidelines* (Water by Design 2006), *Bioretention Technical Design Guidelines* (Water by Design 2019a) and *Wetland Technical Design Guidelines* (Water by Design 2019b). The checklists are typically accompanied by a letter of certification by the preparer of the WSUD strategy confirming that the detailed design is consistent with the approved strategy and the operational phase stormwater quality and quantity targets are achieved.

Chapter 3 – WSUD design considerations

Development will typically generate 3–5 times more runoff than existing or pre-development volumes, depending on the specific development scenario (e.g. greenfield). Infiltrating this excess volume is a common and best practice approach for frequent rain events to reduce impacts on waterways; however, one of the critical considerations for the Wianamatta–South Creek catchment is the highly saline and sodic soils (DPIE 2021c, d).

The soil and hydrogeological landscapes of the catchment are well documented by the NSW Government (DPIE 2021c, d), and include specific actions to manage the high risk of salinity hazard impacts on both the built form and the water dependent ecosystems. As shown in Figure 2, almost all the development area within the Aerotropolis is identified as having high to very high salinity hazard risk. The specific management actions outlined by the NSW Government were therefore key factors in developing the WSUD design considerations set out in this guide. These considerations should be applied with reference to other documents listed in this guide (see section titled 'Relationship to other documents') to ensure best contemporary practice, in the context of relevant legislation and policies.

Figure 1 *Juncus acutus* (tussock forming rush) indicates presence of saline subsoils in the Wianamatta–South Creek catchment

Photo: Rob Muller

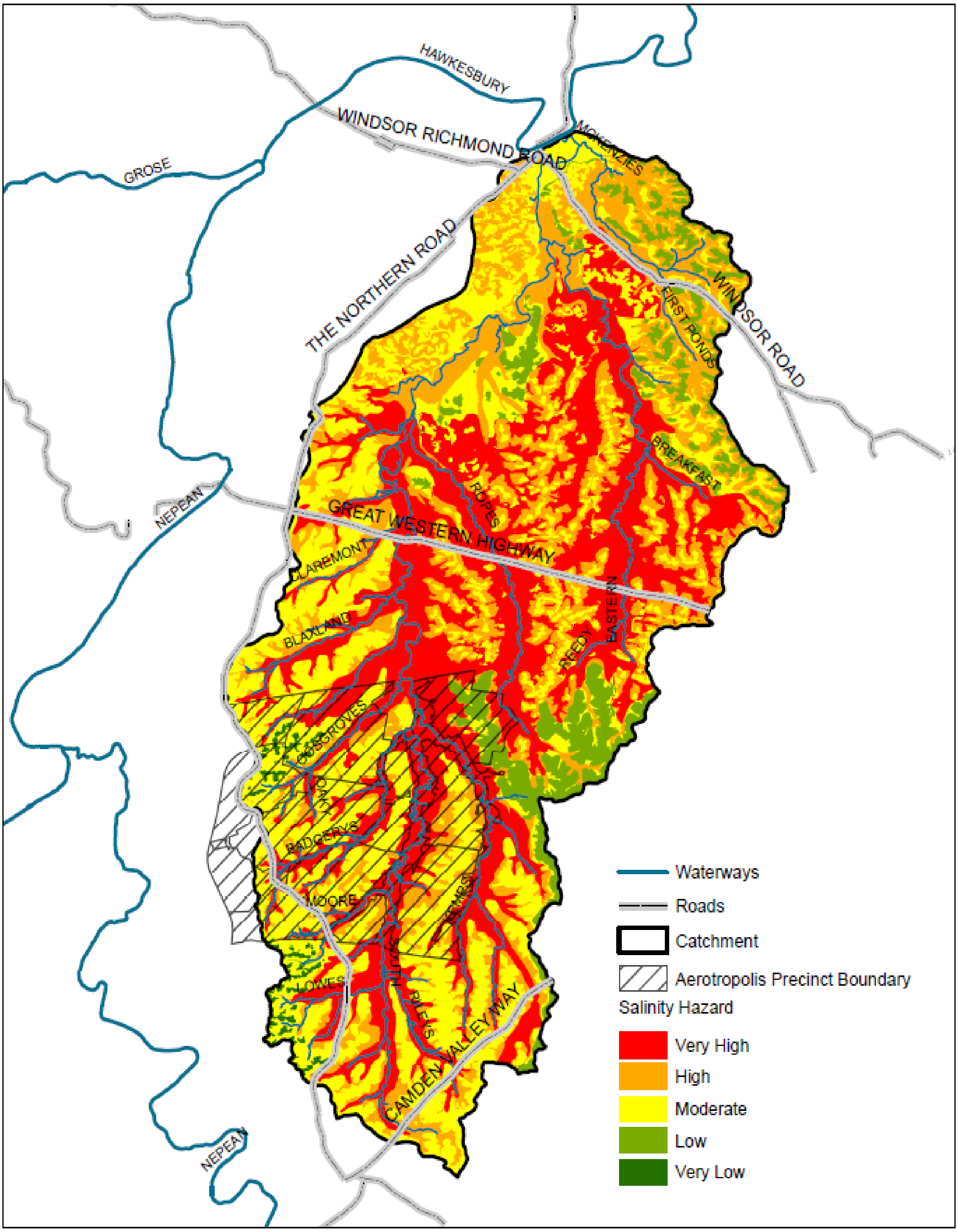

Figure 2 Landscape salinity hazard risk in Wianamatta–South Creek
Data source: South Creek Hydrogeological Landscapes: June 2020 (First Edition)

Erosion and sediment control design principles

The intent of an ESCP is to prevent water contaminants from being released from a construction or building site. Best practice measures to be undertaken would be consistent with the Blue Book (NSW Government 2004). These would typically include components that cover:

- minimising soil exposure and erosion
- drainage and stormwater control
- sediment capture and minimising contaminant releases
- work within waterways.

Best practice initiatives that strengthen the elements in the Blue Book include achieving the construction phase targets outlined in Table 2. For areas larger than 2,500 m^2, this involves designing and implementing sediment controls that treat at least 80% of the average annual runoff volume (i.e. 80% hydrological effectiveness) to 50 mg/L TSS or less, and pH in the range 6.5–8.5. To achieve these construction phase targets, the design of the basins generally needs to:

- be sized and operated in accordance with either a Type-A or Type-B sediment basin as documented in IECA (2008) Appendix B (June 2018)
- be provided with an automated system of flocculant dosing and a suitable supply of flocculant/coagulant, with the type of flocculant/coagulant determined based on the International Erosion Control Association (IECA) chemical coagulants and flocculants fact sheet (IECA 2018)
- have markers within each basin to show the maximum sediment storage level and any additional water storage capacity for water reuse
- limit discharge from the primary outlet system to 50 mg/L TSS, with a pH within the range of 6.5–8.5
- be operational before any disturbance occurs in the catchment upslope of the basin.

Figure 3 High efficiency basin
Photo: Design Flow Consulting

WSUD design principles

The main WSUD design principles that should be considered when selecting WSUD measures for a particular WSUD strategy are:

1. Preference for vegetated treatment systems as they provide hydrologic and green infrastructure benefits.
2. Infiltration measures (including unlined porous pavements) are unlikely to be feasible because of saline and sodic soils, unless detailed site analysis is done to confirm feasibility.
3. Stormwater treatment systems should be arranged in parallel as much as possible, to minimise double treating of stormwater.
4. Stormwater harvesting is likely to be a fundamental part of the WSUD strategy for protecting waterways. Preference is for a reticulated scheme that delivers harvested water to all lots and for all non-potable demands.
5. Irrigation rates are managed to avoid over irrigation and exacerbating saline and sodic soil issues.
6. Stormwater management systems should be lined to minimise infiltration (e.g. engineered clays or synthetic liners).
7. Stormwater treatment and harvesting systems can be located within the 1% AEP. However, they are to be avoided in flood conveyance areas (i.e. 1% AEP floodways and high floodways) and critical flood storage areas unless a flood impact and risk assessment for the development demonstrates that their impacts on flood behaviour and on the community can be managed. Refer to principles set out for the floodplain in this chapter of the guide (see section ‘Location on the floodplain and design principles’).
8. Stormwater treatments and harvesting storages can be located within the vegetated riparian zone (VRZ), provided the function of the VRZ is preserved and design principle 7 (above), and those set out for waterfront land in this chapter of the guide are satisfied (see section ‘WSUD design principles on waterfront land’).

Water demands

Non-potable water demands on lots and in public open spaces are a critical consideration in achieving the stormwater quantity (flow) targets (Table 5, Table 6). The higher the water demand, the easier it is to achieve the targets. Demands for water on industrial, retail or business lots vary a great deal depending on the tenant.

End use assessment by Sydney Water (2021) for industrial users in Sydney found the average total water demand to be 12.5 kL/ha/day with the non-potable portion of this to be approximately 50%. This average total water demand was determined after excluding the very high and very low demands from the analysis, with only properties having demands between the 5th and 95th percentiles included. From this perspective, the average total water demand of 12.5 kL/ha/day was considered to be conservatively low.

The demand for water on industrial land varies considerably from lot to lot as illustrated in Figure 4. It is therefore inappropriate to rely on these high demands when applying rainwater tanks that assume an even demand across lots. The only way of accessing these high average demands is with a reticulated recycled water system that delivers the recycled water to all allotments.

Non-potable water demand data for use in MUSIC modelling are provided in Appendix B of this guide. The data covers industrial, business/commercial and residential land uses including indoor and outdoor demands. Adopting consistent values for non-potable water demands is critical to ensure WSUD strategies can be compared between different areas. Hence, the water demand data in Appendix B are intended to provide a level of consistency in establishing WSUD strategies for a site (as input into MUSIC models). When designing a regional-scale strategy, the stormwater drainage manager should be referred to for the appropriate water demand in that catchment.

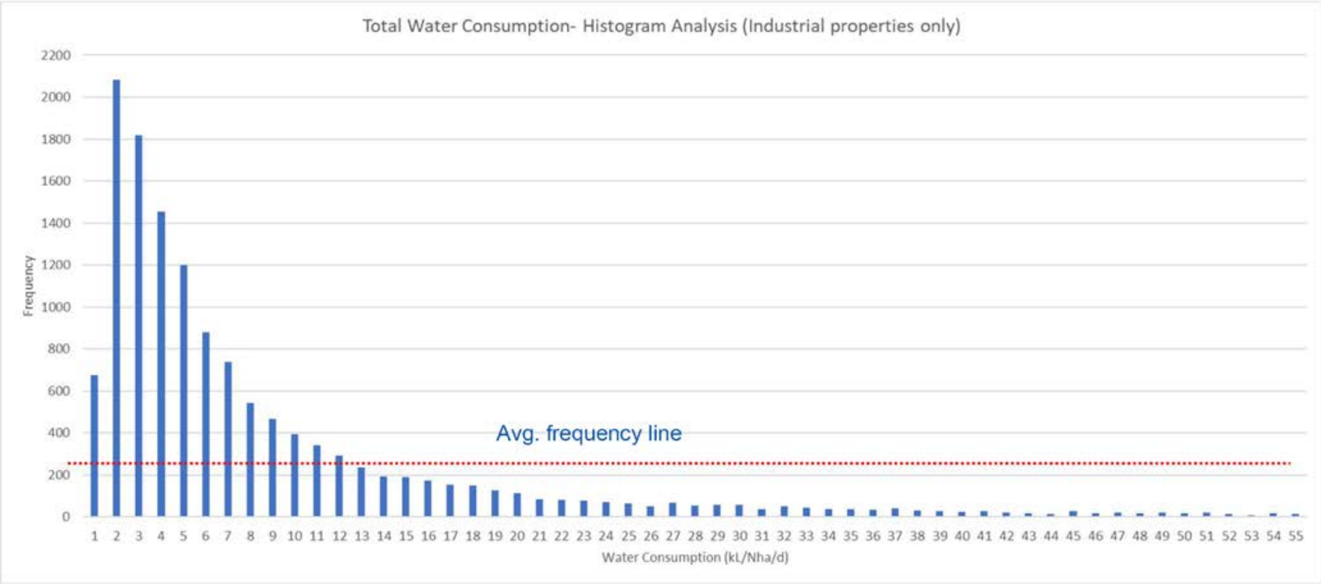

Figure 4 Water demands for industrial developments
Data source: Sydney Water 2021

Streetscape measures

Streetscape measures may form part of WSUD strategies to manage streetscape runoff and contribute to other objectives such as cooling and tree canopy targets. Typical streetscape measures include:

- irrigated street trees
- passively watered street trees
- bioretention street trees
- bioretention basins.

The design of a streetscape measure should consider existing documents relevant to the Wianamatta–South Creek catchment (see section 'Relationship to other documents'). Important considerations include:

- accounting for service corridor requirements in the road reserve
- carefully considering the interaction with pathways and driveway cross-overs
- complying with all the road safety standards
- the number of bioretention trees and raingardens should be optimised by careful design of the road survey and kerb/gutter drainage.

On lot or allotment measures

Typical on lot or allotment WSUD measures include, but are not limited to:

- rainwater tanks
- on-site stormwater detention
- gross pollutant traps (GPTs)
- bioretention basins
- swales
- wetlands, subject to relevant wildlife risk mitigation measures to manage bird strikes (note that wetlands are likely to be interim or temporary under a regional-scale WSUD strategy, see Chapter 4 of this guide)
- stormwater harvesting systems (likely to be interim or temporary under a regional-scale WSUD strategy, see Chapter 4 of this guide).

The design of on lot or allotment measures should consider the existing documents relevant to the Wianamatta–South Creek catchment (see section ‘Relationship to other documents’). Important considerations include:

- accessibility for inspections and maintenance
- protection from damage during construction and building phase and then finalised once the site is finished and landscaped
- careful integration with the landscape but avoiding large level drops and walls, and vegetated with trees.

Soils, infiltration and impermeable liners

Given the saline and sodic nature of the soils in the Wianamatta–South Creek catchment, the following principles are recommended when designing WSUD measures:

- infiltration of collected stormwater should generally be avoided unless detailed site analysis is done to confirm feasibility
- WSUD systems should incorporate an impervious liner (e.g. 1×10^{-9} m/s maximum) to avoid infiltration to local soils
- passively irrigated landscapes that are designed to accept and reduce stormwater runoff volume should be lined and appropriately vegetated (i.e. promoting high evapotranspiration and supporting root systems)
- vegetate pervious areas to promote evapotranspiration
- irrigate landscapes to meet the needs of vegetation and avoid any infiltration past the root zone. Higher profile landscapes requiring additional irrigation may require lining to avoid infiltration, careful control of irrigation rates and potential management of flows downstream (i.e. capture)
- where a core/priority groundwater dependent ecosystem is present and the soils and geology are suitable, infiltration should be considered but subject to a detailed soil and groundwater assessment and ongoing monitoring. A list of core/priority groundwater dependent ecosystems is available in the *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011*.

Landscape integration and interfaces

The design of WSUD measures should complement and integrate within the public and private realm, using natural processes to the greatest extent possible. Important considerations include:

- location and spatial requirements of WSUD should occur early in the site planning and design process
- locate to protect and complement retained vegetation and areas of environmental significance
- integrate within the development layout and landscape to increase visual amenity and biodiversity
- locate adjacent to public open space and waterway corridors to increase amenity and reduce maintenance
- achieve a naturalised shape and design for the stormwater infrastructure to complement the natural landform and retained trees
- ensure all overland flows entering and exiting stormwater management systems do not compromise the intent, function and safety of co-located uses (e.g. recreational parks)
- ensure stormwater management infrastructure is safe
- use endemic plants wherever possible
- minimise level differences between WSUD measures and surrounding landscapes
- minimise the use of walls, but where walls are required, designs should be sufficiently developed to show they do not negatively affect surrounding landscapes
- adopt suitable batters in accordance with documents relevant to the Wianamatta–South Creek catchment (see section ‘Relationship to other documents’).

WSUD levels and outlets

It is critical that WSUD measures can freely drain to a receiving waterway. Sufficient design investigations are required to demonstrate the functionality of the WSUD measures. These would typically consider inlet pipe levels, the level of the WSUD measure (normal water level or surface), the outflow inverts from the WSUD measure and the tailwater level in the receiving waterways. This may require survey to confirm invert levels and standing water levels, capacity to accept flows, and review of downstream waterway condition and stability.

Refer to the documents relevant to the Wianamatta–South Creek for further requirements, in particular refer to any WSUD technical guidelines (for bioretention basins and wetlands) when setting WSUD levels and designing stormwater outlets in and out of the WSUD measures.

Designing for maintenance

The design of WSUD measures needs to carefully consider future maintenance requirements. There are 2 key aspects to consider in designing for maintenance:

- providing adequate access so the intended maintenance activities can be safely carried out
- ensuring the design and materials specified do not result in unnecessarily intensive, costly, onerous or risky maintenance.

Access

Suitable access tracks are required from roads to the location of the WSUD measure. Access should be to the inflow level to allow access for bobcats or excavators, not to the top of headwall or other location away from the inlet zone.

Access tracks for GPTs (where not serviced directly from a roadway), sediment basins or forebays associated with bioretention basins or wetland inlet ponds should ideally have the following characteristics and be consistent with documents relevant to the Wianamatta–South Creek:

- minimum width of 3 m
- constructed of reinforced access track suitable to withstand loads of full trucks
- include provision for turning and stockpiling of material as required
- provide a lockable gate to restrict public access.

Location on the floodplain and design principles

When locating WSUD measures on the floodplain, 2 important factors need to be considered:

- WSUD measures should not adversely impact on flood behaviour and the community locally and at a strategic catchment scale.
- WSUD measures are not washed away or destroyed up to a defined flood event.

In accordance with these factors, WSUD measures may be located within the 1% AEP flood extent provided the following criteria are met:

- no adverse impact on regional flood behaviour or the community, in accordance with a Flood Impact and Risk Assessment (FIRA) undertaken by a qualified professional engineer
- considering the following areas as identified in *Wianamatta South Creek Catchment Flood Study – Existing Conditions* (Advisian 2022):
    - WSUD measures are allowed within the 1% AEP flood fringe areas provided the first bullet point above is demonstrated
    - WSUD measures are allowed within the 1% AEP non-critical flood storage areas provided the first bullet point above is demonstrated
    - WSUD measures are avoided in flood conveyance areas (i.e. 1% AEP floodway and high floodway) and 1% AEP critical flood storage areas, other than waterway rehabilitation, waterway diversion works, dam rehabilitation works or works to support significant stormwater harvesting infrastructure. Any works must demonstrate the first bullet point above
    - WSUD measures are to achieve the levels of protection suggested in Table 8
- generally, WSUD measures should be located offline from external waterways for drainage areas greater than 25 ha to provide a level of protection from stormwater related damage
- appropriate hydraulic modelling should confirm the relevant flood levels, velocities and inundation periods. Where a WSUD measure is potentially prone to high velocity, a geomorphic assessment may be required to confirm the WSUD measure and associated embankments will be stable and will not cause erosion in an adjacent waterway.

Table 8 Protection of WSUD measures on a floodplain

Treatment type	Regional flooding	Local stormwater flooding	Flow velocities in adjacent floodplain
Bioretention	Top of embankment >50% AEP flow level (with 200 mm freeboard) Inundation period <24 hours for events up to 50% AEP Velocity over surface <1 m/s in 1% AEP	Top of embankment >50% AEP flow level (with 200 mm freeboard) Inundation period <12 hours for events up to 50% AEP Velocity over surface <1 m/s in 1% AEP	Embankments (external and internal) designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s
Wetland	Top of embankment >63% AEP level (with 200 mm freeboard) Inundation period <5 days for events up to 63% AEP Velocity over surface <0.5 m/s in 20% AEP and <1 m/s in 1% AEP	Top of embankment >63% AEP flood level (with 200 mm freeboard) Inundation period <3 days for events up to 63% AEP Velocity over surface <0.5 m/s in 20% AEP and <1 m/s in 1% AEP	Embankments (external and internal) designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s
Sediment basin	Top of embankment >63% AEP level (with 200 mm freeboard)	Top of embankment >63% AEP flood level (with 200 mm freeboard)	Embankments designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s
Stormwater harvesting storage	Top of embankment >63% AEP level (with 200 mm freeboard)	Top of embankment >50% AEP flood level (with 200 mm freeboard)	Embankments designed to withstand flood velocities for all events up the 1% AEP. Allowance to be made for appropriately sized rock armour for flows above 1 m/s

Integration with on-site stormwater detention

A WSUD measure and on-site stormwater detention can be co-located where the area of stormwater treatment for a development site is coincident with the area for the local stormwater quantity detention (on-site stormwater detention), or there is only a small external catchment (<25 ha). This co-location effectively reduces the overall land required to manage stormwater.

In these situations, WSUD measures will infrequently become inundated to greater depths than the extended detention depth. The inundation duration is relatively short (hours) and is unlikely to affect the vegetation in the treatment system provided that water can drain following frequent storm events (i.e. 50% AEP, 63% AEP) without scouring the surface or batters.

The following design principles should be addressed when combining WSUD measures and on-site stormwater detention:

- on-site stormwater detention is designed in accordance with the relevant approval or consent authority requirements
- extended detention volume for the treatment system is not included in on-site detention volume (i.e. is assumed to be full, prior to the storm event)
- on-site detention volume is not part of the extended detention of the WSUD measure (i.e. on-site detention volume is not considered in the MUSIC modelling for the WSUD measure)
- for the following situations, an inlet pond and high flow bypass system will be required to ensure higher flow rates than a peak 63% AEP bypass are contained in the detention facility. The hydraulic controls provided at the on-site detention outlet will control flows greater than 63% AEP ensuring higher flows backwater over the top of the WSUD treatment system(s):
    - stormwater detention drainage area is larger than the stormwater treatment drainage area
    - bioretention system size is greater than 800 m^2
    - all wetland systems
- address public safety risks in accordance with the relevant approval or consent authority requirements, noting that these design principles apply to frequent storm events
- avoid vertical drops that will be hidden when the flood storage is engaged
- densely vegetate the on-site detention surface that will be inundated by the peak 63% AEP water level with appropriate native plant species.

WSUD design principles on waterfront land

The following design principles are relevant to WSUD measures proposed to be located on waterfront land, especially where a buffer area is degraded to such an extent that the construction of the WSUD measure would result in an enhancement of the condition and ecological function of the buffer area. The design principles are intended to support existing requirements in the *Guidelines for controlled activities on waterfront land: Riparian corridors* (DPI–NRAR 2018).

- Waterfront land is generally part of the 1% AEP flood function area, and therefore the design principles should be read in conjunction with the design principles for the floodplain set out this guide. As such any works in the 1% AEP flood function area should demonstrate no adverse impact on flood behaviour or on the community in accordance with an FIRA.
- Only vegetated stormwater management systems (earth and vegetation) that provide stormwater management and ecological function should be used.

- Avoid construction of WSUD measures in areas of existing native vegetation.
- Vegetation in the WSUD measures should complement riparian vegetation and provide fauna friendly movement.
- The toe of batters should be set back in accordance with the *Guidelines for controlled activities on waterfront land – Riparian corridors*, which is 50% of the required setback required by the category of stream order in accordance with the Strahler system, and be certified by a geomorphologist that works will not impact on the stream stability. Stormwater infrastructure must include a VRZ or an offset in accordance with the guidelines.
- Ensure there is minimal impact as a result of earthworks when narrowing a flood prone area to prevent adverse hydrologic and hydraulic impacts to vegetation and stream stability. Where there is no formed channel or bank features, the channel width is to be determined by measuring open channel width reaches up or downstream of the site. Top of bank is to be measured from the edge of the assumed channel width.
- If a waterway has a wider buffer on one side of a waterway, WSUD measures could be placed in the wider buffer provided it only takes up half of the overall waterway buffer width (i.e. on both sides of the waterway).
- Any encroachment into the buffer should be offset along the same watercourse alignment (within 300 m).
- Areas requiring scheduled maintenance such as inlet ponds should remain at the outer edge of a buffer to avoid maintenance access encroachment.
- Detailed assessment of the geomorphology of the waterway and stabilisation of both the waterway and stormwater system are required where:
    - it has been identified as an erosion prone area by consent authorities
    - there is instability, erosion, steep banks or waterway movement has occurred or is a risk of occurring in the future
    - there is a risk of hydrologic change in the waterway due to changes in the catchment that may increase stream instability
    - placement of the WSUD measure will increase risk of stream instability or risk of the WSUD measure being eroded.

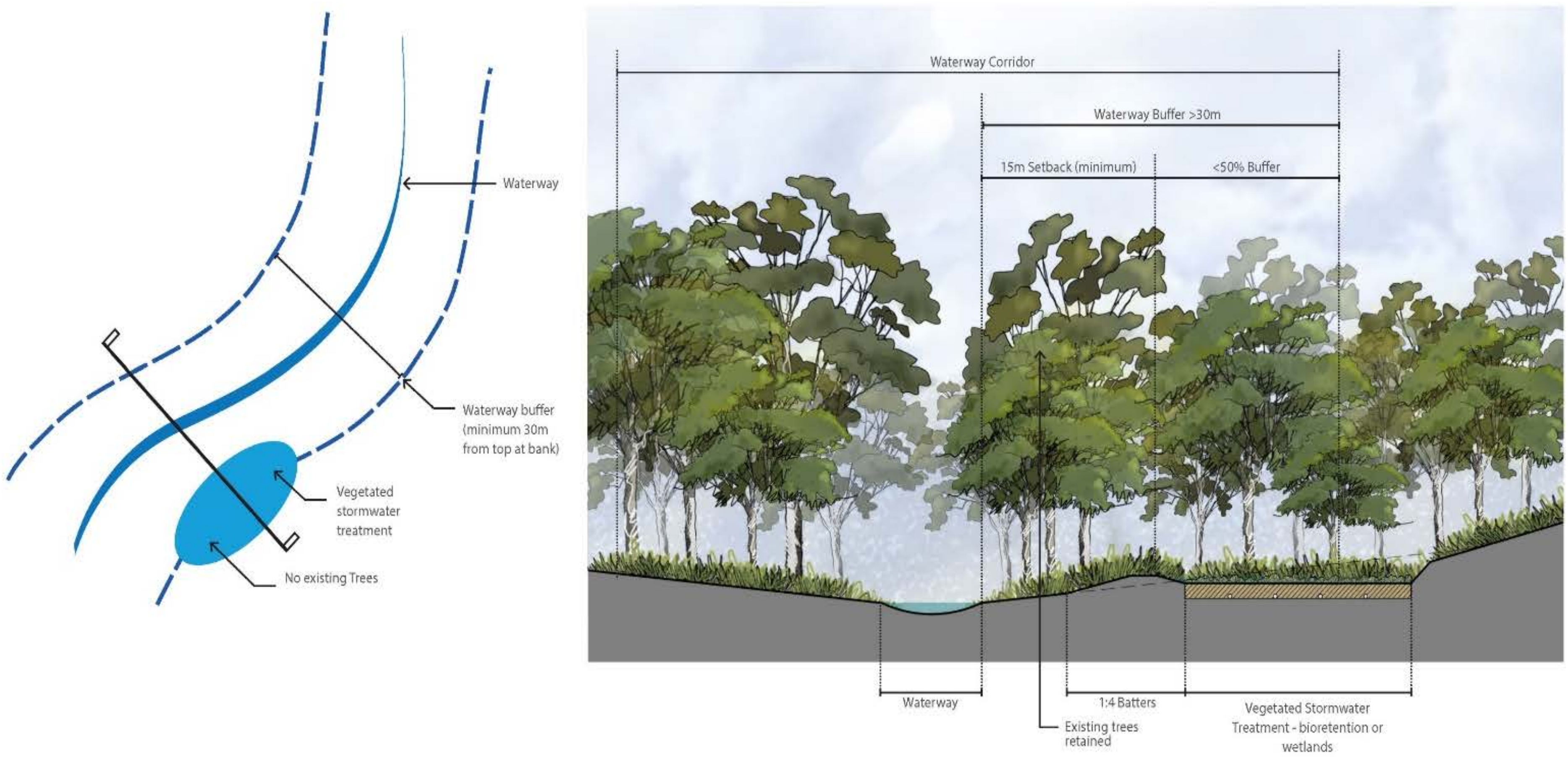

Figure 5 Example layout of WSUD within waterway buffer (waterfront land)

WSUD measures

The following WSUD measures are recognised as practical and reliable measures for performance assessment (MUSIC) modelling, and form the basis of the example WSUD strategies described in Chapter 4 of this guide. The concise descriptions below outline specific design principles for the Wianamatta–South Creek catchment context. More comprehensive guidance on the function and design of these systems is available in a range of existing guidelines (see section 'Relationship to other documents').

Rainwater tanks

Rainwater tanks will likely be required to achieve the stormwater quantity (flow) targets (Table 5 and Table 6), particularly when a reticulated stormwater harvesting system is not available.

Allotment tanks (collecting roof water) should be designed to:

- meet BASIX and/or council requirements for residential land uses
- supply 80% of industrial, commercial and business non-potable water demands.

Supplying 80% of non-potable demands may not be possible where demands on industrial, commercial and business are high. Under this case, tank sizes could be optimised by considering the diminishing rate of return of cost and performance as well as achieving the stormwater quantity (flow) targets.

Street trees

Creating the Western Parkland City requires an increase in tree canopy cover to 40% (see the Premier's Priority 'Greening Our City'). Part of this strategy is the placement of trees along streets and providing suitable water to support these trees. The following types of measures for watering street trees should be considered, in addition to the documents relevant to Wianamatta–South Creek catchment (see section 'Relationship to other documents'):

- **Irrigated street trees** – These are street trees that are delivered in accordance with normal standards but are provided with irrigation from a reticulated stormwater harvesting (and/or recycled water) system. These measures represent the simplest implementation of street trees with a non-potable source of irrigation.
- **Passively irrigated street trees** – These measures operate by diverting small proportions of stormwater via kerb inlet connections to the soil surrounding the trees to increase soil moisture around the tree. Their purpose is to maintain tree health, rather than providing any significant management of stormwater quality or flows. There are various types of passive irrigation techniques for street trees, including open kerb inlets (that deliver stormwater flow on the surface around trunks) and kerb diverters that filter flows and transfer stormwater from a kerb to soakaway pits and/or perforated pipes around a tree. There are industry guidelines and designs available for passively irrigated trees. It is important to note that the standard requirements for healthy street trees still apply (i.e. root zones, topsoil depths, setback to pavement/paths/services) with the only addition being a connection from a kerb to a watering system in the tree root zone that delivers stormwater into the soil around the tree when it is raining.
- **Bioretention street trees** – These street trees provide a stormwater treatment function. They require an open connection from the kerb/gutter that delivers stormwater onto the (depressed) surface of bioretention filter media into which the trees are planted. The system functions as a bioretention system with excess stormwater collected in the base of the system and discharged out to the street pit and pipe drainage. Filter media depth,

excluding drainage and transition layers, should be a minimum 700 mm to support the tree. A saturated zone can be created below the bioretention street tree to hold water for dry periods. Bioretention tree pits are generally expensive stormwater management systems and therefore, are only recommended where road reserve runoff cannot be managed at a precinct or regional scale.

Bioretention basins

Bioretention basins are a fundamental part of WSUD strategies in the Wianamatta–South Creek catchment, and are typically delivered at lot, street, precinct and regional scale. The following design principles are intended to support existing requirements in relevant documents for Wianamatta–South Creek (see section 'Relationship to other documents'):

- extended detention depth to be a maximum of 300 mm for basins, with streetscape systems having a maximum of 150 mm
- have a mixture of groundcovers, shrubs and trees to get shading onto the surface of the basin; therefore, filter media depth is to be >600 mm excluding drainage and transition layers
- bioretention systems with groundcovers should only be considered for small systems (<100 m^2) in highly visual locations or that are co-planted with trees on the batters and surrounds, and filter media depths need to be >400 mm
- a saturated zone to be adopted for all bioretention systems
- an impermeable liner or equivalent (e.g. compacted clays) to the base and sides is required to create the saturated zone and avoid infiltration to in-situ saline and sodic soils
- a sediment forebay is acceptable for catchments up to 10 ha; above 10 ha a sediment basin (or wetland) is to be adopted to pre-treat flows entering the bioretention system
- the surface of the bioretention system to be planted at high diversity and density (e.g. 4–6 groundcover plants per m^2).

Sediment basins

Sediment basins commonly form part of WSUD strategies. The following design principles should be considered, in addition to existing principles in relevant documents for Wianamatta–South Creek (see section 'Relationship to other documents'):

- minimum 1.5 m depth (2 m maximum)
- include 1 in 8, 1.5 m wide minimum safety bench around the perimeter (refer to relevant documents)
- reinforced access to base of sediment basin of thickness and reinforcing suitable for heavy vehicles (e.g. concrete or cement stabilised rubble)
- reinforced base and sides up to within 300 mm of normal water levels
- include an impermeable liner that can operate under both wet and dry conditions (i.e. not crack)
- edges and batters to be fully vegetated with suitable species
- consider public safety requirements
- where a sediment basin is combined with a bioretention basin and the levels of both measures is the same or similar, they can share the extended detention (i.e. the extended detention of the sediment basin and bioretention are the same).

Wetlands

Wetland measures (including sediment basins) are a fundamental part of WSUD strategies in the Wianamatta–South Creek catchment, and will apply at lot (only large lots), precinct and regional scales. The following design principles should be considered, in addition to existing principles in relevant documents for Wianamatta–South Creek (see section 'Relationship to other documents'):

- extended detention depth to be a maximum of 350 mm
- notional detention times of between 48 and 72 hours are to be achieved when extended detention depth is above 100 mm
- in some cases, small extended detention depths (<100 mm) may be used with longer extended detention times to help achieve stormwater quantity (flow) targets
- include an impermeable liner that is protected so it can operate under both wet and dry conditions (i.e. not crack)
- harvesting stormwater directly from a wetland can occur but only from the top 100 mm (to ensure water plant health). Typically treated water from a wetland will be directed to a dedicated storage system as part of a reuse scheme
- consider public safety requirements such as 1 in 8 safety bench or fencing around the perimeter
- wetland to consist of a mixture of marsh depths and species and generally use at least 12 different wetland species
- where the wetland is combined with a bioretention system and the levels of both systems are the same or similar, they can share extended detention (i.e. the extended detention of the wetland and bioretention are the same). In this case, the MUSIC modelling method changes such that the wetland extended detention depth is reduced to <50 mm and the bioretention extended detention surface area is increased to include the wetland area
- minimise the risk of large populations of flying waterbirds by addressing requirements set out in relevant in Development Control Plans (e.g. DPIE 2021a, b), and ensure the wetland is supported by a Wildlife Hazard Assessment and Management Plan if located within 13 km of the Western Sydney Airport (WSPP 2020). This will involve but is not limited to avoiding islands and perching/roosting areas, avoiding rock/turf edges that are easily accessed by birds, minimising trees that overhang water, disrupting bird flight paths and adopting wetland vegetation to dissuade birds.

Proprietary devices

Proprietary devices are WSUD measures that are manufactured by a corporate entity, and that have proprietary components specific to the manufacturer.

Gross pollutant traps

GPTs are proprietary devices that target litter, debris and coarse sediment and can be accepted as both private and public infrastructure in appropriate situations. There are 2 broad classes of devices:

- GPTs / in-line devices
- gully pit baskets.

Proprietary nutrient removal devices

Proprietary devices for nutrient and fine sediment removal may be considered for private infrastructure under the following situations:

- the device is approved and certified through the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018)
- use is limited to HDR (>60 dwellings/ha), commercial, or industrial developments only
- the site is constrained such that the application of vegetated WSUD measures on the private allotments is not practicable
- performance (MUSIC) modelling of such devices is to be consistent with claims verified through the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018).

Stormwater harvesting and reuse systems

Stormwater harvesting and reuse represents the most effective measure for reducing stormwater flow volumes from frequent flow events to achieve the stormwater quantity (flow) targets (Table 5 and Table 6). Common options for stormwater harvesting most relevant to Wianamatta–South Creek catchment include:

- **Private allotment stormwater harvesting** (privately owned) – This may involve capturing roof runoff, overflows from tanks and ground level runoff and then treatment, storage and reuse for irrigation of landscape and undeveloped zones. Likely to be an interim or temporary measure only as a way to reduce stormwater export until a regional stormwater system is implemented.
- **Stormwater harvesting and open space irrigation** (publicly owned) – Capture, treatment, storage, disinfection and reuse of stormwater to irrigate public open space and reduce stormwater flow reaching waterways.
- **Reticulated stormwater harvesting** (managed by a stormwater drainage manager) – Capture, treatment, diversion and storage of stormwater that is then directed to a regional reuse system. Stored flows are disinfected and then fed into a reticulated recycled water pipe that is connected to all lots to provide non-potable water for a variety of uses (including to irrigate street trees and parks).

Under the *Water Management Act 2000*, water is only permitted to be taken under a water access licence, a basic landholder right or an access licence exemption. The Natural Resources Access Regulator should be consulted regarding the regulatory settings that apply to the take of water.

General

The following apply to the design of stormwater harvesting systems:

- only treated water from stormwater treatment systems is to be directed to reuse storages (i.e. overflows or bypasses should bypass)
- *Managing Urban Stormwater: Harvesting and reuse* guidance (DEC 2006) and *Stormwater Harvesting Guidelines* (Water by Design 2009)
- *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks: Stormwater harvesting and reuse* (NRMC, EPHC and NHMRC (2009).

Storage

Storage systems will vary depending on context, scale and ownership:

- small-scale systems may use above or below ground tanks
- moderate and large systems may use tanks or open storages with an active storage that will be dewatered. In most situations the active storage depth will be at least 2 m to reduce the footprint of the system. These systems will have a variable water level and dry out at times, which can result in poor amenity during those times. Hence, the location and design of the storage needs to consider local amenity and safety
- very large stormwater harvesting systems may divert or pump treated stormwater flows from WSUD measures to large, centralised storages. The storage will be open and could have a large active storage depth thus have limited amenity at times, or could have a small active storage depth (e.g. <0.3 m) that preserves a permanent waterbody for amenity reasons. In this case, the sustainability of the lake system needs to be carefully considered
- where an open water storage is adopted it should:
    - include an impermeable liner that can operate under both wet and dry conditions (i.e. not crack)
    - consider public safety requirements
    - minimise the risk of large populations of flying waterbirds by addressing requirements set out in relevant Development Control Plans (e.g. DPIE 2021a, b), and be supported by a Wildlife Hazard Assessment and Management Plan if located within 13 km of the Western Sydney Airport (WSPP 2020). This will involve but is not limited to avoiding islands and perching/roosting areas, avoiding rock/turf edges that are easily accessed by birds, minimising trees that overhang water, disrupting bird flight paths and adopting wetland vegetation to dissuade birds.

Disinfection

The stormwater harvesting and reuse system should meet requirements set out in the national stormwater reuse guidelines: *Australian Guidelines for Water Recycling: Managing Health and Environmental Risks: Stormwater harvesting and reuse* (NRMC, EPHC and NHMRC 2009).

These national guidelines include requirements for pathogen log reduction values to adequately manage public health risks during public open space irrigation. The log reductions can be achieved by either limiting exposure (e.g. limiting access during times of irrigation or using subsurface irrigation) or through treatment processes. For public parks it is likely that treatment will be used to achieve the required log reductions.

If full restriction can be achieved (e.g. on private property), such as restricted access during irrigation and 25–30 m buffers to public access, then the national guidelines suggest no additional treatment is required.

The national guidelines specify likely reductions for a range of treatment types for the different criterion (Table A3.5 in Appendix 3 of NRMC, EPHC and NHMRC 2009). It is likely that an ultraviolet (UV) treatment system would be most economically effective, and these are quoted as being able to reduce pathogens by >1.0, >3.0 and 2–4 for viruses, protozoa and bacteria, respectively.

The national guidelines also suggest that ‘for most small-to-medium sized schemes, UV disinfection is the most practical and commonly used disinfection technique for achieving the required log reductions’.

Another important criterion in selecting a UV system is to ensure there is adequate dosing (i.e. light bulb strength for a given turbidity). Typically, for treated stormwater a transmissivity of 50% is assumed and a dosing rate of at least 40 mJ/cm^2. The selection of the UV system should be co-designed with the supplier.

Lakes and existing dams

The design principles below are applicable to constructed lakes or retained dams dominated by open water, noting wetlands have 80% vegetation coverage and are considered separately. The approval of the lake or dam is at the discretion of the relevant approval or consent authority, and the design principles below are intended to support existing requirements:

- the lake or existing dam does not form part of the stormwater quality treatment train. Stormwater must be treated prior to entering the lake. Lakes can contribute towards achieving the stormwater quantity (flow) target
- the lake system incorporates suitable turnover and treatment to minimise the risk of algal blooms and aquatic weeds. Residence time in the lake of <15 days is achieved through natural or mechanical flushing
- the lake system is designed to support landscape, passive recreation and ecological values, and should not pose a health, safety or aesthetic risk
- the lake is designed such that it can be dewatered for maintenance, and if required, dewatered and converted to a waterway or ephemeral wetland
- the system is designed and managed to protect downstream receiving waterways, maximise resource use efficiency and minimise life cycle costs and risks
- a detailed maintenance and monitoring program is developed to show how a constructed lake will be adaptively managed to ensure the water quality of the lake meets the performance criteria (water quality objectives) for Wianamatta–South Creek (DPE 2022c).

Key factors that should be considered when designing lakes or retaining existing dams include, but are not limited to, the following:

- Dam Safety NSW requirements
- impacts on flood behaviour and on the community as per design principles set out in this chapter of the guide
- weeds, in particular floating weeds
- nutrients, light, temperature and turbidity
- algae growth
- organic carbon loads
- lake detention time (<15 days) and flushing rates
- salinity
- water level and depth (maximum 3 m)
- shape, mixing and stagnant zones
- hydraulic control (lowering water level for maintenance)
- maintenance access (for desilting, access for weed harvesting, litter removal, outlet hydraulic structures, perimeter for riparian weeds)
- pest and bird management (i.e. consider recommendations in the Wildlife Management Assessment Report for the Aerotropolis – see WSPP 2020)
- erosion, particularly during large events and from wave action

- inflow and outflow locations
- public safety
- whether the lake/dam is a Prescribed Dam under the *Dam Safety Act 2015* and requires referral to the NSW Dam Safety Committee
- whether a licence is required from Water NSW to capture more water than the Maximum Harvestable Right Dam Capacity (MHRDC)
- wall/embankment stability, seepage and scour protection.

Chapter 4 – Example WSUD strategies

This chapter provides examples of WSUD strategies for select typologies to demonstrate the type and scale of WSUD measures required to meet the operational phase stormwater quality and quantity targets (Table 3 to Table 6). The examples should not be viewed as solutions that are 'deemed to comply'.

Three typologies were selected to represent a range of impervious area impacts of development and different potentials for allotment non-potable water demands. Examples of WSUD strategies for varying scales of development are presented for LFI, HDR and LDR typologies. The varying scales include:

- **Lot and streetscape** – The WSUD strategy for the development is limited to allotments and streets only.
- **Lot and precinct** – The WSUD strategy for the development includes allotments, streets and area of public open space.
- **Regional treatment** – The WSUD strategy for the development is planned for larger scales than one development parcel (or owner), and is planned and coordinated by a separate entity from the developer (e.g. planning for a reticulated stormwater harvesting and reuse scheme).

WSUD measures used in WSUD strategies

The WSUD measures used in the examples of WSUD strategies are outlined in Table 9, together with brief descriptions of the assumed configuration of each measure.

Table 9 Description of WSUD measures used in WSUD strategies

Measure	Description
Green roofs	Roof areas that are covered with soil and vegetation. They act to capture rainwater, promote evaporation, reduce runoff volumes and cool the buildings
Gross pollutant traps	GPTs filter litter and debris from stormwater and act to contain oil spills
Roof water tanks	Tanks that collect roof water that is then pumped to supply indoor uses (e.g. toilets, laundries and sometimes hot water) and/or outdoor uses (irrigation)
On-site stormwater detention	Sunken landscaped areas that provide stormwater storage during infrequent local stormwater flooding events
Lot bioretention	Bioretention basins that collect and filter stormwater within a lot, typically targeting roads, carparks and hardstand areas
Lot wetlands	Constructed wetlands for the purpose of stormwater treatment. Once treated, the water is commonly pumped to storages for reuse
Lot storages	Lot storage can either be in tanks (e.g. above ground) or open storages (e.g. dam) and is used to supply pumps for reuse systems (e.g. irrigation)
Street bioretention	Bioretention basins located in road verges that collect and filter stormwater from the road (assumed earth batters and no grate covers)
Passively irrigated street trees	Stormwater diverters installed in kerbs to direct small amounts of stormwater into soils around street trees for irrigation (not bioretention)

Measure	Description
Precinct wetland	Constructed wetlands for the purpose of stormwater treatment, habitat and recreation in public open spaces. Treated water is commonly directed to storages for reuse. Can be located above or below the 1% AEP level, in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide
Precinct bioretention	Bioretention basins that collect and filter stormwater located in public open space above or below the 1% AEP level, in accordance with the floodplain and waterfront principles set out in Chapter 3 of this guide
Combined wetland/ bioretention	Wetlands in combination with bioretention, where wetlands treat baseflows and then overflow into bioretention basins during storm events – both share extended detention volumes
Public open space storage tank and reuse	Treated water storage in public open space can either be in tanks (in smaller parks) or open water storage (e.g. dams/ lakes) and is then used for irrigation
Regional reuse storage	Treated water storage in open water dams or lakes, can be located above or below the 1% AEP level (in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide), and is then transferred to a regional reuse scheme
Reticulated reuse pipe	A dedicated reticulated water pipe to supply recycled stormwater to allotment and open space. Can be combined with recycled wastewater

Large format industrial

The LFI typology represents the largest land-use zone in the initial precincts for the Western Sydney Aerotropolis and Mamre Road. It was considered to be the most challenging typology in terms of achieving the stormwater quality and quantity targets (DPE 2022d, e). This is because LFI typologies are typically characterised by large expanses of roof space, hardstand and limited landscape. So while the vision for the Western Parkland City is for relatively more green space, there will still be large areas within an LFI typology that are impervious. It was assumed that if a compliant WSUD strategy can be developed for an LFI typology, then it can also be replicated for other typologies.

The following range of example WSUD strategies were devised for delivery at the lot/ allotment, precinct or regional scale. Some of the latter examples include regional treatment, stormwater harvesting and reticulated reuse, as part of or making up a regional stormwater system. An interim approach is provided for the example lot/allotment WSUD strategies to show how partial development can achieve the targets until the site is fully developed and connected to a regional stormwater system.

All example WSUD strategies below account for the WSUD design considerations in Chapter 3 of this guide, and are especially subject to the principles under the section titled 'Soils, infiltration and impermeable liners'. Infiltrating stormwater is generally inappropriate because of the saline and sodic soils, making it additionally challenging to capture and find methods for losing or using the excess stormwater.

Example WSUD strategies for LFI

Example WSUD strategies for LFI are shown in Table 10, and described more generally below. These WSUD strategies cover a mix of allotment measures, streetscape measures, local public open space and regional stormwater systems. Table 11 shows the types and sizes of WSUD measures required to achieve the operational phase stormwater quality and quantity (flow) targets under each WSUD strategy.

In general, WSUD strategies that include measures on allotments, in streetscapes and local parks also rely on a reduction in the impervious coverage of allotments compared to the maximum allowable (i.e. 85%, see the *Mamre Road Precinct Development Control Plan 2021* (DPIE 2021b)). When a reticulated stormwater reuse system is adopted, WSUD strategies can adopt a variety of stormwater measures along with maximum site imperviousness to achieve the operational phase stormwater quality and quantity (flow) targets.

The WSUD strategies are specifically discussed in more detail, including cost estimates, in a companion study (DPE 2022d). There are 5 types of WSUD strategies for LFI provided as examples in this guide:

- **LFI A option** – 50% of roof areas drain to tanks for toilet use and irrigate 50% of lot garden beds. Each lot includes a GPT and bioretention system and there is also a precinct bioretention to meet post development load reduction stormwater quality targets (TSS 85%, TP 65%, TN 45%). *This option does not comply with the stormwater quality and quantity (flow) targets outlined in Table 3 to Table 6 of this guide, and is provided for comparison only*.
- **LFI B options** – Lot yields are reduced to an equivalent of 40–50% of lot area being pervious. The remaining undeveloped areas are used for treatment (wetland or bioretention) and storage ponds before irrigating the pervious areas. Tanks are used for toilet flushing and bioretention is used for allotment carparks and along streetscapes.
- **LFI C1 to C3 options** – Lot yields are reduced to an equivalent of 20–30% of lot area being pervious. Allotment bioretention is used for hardstand areas, streetscape bioretention is implemented and local public open space is used for treatment (wetland) and evaporation (and sometimes reuse to irrigate the local parks).
- **LFI C4 option** – This option adopts full development yields and requires considerable stormwater harvesting and reuse. It requires large tanks within the allotment for toilets and to irrigate 100% of allotment gardens in addition to allotment and streetscape bioretention for treatment. A precinct wetland then treats and evaporates stormwater to contribute to a reuse scheme that irrigates 100% of public open space areas.
- **LFI D options** – Lots are fully developed with regional treatment and the treated water is directed to regional storage ponds as part of a broader reuse scheme. Reticulated treated stormwater is used for all non-potable uses as well as irrigating public open spaces. Tanks and allotment / streetscape bioretention may or may not be required depending on the particular option.

Interim solution

LFI B options and LFI C1 to C3 options could be considered an interim solution (by fully developing some allotments and leaving others pervious) until a regional stormwater system is implemented and the lot can be fully developed to maximum imperviousness (as outlined in the relevant Development Control Plan).

More detailed descriptions and example layouts for different WSUD strategy types are shown in the following sections for:

- lot and streetscape strategies (LFI B2)
- lot and precinct strategies (LFI C4)
- regional treatment and reticulated reuse strategies (LFI D2-b)

Table 10 Example WSUD strategies for LFI typologies

WSUD strategy – LFI		Delivery approach – dependent on scale of development and options for regional harvesting and reuse								
		Reduced site coverage	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Regional WSUD (maximise below 1% AEP)	Stormwater quantity detention	Public open space stormwater harvesting	Reticulated regional stormwater harvesting
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)		✓	✓		✓		✓		
B1	Lot and streetscape	✓	✓	✓	✓			✓		
B2	Lot, streetscape and local irrigation	✓	✓	✓	✓			✓		
C1-a	Lot, local public open space and regional treatment (above 1% AEP)	✓	✓	✓	✓	✓		✓		
C1-b	Lot, local public open space and regional treatment (above 1% AEP)	✓	✓	✓	✓	✓		✓		
C2-a	Lot, local public open space and regional treatment (below 1% AEP)	✓	✓	✓	✓		✓	✓		
C2-b	Lot, local public open space and regional treatment (below 1% AEP)	✓	✓	✓	✓		✓	✓		
C3-a	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	✓	✓	✓	✓		✓	✓	✓	
C3-b	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	✓	✓	✓	✓		✓	✓	✓	
C4	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)		✓	✓	✓		✓	✓	✓	
D1-a	Lots, regional treatment and reticulated stormwater reuse		✓	✓			✓	✓		✓
D1-b	Lots, regional treatment and reticulated stormwater reuse		✓				✓	✓		✓
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)						✓	✓		✓
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)						✓	✓		✓
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse		✓	✓	✓		✓	✓		✓
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse		✓	✓	✓		✓	✓		✓

*Differences between the 'a' and 'b' options are different mixes of wetlands and bioretention systems for treatment. Option A does not achieve the stormwater quality and quantity targets.

Table 11 Sizes of WSUD measures and impervious cover of example WSUD strategies for LFI typologies

WSUD strategy – LFI		WSUD measures												% Open space proportion		% Impervious	
		Tanks (kL/ha)	Lot bioretention (m^2/ha)	Street bioretention (m^2/ha)	Lot / precinct wetland (m^2/ha)	Regional wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater harvesting on lot storage (m^3/ha)	Stormwater harvesting on lot to irrigation (ML/y/ha)	Stormwater harvesting to public open space storage (m^3/ha)	Stormwater harvesting (local) to POS irrigation (ML/y/ha)	Regional stormwater harvesting storage (m^3/ha)	Reticulated regional stormwater harvesting (ML/y/ha)	Local	Regional	Lot imperviousness	Total imperviousness
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)	31	42				40							7.4	7.0	85	72
B1	Lot and streetscape	140	10	35	550									0	0	50	48
B2	Lot, streetscape and local irrigation	14	10	35	550			300	0.7					0	0	60	53
C1-a	Lot, local public open space and regional treatment (above 1% AEP)	104	69	25	500									7.4	7.0	70	62
C1-b	Lot, local public open space and regional treatment (above 1% AEP)	47	56	20	600									5.6	30	85	54
C2-a	Lot, local public open space and regional treatment (below 1% AEP)	104	69	25		500								7.4	7.0	70	62
C2-b	Lot, local public open space and regional treatment (below 1% AEP)	47	56	20		600								5.6	30	85	54
C3-a	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	75	69	24		500				200	0.3			7.4	7.0	75	65
C3-b	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	47	60	14		350				200	0.6			6	20	85	62
C4	Lot, local public open space and regional treatment and public open space irrigation (below 1% AEP)	60	69	24		350				200	0.8			7.4	7.0	85	72
D1-a	Lots, regional treatment and reticulated stormwater reuse	55	24			500						300	1.3	7.4	7.0	85	72
D1-b	Lots, regional treatment and reticulated stormwater reuse	14				200	60					300	1.9	7.4	7.0	85	72
D2-a	Regional treatment and reticulated stormwater reuse (no tanks)					375	60					380	1.6	7.4	7.0	85	72
D2-b	Regional treatment and reticulated stormwater reuse (no tanks)					200	60					380	2.0	7.4	7.0	85	72
D3-a	Lots and streetscape with regional treatment and reticulated stormwater reuse	55	69			300						300	1.4	7.4	7.0	85	72
D3-b	Lots and streetscape with regional treatment and reticulated stormwater reuse	55	69	24		150	40					300	1.6	7.4	7.0	85	72

Note that Option A does not achieve the stormwater quality and quantity targets, and Option B has a 0% open space proportion because it considers a development of only allotments and streets (not public open space)

LFI lot and streetscape strategy

Summary

This strategy (B2 in Table 10 and Table 11) focuses on delivering the operational phase stormwater quality and quantity (flow) targets on allotments and in adjacent streets. It is not possible to achieve the stormwater targets using a standard development footprint (i.e. the maximum allowable impervious area, such as 85% for the Mamre Road Precinct) and adopting only lot and streetscape measures, because too much stormwater is generated and there are insufficient reliable demands to use the stormwater before discharge.

The approach taken for this strategy is to reduce the impervious proportion of the development and use a part of that (pervious) area for irrigation. Runoff from the lots is collected, treated, stored and then used for this irrigation.

This approach is in addition to collecting and reusing roof water for toilets, and incorporating bioretention for allotment hard paved areas of the lot and installing streetscape bioretention. Monitoring of the lot/allotment storage and irrigation system is likely to be required along with independent audits on a regular basis of all allotment WSUD measures, to ensure they are meeting the design intent.

It may be possible that this approach is adopted as an interim solution until a regional treatment and reticulated reuse scheme is implemented. The example layout shown in Figure 6 shows one potential configuration that would enable development of the full site should a regional treatment and reticulated reuse scheme be delivered at a later date.

Strategy components

A summary of the size of the WSUD measures required in this example is presented in Table 12.

Table 12 LFI B2 option – lot and streetscape strategy components

LFI B2 option	Tank for toilet use	Lot bioretention	Allotment wetland	Storage for allotment irrigation	Maximum lot imperviousness	Amount of pervious lot irrigated	Street bioretention	On-site stormwater detention
	kL/ha	m^2/ha	m^2/ha	kL/ha	%	%	m^2/ha	m^3/ha
Requirements	14	10	550	300	60	50	35	390

Indicative layout

An indicative layout for this LFI (B2) option, which only proposes WSUD measures on the allotment (i.e. private land) and adjacent streets is shown in Figure 6. As indicated by the yellow dashed lines, LFI development could expand to cover the full site if a regional treatment and reticulated stormwater harvesting scheme is implemented (e.g. any of the Option D strategies in Table 10 and Table 11). In the example shown, the lot/allotment wetland, storage and irrigated area could be decommissioned, and the area developed into industrial lots with all drainage contributing to a regional treatment and harvesting scheme.

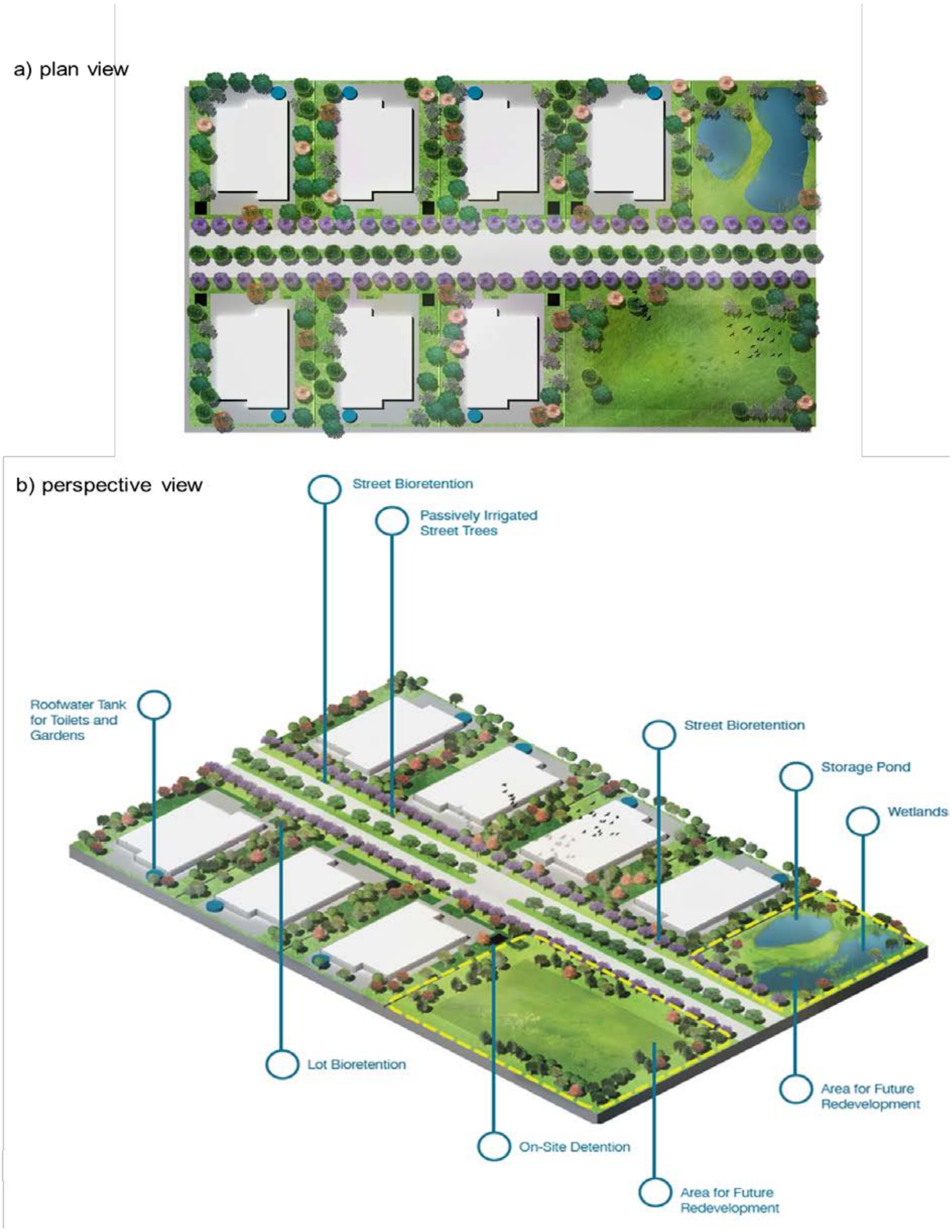

Figure 6 Indicative layout for LFI lot and streetscape measures

Note the yellow dotted boundaries indicating opportunities for future development if a regional stormwater system is established.

Stormwater targets achieved

An example MUSIC model is shown in Figure 7 to demonstrate how the treatment nodes relate to the source catchments/drainage areas for all works to be contained within the lots or streets. Table 13 and Table 14 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

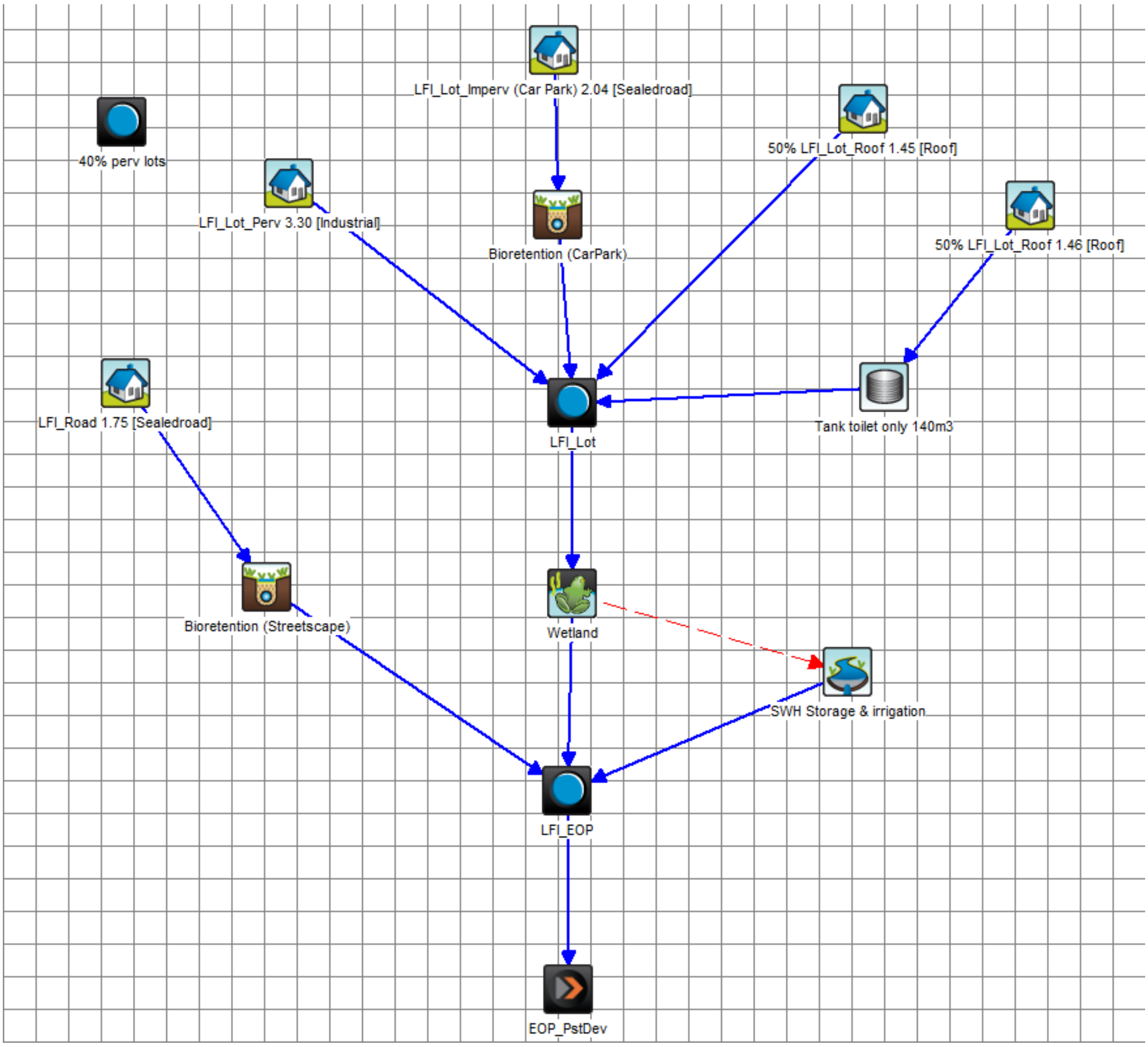

Figure 7 Example MUSIC model structure for LFI lot and streetscape measures

Perv denotes pervious, Imper denotes impervious, EPO denotes end of pipe, PstDev denotes post development, and SWH denotes stormwater harvesting.

Table 13 Compliance of WSUD strategy LFI B2 option with operational phase stormwater quantity (flow) targets

Flow targets based on flow percentiles			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	13,608	Yes
90%ile flow	1,000–5,000 L/ha/day	4,826	Yes
75%ile flow	100–1,000 L/ha/day	486	Yes
50%ile flow	5–100 L/ha/day	8	Yes
Cease to flow	10–30%	31	Yes

Table 14 Compliance of WSUD strategy LFI B2 option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	91	Yes
Total phosphorus (TP)	80%	81	Yes
Total nitrogen (TN)	65%	68	Yes

LFI lot and precinct strategy

Summary

This strategy (C4 in Table 10 and Table 11) adopts a suite of WSUD measures on lots, in streets and in public open space to enable full development of each lot (i.e. up to 85% impervious, see the *Mamre Road Precinct Development Control Plan 2021*) and still comply with the operational phase stormwater quality and quantity (flow) targets (Table 3 to Table 6).

The strategy includes collecting roof water in tanks and using this to supply toilets within the building as well as irrigating 100% of the pervious area of allotments with a dedicated irrigation system. This irrigation coverage is more than the recommended areas for irrigation (see Appendix B of this guide), and should therefore be confirmed with the consent/approval authority and/or stormwater drainage manager. Adopting this example strategy would be subject to detailed salinity and sodicity assessments and/or delivery of suitable WSUD measures (e.g. lining; see also DPIE 2021c, d). Adopting this example strategy will also likely require certification of the design to ensure 100% irrigation coverage and monitoring/ reporting of the system, and independent auditing to ensure the system is achieving the design intent.

Bioretention is implemented for driveways and carparks in the lots, as well as along the streets. A wetland is to be integrated into local parks and this will treat stormwater that is then used to irrigate the park area, as well as losing some water to evaporation. Treated water could be stored in a tank (either above or below ground) or in an open storage pond that could be integrated within the park setting (as long as water level variations can be managed for amenity and safety).

Agreement is required with the consent authority and/or stormwater drainage manager for the ownership and operation of the precinct wetland, storage and reuse scheme.

Any Positive Covenant for ongoing operation and maintenance of WSUD and on-site stormwater detention measures should be registered on title. Monitoring of tanks and allotment irrigation systems is also likely to be required along with independent audits on a regular basis of all allotment WSUD measures, to ensure they are meeting the design intent.

Strategy components

A summary of the size of the WSUD measures required in this example is presented in Table 15.

Table 15 LFI C4 option – lot and precinct strategy components

LFI C4 option	Tank for indoor use and lot irrigation	Number of gardens irrigated	On-site stormwater detention	Lot bioretention	Streetscape raingarden	Precinct wetland	Reuse storage for public open space	Amount of public open space irrigated
	kL/ha	%	m^3/ha	m^2/ha	m^2/ha	m^2/ha	kL/ha	%
Requirements	60	100	390	69	25	450	300	50

Indicative layout

An indicative layout for this LFI (C4) option, which proposes WSUD measures on the allotment (i.e. private land), adjacent streets and local parks is shown in Figure 8. The layout shows how allotment and streetscape measures complement WSUD measures that have been integrated into a local park, and how captured stormwater is used to irrigate the park. In addition, a waterway is incorporated into the open space that increases the blue grid components in the developed area.

Stormwater targets achieved

Table 16 and Table 17 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 16 Compliance of WSUD strategy LFI C4 option with operational phase stormwater quantity (flow) targets

Flow targets based on flow percentiles			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	9,485	Yes
90%ile flow	1,000–5,000 L/ha/day	3,968	Yes
75%ile flow	100–1,000 L/ha/day	921	Yes
50%ile flow	5–100 L/ha/day	42	Yes
Cease to flow	10% to 30%	14	Yes

Table 17 Compliance of WSUD strategy LFI C4 option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	82	Yes
Total nitrogen (TN)	65%	73	Yes

Figure 8 Indicative layout for LFI lot and precinct-scale measures

LFI regional treatment and reticulated stormwater reuse strategy

Summary

LFI areas that have reticulated stormwater reuse (D2-b in Table 10 and Table 11) will provide stormwater treatment and storage at precinct or regional scales that is managed by a stormwater drainage manager. The WSUD systems would deliver treated stormwater to a regional stormwater reuse scheme that is then reticulated through the development for all non-potable uses (e.g. toilets, irrigation, as well as any industrial applications).

On-site stormwater detention is included in the landscape of each lot with the potential for some detention to also occur over the regional stormwater system. On-site stormwater detention requirements should be determined with reference to relevant legislation and policies, including those listed in the section of this guide titled ‘Relationship to other documents’.

Street trees throughout the area would incorporate passive irrigation techniques to increase soil moisture retention in street verges to increase canopy cover. Under this example strategy the street trees do not play a role in achieving the stormwater targets. These passive irrigation techniques transfer a very small proportion of stormwater into the soil, and play an insignificant role in stormwater treatment, but are valuable for soil moisture and much less expensive than bioretention street trees.

Treatment in this example WSUD strategy is via a wetland and adjacent bioretention combination where the extended detention is shared. Low flows are maintained in downstream waterways by configuring the wetland with a small extended detention and wetland riser flows directed to the waterway. When the extended detention of the wetland is exceeded, flow is transferred to adjacent bioretention basins that treat flows and direct treated water to the stormwater harvesting storage with overflows/bypasses discharged to the creek. The stormwater treatment and stormwater harvesting storage components are integrated into the regional open space and located below the 1% AEP level, in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide.

Agreement is required with the stormwater drainage manager for the ownership and operation of the precinct/regional wetland, bioretention, storage and reuse scheme.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 18 and an indicative layout is shown in Figure 9.

Table 18 LFI D2-b option – regional treatment and reuse strategy components

LFI D2-b option	On-site stormwater detention	Precinct / regional wetland	Precinct / regional bioretention	Reuse storage for public open space (tank or pond)
	m^3/ha	m^2/ha	m^2/ha	kL/ha
Requirements	390	200	60	380

Figure 9 Indicative layout for an LFI regional treatment and reticulated reuse strategy

Stormwater targets achieved

Table 19 and Table 20 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Figure 10 is a plot of a flow duration curve as an alternative to the tabular format for demonstrating compliance with the operational phase stormwater quantity (flow) targets. The flow duration curve can be obtained directly from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 19 Compliance of WSUD strategy LFI D2-b option with operational phase stormwater quantity (flow) targets

Flow targets based on flow percentiles			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	10,174	Yes
90%ile flow	1,000–5,000 L/ha/day	1,660	Yes
75%ile flow	100–1,000 L/ha/day	917	Yes
50%ile flow	5–100 L/ha/day	29	Yes
Cease to flow	10% to 30%	22	Yes

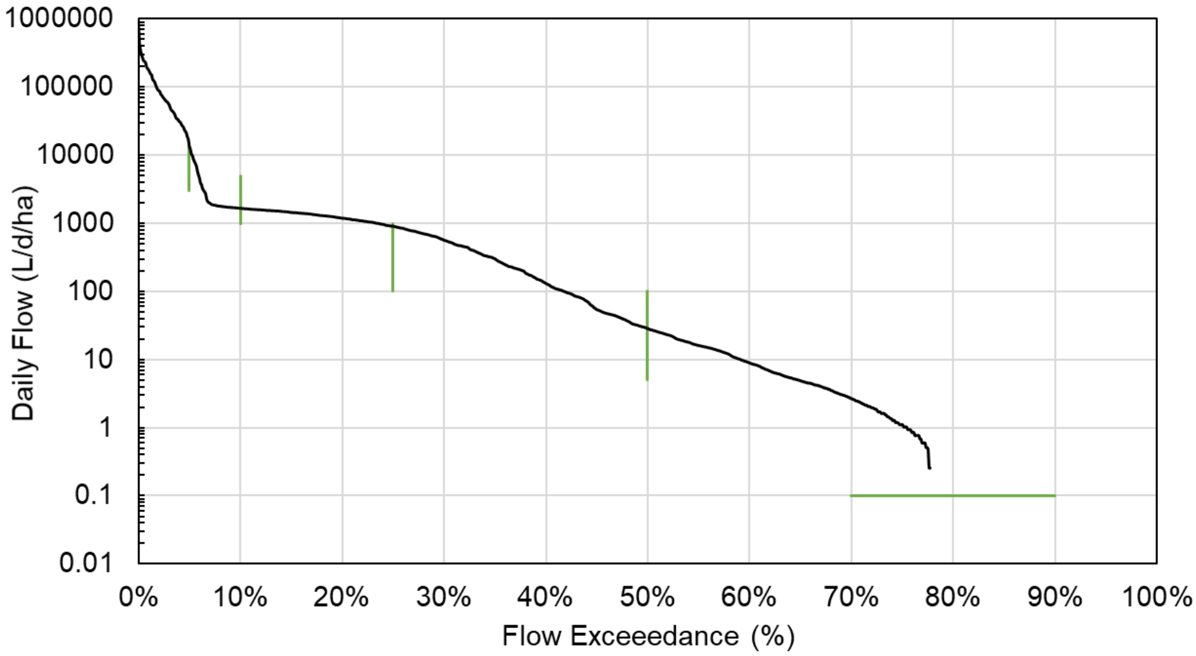

Figure 10 Flow duration curve for an LFI regional treatment and reticulated reuse strategy (D2-b in Table 10 and Table 11)

Green bands represent ranges of stormwater quantity (flow) targets.

Table 20 Compliance of WSUD strategy LFI D2-b option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	86	Yes
Total nitrogen (TN)	65%	74	Yes

High density residential

HDR developments are characterised by relatively large populations (e.g. 125 people per hectare) with multi-storey dwellings set amongst landscaped areas. The non-potable water demands of these typologies provide an opportunity to supply harvested stormwater, and the landscaped surrounds offer a potential to integrate WSUD measures with multiple functions including treatment, harvesting, cooling and amenity improvements. Local parks in HDR areas also provide opportunities to integrate water into the urban fabric and increase the blue–green network that is central to the vision for the Western Parkland City.

Careful management of stormwater quality and quantity (flow) is still required to ensure the performance criteria (water quality and flow objectives; DPE 2022c) for protecting and restoring the blue grid are met. Similar to the LFI typology, a challenge for HDR typologies is intercepting and using sufficient stormwater to limit the quantity of discharges to meet the stormwater quantity (flow) targets.

A range of example WSUD strategies are provided in the following sections, which apply depending on the scale of development and whether there is a regional stormwater treatment, harvesting and reticulation system, as well as the proponent's preference.

Three example WSUD strategies are presented in more detail for street and allotment measures, using local parks and public open space, and one that incorporates a reticulated stormwater harvesting scheme.

Example WSUD strategies for HDR

Six WSUD strategies that achieve the operational phase stormwater quality and quantity (flow) targets are presented in Table 21. Two are for allotment and streetscape measures only, 2 use local parks in addition to lots and streetscape measures, and 2 have a reticulated stormwater reuse system. Table 22 provides the sizes of the WSUD measures used in the WSUD strategies.

The WSUD strategies (B1, B2 in Table 21) that are delivered on the allotment and streetscape rely on green roofs being implemented for at least 70% of the roof area. Such a strategy would improve amenity and contribute to connecting the green grid and other benefits such as cooling and increased biodiversity.

The strategies are described in general below, and further detail is provided in a companion study (DPE 2022d):

- **HDR A option** – bioretention in local public open space. *This option does not comply with the stormwater quality and quantity (flow) targets outlined in Table 3 to Table 6 of this guide, and is provided for comparison only.*
- **HDR B options** – these options rely on 70% of the roof area being a green roof and the remaining 30% of the roof draining to a tank for indoor uses. An allotment treatment system (either wetland or bioretention) then treats water to store in a pond or tank for irrigation of the gardens. Streetscape bioretention is also implemented.

- **HDR C options** – roof water tanks are used for indoor and allotment irrigation and bioretention treats hardstand areas of the allotments. Local parks have treatment systems (either wetland or wetland/ bioretention combinations) with treated water collected to irrigate the parks. Streetscape raingardens are also adopted for Option C1.
- **HDR D options** – lots are fully developed with regional treatment and treated water directed to regional storage ponds as part of a broader reuse scheme. Reticulated treated stormwater is used for all non-potable uses as well as irrigating public open spaces. Bioretention is implemented in allotment carparks and streets for Option D1.

More detailed descriptions and example layouts for different WSUD strategy types are shown in the following sections for:

- lot and streetscape (HDR B1)
- lot, streetscape and public open space bioretention and reuse (HDR C2)
- regional treatment (bioretention) and reticulated stormwater reuse (HDR D2).

Table 21 Example WSUD strategies for HDR typologies

WSUD strategy – HDR		Delivery approach – dependent on scale of development and options for regional harvesting and reuse								
		Reduced site coverage (green roof)	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD (above 1% AEP)	Stormwater harvesting (local)	Stormwater quantity detention	Regional WSUD (maximise below 1% AEP)	Reticulated regional stormwater harvesting
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)					✓		✓		
B1	Lot (wetlands) and streetscape	✓	✓	✓	✓			✓		
B2	Lot (bioretention) and streetscape	✓	✓	✓	✓			✓		
C1	Lot, streetscape and public open space wetland and reuse		✓	✓	✓	✓	✓	✓		
C2	Lot, streetscape and public open space bioretention and reuse		✓	✓	✓	✓	✓	✓		
D1	Lot, street and regional treatment and reticulated stormwater reuse			✓	✓			✓	✓	✓
D2	Regional treatment (bioretention) and reticulated stormwater reuse							✓	✓	✓

Note that Option A does not achieve the stormwater quality and quantity targets

Table 22 Sizes of WSUD measures and impervious (imperv.) cover of example WSUD strategies for LFI typologies

WSUD strategy – HDR		WSUD measures													% open space		% imperv.	
		Green roof (m^2/ha)	Tanks (kL/ha)	Lot bioretention (m^2/ha)	Street bioretention (m^2/ha)	Lot / precinct wetland (m^2/ha)	Regional wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater harvesting on lot (m^3/ha)	Stormwater harvesting on lot to irrigation (ML/yr/ha)	Stormwater harvesting to public open space (m^3/ha)	Stormwater harvesting (local) to public open space irrigation	Reticulated regional stormwater harvesting (m^3/ha)	Reticulated regional stormwater harvesting (ML/yr/ha)	Local	Regional	Lot	Total
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)							80							10	5	70	62
B1	Lot (wetlands) and streetscape	2,600	94		41	100			52	0.2					0	0	32	41
B2	Lot (bioretention) and streetscape	2,200	94	200	55				52	0.3					0	0	32	41
C1	Lot, streetscape and public open space wetland and reuse		125	5	9	400					60	0.2			10	5	70	62
C2	Lot, streetscape and public open space bioretention and reuse		125	5		150		30			60	0.3			10	5	70	62
D1	Lot, street and regional treatment and reticulated stormwater reuse			5	13		500						200	1.2	10	5	70	62
D2	Regional treatment (bioretention) and reticulated stormwater reuse						150	30					200	1.6	10	5	70	62

Note that Option A does not achieve the stormwater quality and quantity targets, and Option B has a 0% open space proportion because it considers a development of only allotments and streets (not public open space).

HDR lot and streetscape strategy

Summary

This strategy (B1 in Table 21) focuses on delivering the operational phase stormwater quality and quantity (flow) targets on allotments and in the adjacent streets. A major component of the strategy is the use of green roofs for at least 70% of roof areas, with the remaining area of roof draining to tanks that supply indoor toilets and laundry facilities. In addition, all surface stormwater from the allotment is collected and treated in a wetland located on the allotment. The wetland also incorporates the on-site stormwater detention components. Treated water from the wetland is stored in a tank that then supplies irrigation to 50% of the allotment garden areas.

The adjacent street includes streetscape bioretention to treat runoff from the hard paved areas as well as passively irrigated street trees along the full length of the roads.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 23, and an indicative layout is shown in Figure 11.

Table 23 HDR B1 option – lot and streetscape strategy components

HDR B1 option	Green roof area	Tank for indoor use	Allotment wetland	Tank for garden irrigation	Amount of lot gardens irrigated	On-site stormwater detention	Street bioretention
	m^2/ha	kL/ha	m^2/ha	kL/ha	%	m^3/ha	m^2/ha
Requirements	260	94	100	52	50	390	41

Stormwater targets achieved

Table 24 and Table 25 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 24 Compliance of WSUD strategy HDR B1 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.51	Yes
90%ile flow	1,000–5,000 L/ha/day	4,769	Yes
50%ile flow	5–100 L/ha/day	31	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 25 Compliance of WSUD strategy HDR B1 option with operational phase stormwater quality targets

Quality targets based on allowable mean annual load			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	<80 kg/ha/y	64	Yes
Total phosphorus (TP)	<0.3 kg/ha/y	0.2	Yes
Total nitrogen (TN)	<3.5 kg/ha/y	2.1	Yes

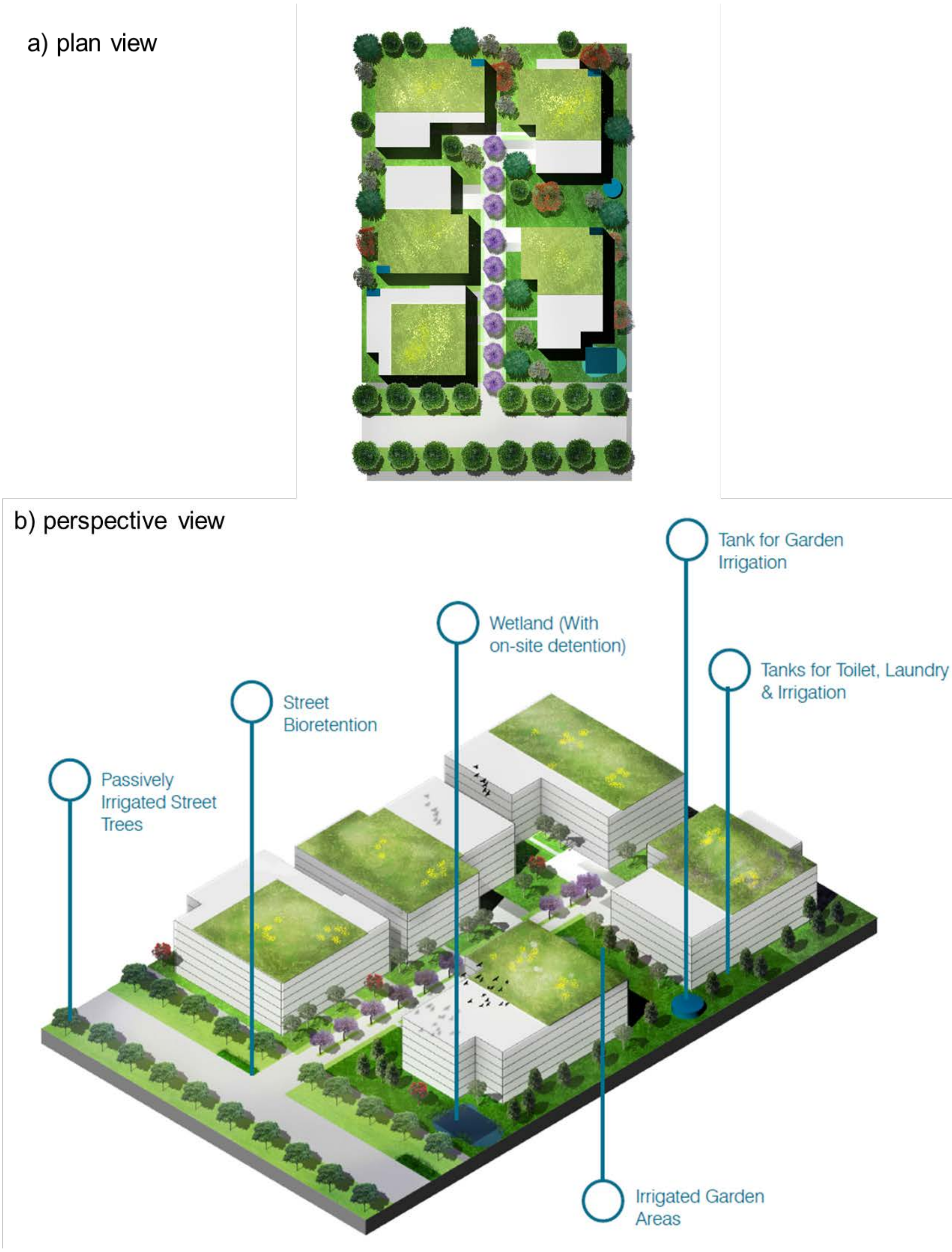

Figure 11 Indicative layout for HDR lot and streetscape measures

HDR lot and precinct strategy

Summary

This WSUD strategy (C2 in Table 21) for HDR focuses less on allotment measures and more on measures integrated into public open spaces (parks) within the precinct. This will introduce water into local parks, will add to the blue–green grid and provide multiple co-benefits such as urban cooling and amenity. This strategy will require agreement with an owner and/or stormwater drainage manager to operate the treatment and reuse system in the local parks.

Green roofs are not required to deliver the operational phase stormwater quality and quantity (flow) targets for this strategy. All of the roof areas drain into tanks that are used for toilets and laundries inside, and also to supply irrigation water for the allotment gardens (50%). On-site stormwater detention requirements will be included in the landscape of each lot.

Street trees throughout the area incorporate passive irrigation techniques to increase soil moisture retention throughout the streetscapes.

Runoff from the allotment and roads is conveyed into wetlands that are integrated into local parks. The wetland treatment system works in conjunction with an adjacent bioretention basin (which shares extended detention) to treat the majority of runoff from the area.

The wetlands are configured with small extended detention so that water from the wetland riser can be directed to the creek to maintain low flows (e.g. 50%ile). Higher extended detention depths transfer into the bioretention that treats the majority of the flow and directs treated water into a holding storage (either tank or pond) and this is used to irrigate the local park (50%).

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 26, and an indicative layout is shown in Figure 12.

Table 26 HDR C2 option – lot and precinct strategy components

HDR C2 option	Reuse storage for public open space (tank or pond)	Tank for indoor use and lot irrigation	Precinct wetland	Amount of public open space irrigated	Amount of lot gardens irrigated	On-site stormwater detention	Precinct bioretention
	kL/ha	kL/ha	m^2/ha	%	%	m^3/ha	m^2/ha
Requirements	60	125	150	50	50	390	30

Stormwater targets achieved

Table 27 and Table 28 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 27 Compliance of WSUD strategy HDR C2 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.97	Yes
90%ile flow	1,000–5,000 L/ha/day	2,576	Yes
50%ile flow	5–100 L/ha/day	8	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 28 Compliance of WSUD strategy HDR C2 option with operational phase stormwater quality targets

Quality targets based on post development load reductions			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	82	Yes
Total nitrogen (TN)	65%	72	Yes

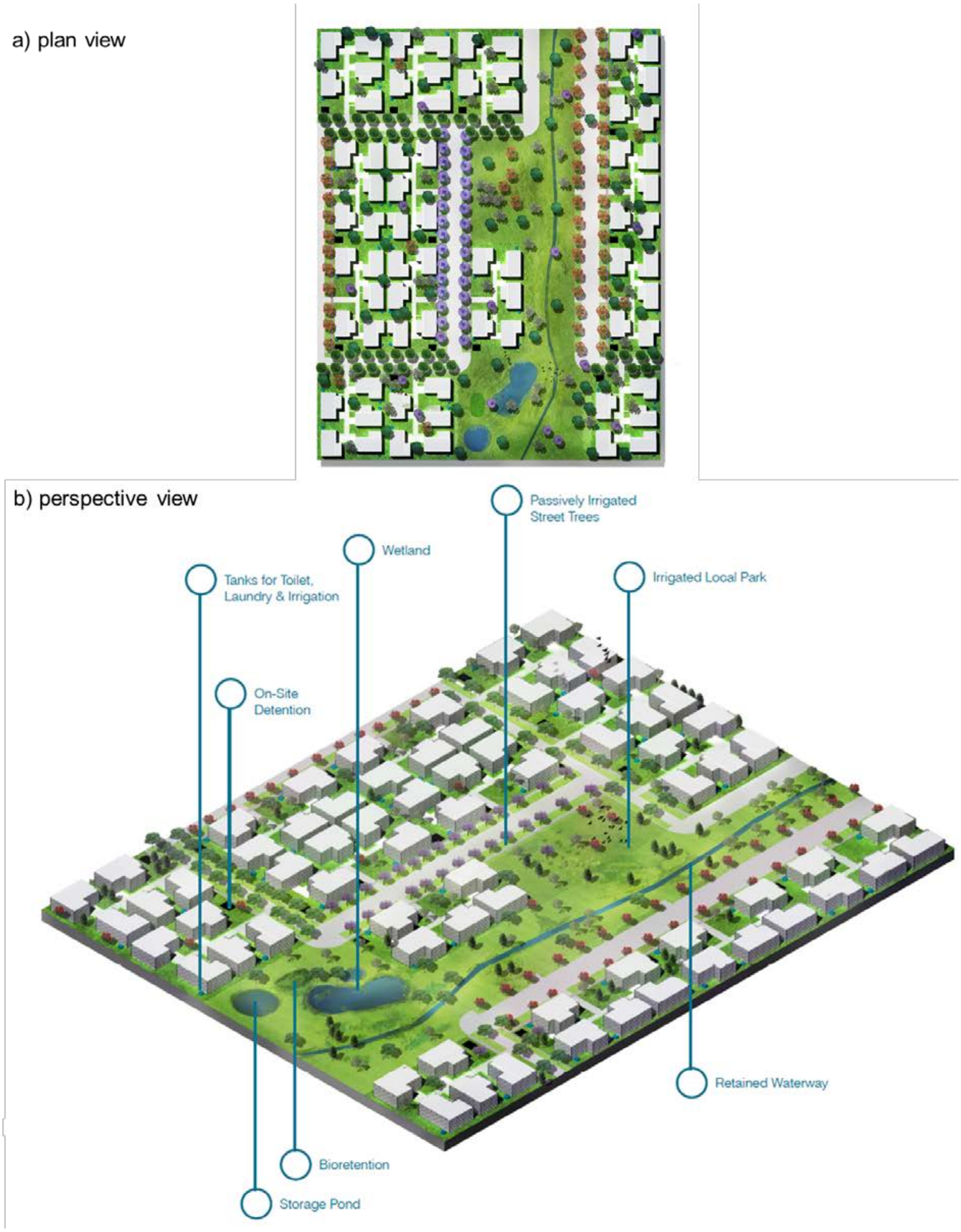

Figure 12 Indicative layout for HDR lot and precinct-scale measures

HDR regional treatment and reticulated reuse strategy

Summary

HDR typologies that have reticulated stormwater reuse will need to provide stormwater treatment and storage on a precinct or regional scale in order to contribute to the reticulated reuse scheme. Allotments are typically supplied with the reticulated harvested stormwater for all non-potable uses on site (e.g. toilets, laundries and outdoor irrigation) and on-site stormwater detention requirements are included in the landscape of each lot. Street trees through the area incorporate passive irrigation techniques to increase soil moisture retention throughout the streetscape, subject to a salinity and sodicity assessment (see Chapter 3 of this guide).

Treatment in this example WSUD strategy (D2 in Table 21) is with a wetland and adjacent bioretention combination, where the extended detention is shared between both. Low flows are maintained in downstream waterways by configuring the wetland with a small extended detention and for flows from the wetland riser to be directed to the waterway. When the extended detention of the riser is exceeded, flow is transferred into the bioretention basin that treats flows and directs treated water to the reuse storages.

The treatment measure will then deliver treated water to an open storage that will be connected to the regional stormwater harvesting and reticulation system. The treatment and storage components are integrated into the regional open space and located below the 1% AEP flood level, in accordance with the floodplain and waterfront land principles set out in Chapter 3 of this guide.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 29, and an indicative layout is shown in Figure 13.

Table 29 HDR D2 option – regional treatment and reticulated reuse strategy components

HDR D2 option	On-site stormwater detention	Precinct/regional wetland	Precinct/regional bioretention	Reuse storage for public open space (tank or pond)
	m^3/ha	m^2/ha	m^2/ha	kL/ha
Requirements	390	150	30	200

Stormwater targets achieved

Table 30 and Table 31 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 30 Compliance of WSUD strategy HDR D2 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.99	Yes
90%ile flow	1,000–5,000 L/ha/day	2,702	Yes
50%ile flow	5–100 L/ha/day	45	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 31 Compliance of WSUD strategy HDR D2 option with operational phase stormwater quality targets

Quality targets based on allowable mean annual load			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	<80 kg/ha/y	55	Yes
Total phosphorus (TP)	<0.3 kg/ha/y	0.3	Yes
Total nitrogen (TN)	<3.5 kg/ha/y	3.1	Yes

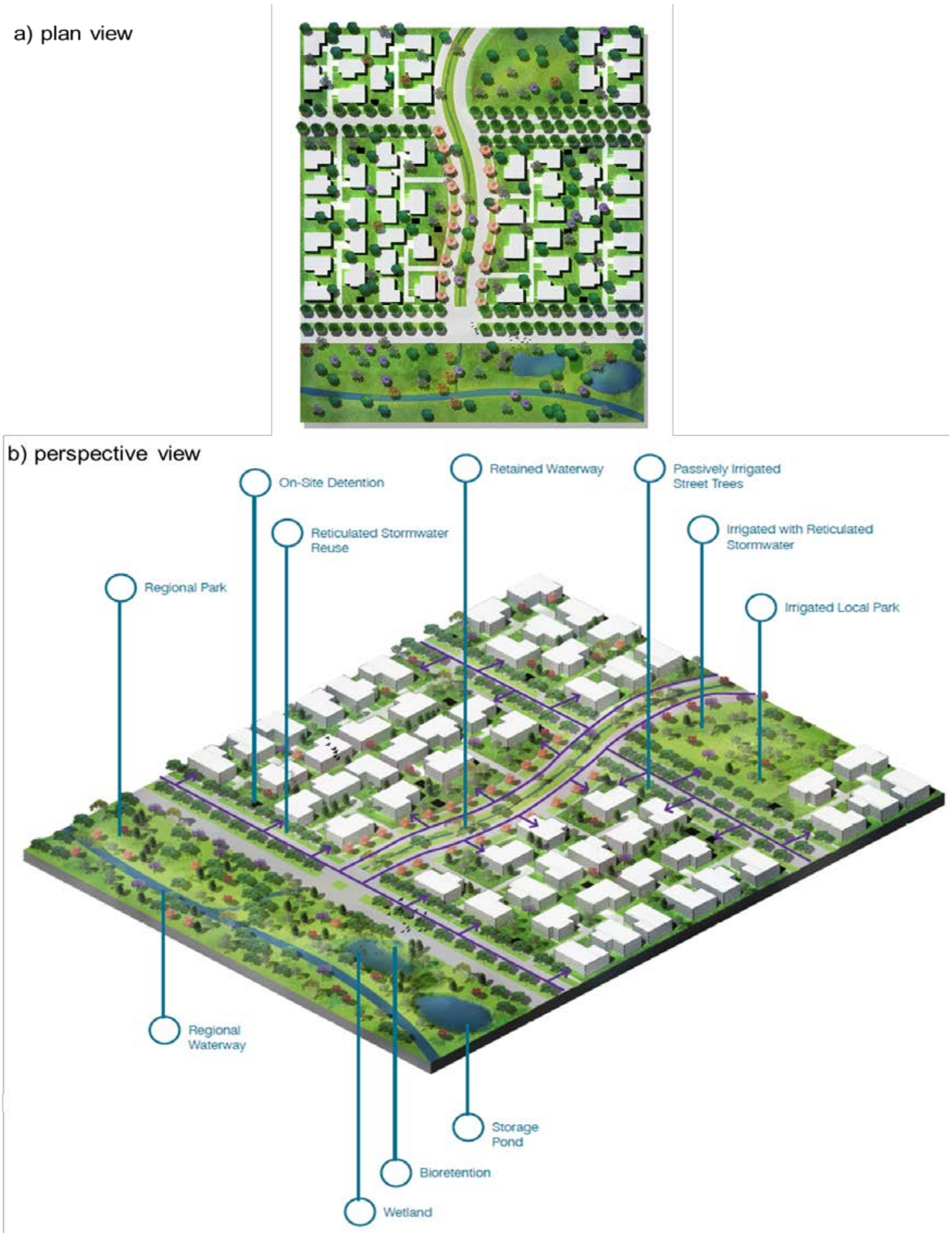

Figure 13 Indicative layout for an HDR regional treatment and reticulated reuse strategy

Low density residential

LDR typologies are characterised by approximately 15–20 allotments per hectare, with single or double storey dwellings. This typology was selected as a representative example of residential development that could occur in the Wianamatta–South Creek catchment.

From a stormwater management perspective, non-potable water demands generated in residential areas provide relatively uniform demands that could be met with harvesting (i.e. tanks) on the lot/allotment. In addition, residential areas are characterised by local parks and vegetated streetscapes, which offer potential to integrate WSUD measures that provide multiple functions of treatment, harvesting, cooling, biodiversity and amenity improvements.

Careful management of stormwater quality and quantity (flow) is still required to ensure the performance criteria (water quality and flow objectives; DPE 2022c) for protecting and restoring the blue grid are met. Similar to LFI and HDR typologies, a challenge for LDR typologies is intercepting and using sufficient stormwater to limit the quantity of discharges to meet the operational phase stormwater quantity (flow) targets.

A basic assumption of 15% pervious allotment is made for this typology. It is recognised that this provides less allotment garden space than development control specifications to achieve the vision for the Western Parklands City. However, this assumption serves to demonstrate how the operational phase stormwater quality and quantity (flow) targets can be met even with limited allotment pervious space.

A general approach adopted here is to avoid using WSUD measures (other than tanks) on individual allotments. The ongoing compliance requirements to ensure long-term operation is considered to be problematic for small-scale WSUD measures on private land. A preference, therefore, is for WSUD measures to be placed in the public domain where they are generally better managed. The approach for stormwater detention requirements is also to locate them in public land with an intent to combine with precinct WSUD measures.

A range of example WSUD strategies are provided in the following sections, which apply depending on the scale of development and whether there is a regional stormwater treatment, harvesting and reticulation system, as well as the proponent’s preference.

Three example strategies are presented in more detail for street and allotment measures, using local parks and public open space, and one that incorporates a reticulated stormwater harvesting scheme.

Example WSUD strategies for LDR

Eight WSUD strategies that achieve the operational phase stormwater quality and quantity (flow) targets are presented in Table 32. Three are for allotment and streetscape measures, 2 use local parks in addition to lots and street measures, and 3 have a reticulated stormwater reuse system. Table 33 presents the size of the WSUD measures needed to support each WSUD strategy. Note that on-site stormwater detention requirements are not listed as these should be determined with reference to relevant legislation and policies, including those listed in the section of this guide titled ‘Relationship to other documents’.

The WSUD strategies are described in general below:

- **LDR A option** – adopting 2.4 kL tanks and using bioretention in local public open space areas. *This option does not comply with the stormwater quality and quantity (flow) targets outlined in Table 3 to Table 6 of this guide, and is provided for comparison only.*
- **LDR B1 option** – 30% of lot area is set aside and used for bioretention and a storage pond to irrigate 50% of the area. The remaining lots are 15% pervious and have 50% of roof areas drain to 5 kL tanks that supply toilets, laundries and 50% of lot gardens.

- **LDR B2 option** – 30% of lot area is set aside and used for a wetland and storage pond to irrigate 50% of the area. The remaining lots are 15% pervious and have 50% of roof areas drain to 5 kL tanks that supply toilets, laundries and 50% of lot gardens.
- **LDR B3 option** – lots are 30% pervious (gardens) and all lots are developed. 100% of roof areas drain to 20 kL tanks that are used for hot water, toilets, laundries and to irrigate 75% of the lot garden areas. The lots drain to street gutters and street bioretention systems treat flows and direct treated water to storages that are used to irrigate (50%) street verges.
- **LDR C1 option** – lots are 15% pervious (gardens) and all lots are developed. 50% of roof areas drain to 6 kL tanks that are used for toilets, laundries and to irrigate 50% of the lot garden areas. Street bioretention systems treat road runoff. A wetland in public open space treats flows and directs treated water to a storage pond that is used to irrigate the local public open space area.
- **LDR C2 option** – lots are 25% pervious (gardens) and all lots are developed. 50% of roof areas drain to 5 kL tanks that are used for toilets, laundries and to irrigate 50% of the lot garden areas. Street bioretention systems treat road runoff. A combined wetland–bioretention system in public open space treats flows and directs treated water to a storage tank that is used to irrigate the local public open space area and street verges.
- **LDR D1 option** – lots are 15% pervious (gardens) and all lots are developed. 50% of roof areas drain to 2.4 kL tanks that are used for toilets and laundries. Stormwater flows to a regional wetland–bioretention combination that stores treated water in a pond as part of a regional stormwater harvesting scheme. Reticulated treated stormwater is used for all outdoor uses as well as irrigating public open spaces.
- **LDR D2 option** – lots are 15% pervious (gardens) and all lots are developed. 50% of roof areas drain to 2.4 kL tanks that are used for toilets and laundries. Street bioretention basins treat road runoff. Stormwater flows to a regional wetland that directs treated water to a storage pond as part of a regional stormwater harvesting scheme. Reticulated treated stormwater is used for all outdoor uses as well as irrigating public open spaces.
- **LDR D3 option** – lots are 15% pervious (gardens) and all lots are developed. No tanks or street bioretention is adopted. Stormwater flows to a regional wetland–bioretention combination that directs treated water to a storage pond as part of a regional stormwater harvesting scheme. Reticulated treated stormwater is used for all non-potable uses as well as irrigating public open spaces.

Interim solution

LDR B1 and B2 options could be considered an interim solution (by fully developing some allotments and leaving others pervious) until a regional stormwater system is implemented and the lot can be fully developed to maximum imperviousness (as outlined in the relevant Development Control Plan).

More detailed descriptions and example layouts for different WSUD strategy types are shown in the following sections for:

- lot and streetscape strategies (LDR B3)
- lot and precinct strategies (LDR C1)
- regional treatment and reticulated reuse strategies (LDR D1).

Table 32 Example WSUD strategies for LDR typologies

WSUD strategy – LDR		Delivery approach – dependent on scale of development and options for regional harvesting and reuse								
		Reduced site coverage	Tanks	Lot WSUD	Streetscape WSUD	Precinct WSUD	Stormwater harvesting (local)	Stormwater quantity detention	Regional WSUD	Reticulated regional stormwater harvesting
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)		✓			✓		✓		
B1	Lot (bioretention) and streetscape (interim)	✓	✓	✓	✓			✓		
B2	Lot (wetland) and streetscape (interim)	✓	✓	✓	✓			✓		
B3	Lot (30% pervious) and streetscape		✓		✓			✓		
C1	Lot, streetscape and public open space wetland and reuse		✓		✓	✓	✓	✓		
C2	Lot (25% pervious), streetscape and public open space WSUD and reuse		✓		✓	✓	✓	✓		
D1	Regional treatment and reticulated stormwater reuse		✓					✓	✓	✓
D2	Regional treatment (wetland) and reticulated stormwater reuse		✓		✓			✓	✓	✓
D3	Regional treatment and reticulated stormwater reuse (no tanks)							✓	✓	✓

Note that Option A does not achieve the stormwater quality and quantity targets.

Table 33 Sizes of WSUD measures and impervious (imperv.) cover of example WSUD strategies for LDR typologies

WSUD strategy - LFI		WSUD measures									% Open space		% imperv.	
		Tanks (kL/ha)	Street bioretention (m2/ha)	Precinct bioretention (m^2/ha)	Precinct wetland (m^2/ha)	Regional wetland (m^2/ha)	Regional bioretention (m^2/ha)	Stormwater harvesting on lot storage (m^3/ha)	Public open space harvesting to storage (m^3/ha)	Regional stormwater harvesting storage (m^3/ha)	Local	Regional	Lot imperviousness (%)	Total imperviousness (%)
A	Post development load reduction targets (85% TSS, 65% TP, 45% TN)	39		100							10	5	85	69
B1	Lot (bioretention) and streetscape (interim)	67		130				90			0	0	53	55
B2	Lot (wetland) and streetscape (interim)	67			550			90			0	0	53	55
B3	Lot (30% pervious) and streetscape	380	85						30		0	0	70	69
C1	Lot, streetscape and public open space wetland and reuse	97	33		750				75		10	5	85	69
C2	Lot (25% pervious), streetscape and public open space WSUD and reuse	81	40	40	300				125		10	5	75	63
D1	Regional treatment and reticulated stormwater reuse	39				200	60			300	10	5	85	69
D2	Regional treatment (wetland) and reticulated stormwater reuse	39	33			500				300	10	5	85	69
D3	Regional treatment and reticulated stormwater reuse (no tanks)					200	60			340	10	5	85	69

Note that Option A does not achieve the stormwater quality and quantity targets, and Option B has a 0% open space proportion because it considers a development of only allotments and streets (not public open space).

LDR lot and streetscape strategy

Summary

The Option B WSUD strategies in Table 32 focus on delivering the operational phase stormwater quality targets on allotments and in the adjacent streets (i.e. without local parks). Generally, to achieve the targets a lower site coverage is required compared to conventional development. This can either be delivered by increasing the pervious coverage of allotments or as an interim solution by developing less lots until a regional reticulated reuse system is implemented.

The WSUD strategy identified as B3 in Table 32, achieves the targets by allowing development of all allotments but increasing the pervious coverage of each lot to 30%. Other examples WSUD strategies include having 100% of roof areas draining to 20 kL tanks that are used for hot water, toilets, laundries and to irrigate 75% of the lot garden areas. The lots drain into street gutters and street bioretention basins treat flows from the lots and streets. Treated water from the bioretention basins is directed to storage tanks located along the streets that are used to irrigate (50%) street verges. There is also a very small proportion of bioretention systems that bypass the tanks and provide low flows to the waterways.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 34, and an indicative layout is shown in Figure 14.

Table 34 LDR B3 option – lot and streetscape strategy components

LDR B3 option	Lot perviousness	Roof area to tank	Water from roofs for reuse	Street bioretention	Tank for verge irrigation	Amount of lot gardens irrigated	Amount of verges irrigated
	%	%	kL/ha	m^2/ha	kL/ha	%	%
Requirements	30	100	380	85	30	75	50

Stormwater targets achieved

Table 35 and Table 36 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 35 Compliance of WSUD strategy LDR B3 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	1.96	Yes
90%ile flow	1,000–5,000 L/ha/day	2,362	Yes
50%ile flow	5–100 L/ha/day	6	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 36 Compliance of WSUD strategy LDR B3 option with operational phase stormwater quality targets

Quality targets based on post development load reduction			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	91	Yes
Total phosphorus (TP)	80%	81	Yes
Total nitrogen (TN)	65%	74	Yes

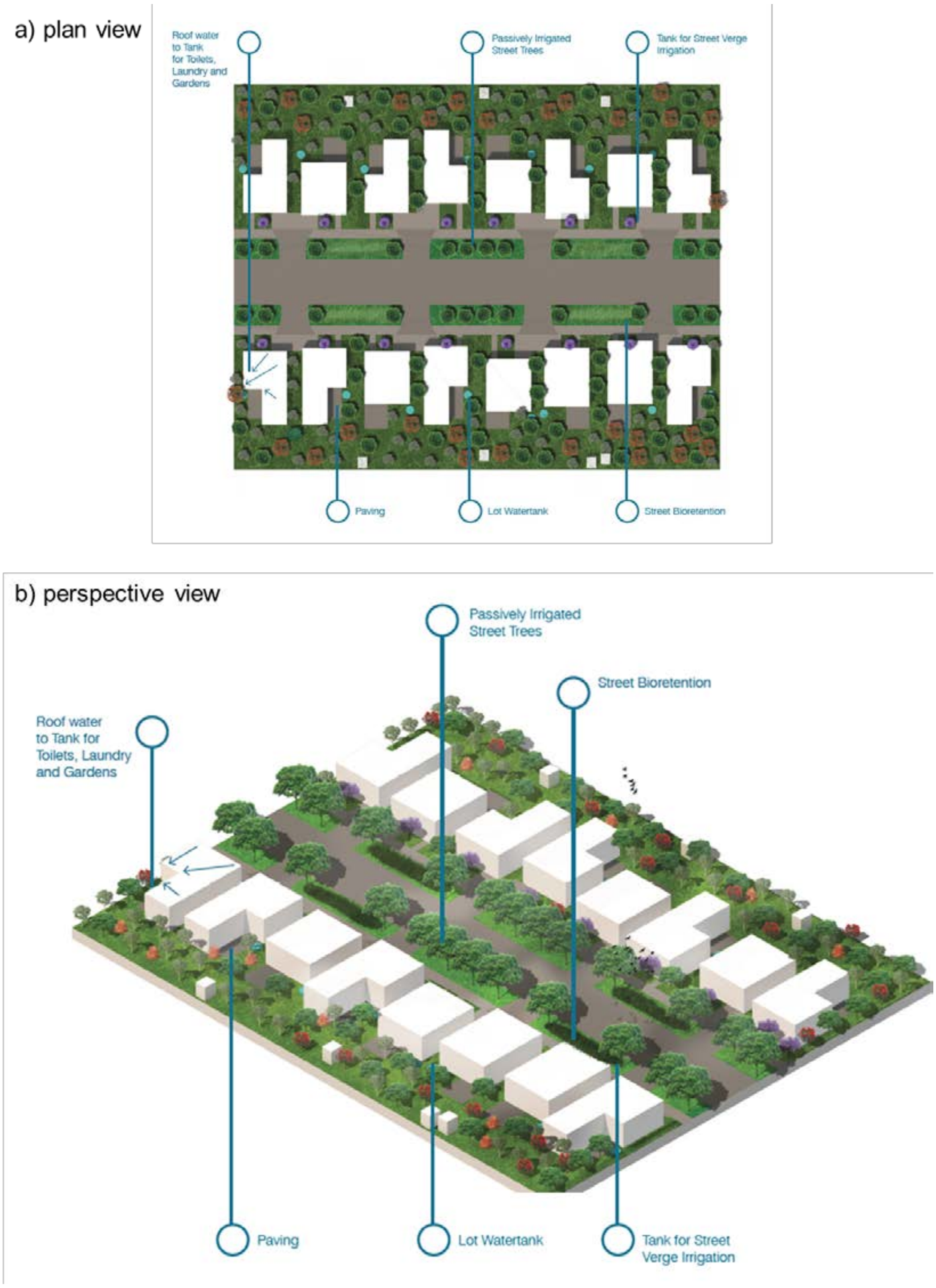

Figure 14 Indicative layout for LDR lot and streetscape measures

LDR lot and precinct strategy

Summary

This WSUD strategy for LDR focuses on providing conventional allotment pervious cover and full development, based on Option C1 in Table 32. To achieve this WSUD strategy and comply with the operational phase stormwater quality and quantity (flow) targets, the local public open space is used for a large wetland system that treats stormwater (for reuse), 'loses' water through evaporation and is a feature of the local park.

In addition, 50% of roof areas drain to 6 kL tanks that are used for toilets, laundries and to irrigate 50% of the lot garden areas. Street bioretention basins treat road runoff to ensure stormwater quality targets are met, and street trees not in bioretention adopt passive irrigation techniques.

A large wetland in public open space (e.g. occupies half of the public open space area) is used to treat flows to be suitable for irrigation. The wetland is configured using conventional design practices; for example, 350 mm of extended detention and 48–72 hours detention time (see Chapter 3 of this guide). Treated water is directed into a storage pond that is used to irrigate all of the local public open space area, subject to a salinity and sodicity assessment.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 37, and an indicative layout is shown in Figure 15.

Table 37 LDR C1 option – lot and precinct strategy components

LDR C1 option	Lot perviousness	Roof area to tank	Water from roofs for reuse	Street bioretention	Precinct wetland	Storage for public open space	Amount of local public open space irrigated
	%	%	kL/ha	m^2/ha	m^2/ha	kL/ha	%
Requirements	15	50	97	33	750	75	100

Stormwater targets achieved

Table 38 and Table 39 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 38 Compliance of WSUD strategy LDR C1 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
Mean annual runoff volume (MARV)	≤2 ML/ha/y	2.00	Yes
90%ile flow	1,000–5,000 L/ha/day	4,545	Yes
50%ile flow	5–100 L/ha/day	11	Yes
10%ile flow	0 L/ha/day	0	Yes

Table 39 Compliance of WSUD strategy LDR C1 Option with operational phase stormwater quality targets

Quality targets based on post development load reduction			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	95	Yes
Total phosphorus (TP)	80%	86	Yes
Total nitrogen (TN)	65%	78	Yes

Figure 15 Indicative layout for LDR lot and precinct-scale measures

LDR regional treatment and reticulated reuse strategy

Summary

LDR typologies that have reticulated stormwater reuse will need to provide stormwater treatment and storage on a precinct or regional scale, to contribute to the reticulated reuse scheme. Allotments are typically supplied with the reticulated harvested stormwater for all non-potable uses on site (e.g. toilets, laundries and outdoor irrigation). Reticulated treated stormwater would also be used as a supply for irrigation of parks and streetscapes (where applicable, i.e. subject to a salinity and sodicity assessment).

Street trees through the area incorporate passive irrigation techniques to increase soil moisture retention throughout the streetscape, noting that no streetscape bioretention is required to meet the operational phase stormwater quality and quantity targets.

Treatment in this example WSUD strategy (D1 in Table 32) is with a wetland and adjacent bioretention combination where the extended detention is shared between both. Low flows are maintained in downstream waterways by configuring the wetland with a small extended detention and for flows from the wetland riser to be directed to the waterway. When the extended detention of the riser is exceeded, flow is transferred into the bioretention basin that treats flows and directs treated water to the reuse storage ponds.

The storage ponds are connected to the regional stormwater harvesting and reticulation system. The treatment and storage components are integrated into the regional open space.

Strategy components and indicative layout

A summary of the size of the WSUD measures required in this example is presented in Table 40, and an indicative layout is shown in Figure 16.

Table 40 LDR D1 option – regional treatment and reticulated reuse strategy components

LDR D1 option	Lot perviousness	Roof area to tank	Water from roofs for reuse	Regional bioretention	Regional wetland	Storage for regional reuse
	%	%	kL/ha	m^2/ha	m^2/ha	kL/ha
Requirements	15	50	39	60	200	30

Stormwater targets achieved

Table 41 and Table 42 demonstrate that both the operational phase stormwater quality and quantity (flow) targets are achieved under this example strategy. The contents of the tables were extracted from the post-processing spreadsheet available from the MUSIC modelling toolkit, which is provided with this guide (see Chapter 2).

Table 41 Compliance of WSUD strategy LDR D1 option with operational phase stormwater quantity (flow) targets

Flow targets based on MARV			
Parameter	**Target**	**Result**	**Compliance**
95%ile flow	3,000–15,000 L/ha/day	3,945	Yes
90%ile flow	1,000–5,000 L/ha/day	1,655	Yes
75%ile flow	100–1,000 L/ha/day	759	Yes
50%ile flow	5–100 L/ha/day	29	Yes
Cease to flow	10% to 30%	15	Yes

Table 42 Compliance of WSUD strategy LDR D1 option with operational phase stormwater quality targets

Quality targets based on post development load reduction			
Parameter	**Target (load reduction)**	**Result**	**Compliance**
Total suspended solids (TSS)	90%	94	Yes
Total phosphorus (TP)	80%	86	Yes
Total nitrogen (TN)	65%	76	Yes

Figure 16 Indicative layout for an LDR regional treatment and reticulated reuse strategy

Appendix A: MUSIC model parameters

This appendix sets out the MUSIC model parameters to use when undertaking performance modelling to demonstrate compliance with the operational phase stormwater quality and quantity (flow) targets. These include the climate details, source node assumptions as well as acceptable ranges for parameters to use for species treatment nodes. If not listed below, the requirements of the relevant documents of local councils in Wianamatta should be followed (see ‘Relationship to other documents’ section of this guide).

A MUSIC file that contains climate data and source nodes is available for use, as is a spreadsheet to post process the modelled flow data to enable comparisons with the stormwater quality and quantity (flow) targets (see Chapter 2 of this guide).

MUSIC modelling climate

Table 43 Rainfall and potential evaporation data

Parameter	Timestep	Value (mm)
Rainfall (Penrith)	6 min. timestep between 01/01/1999 and 31/12/2008	691 (average annual)
Potential evapotranspiration (PET)	January	183
	February	144
	March	127
	April	88
	May	60
	June	41
	July	48
	August	73
	September	107
	October	138
	November	150
	December	177
	Total	**1,336**

MUSIC source node assumptions

Impervious areas should be measured from the layout plans for the development. The effective impervious area should be assumed to be the same as total impervious areas for new development.

Pollutant export parameters should adopt those recommended in relevant documents of local councils in Wianamatta (see ‘Relationship to other documents’ section of this guide).

Rainfall–runoff parameters in the Wianamatta–South Creek catchment should be adopted, as set out in Table 44.

Table 44 Rainfall–runoff parameters

Impervious area parameters	
Rainfall threshold (mm)	1.0
Pervious area parameters	
Soil storage capacity (mm)	150
Initial storage (% of capacity)	30
Field capacity (mm)	130
Infiltration capacity coefficient – a	175
Infiltration capacity exponent – b	2.5
Groundwater properties	
Initial depth (mm)	10
Daily recharge rate (%)	25
Daily baseflow rate (%)	1.4
Daily deep seepage rate (%)	0.0

MUSIC treatment node parameters

Table 45 to Table 50 set out the parameter ranges for sedimentation basins, wetlands, bioretention (raingardens), swales, tanks and storage ponds (dams).

Table 45 Parameter ranges for sedimentation basins

Sedimentation basin	Acceptable parameter ranges
Surface area	User defined
Extended detention depth	Maximum extended detention depth of 350 mm when part of a wetland system and up to 1.0 m when acting in isolation
Permanent pool volume	Calculate with depth up to a maximum of 2.0 m
Initial volume	Same as permanent pool volume
Exfiltration rate	Maximum of 0.01 mm/hour
Evaporative loss	Maximum of 100% of PET

Table 46 Parameter ranges for wetlands

Wetlands	Acceptable parameter ranges
Inlet pond volume	Set to zero if upstream sediment basin is modelled separately or sized to target 95% removal of 125 µm particles for 4EY[1] flow events
Extended detention depth	Maximum of 350 mm
Permanent pool volume	0.3–0.4 m x wetland surface area
Exfiltration	Maximum of 0.01 mm/hour
Evaporative loss	Maximum of 125% of PET
Outlet pipe	Adjust to ensure notional detention time is within ranges
Notional detention time	48–72 hours for detention depths of 100–350 mm No less than 48 hours for detention depths <100 mm
k & C* values (MUSIC)	Use default values

[1] 4EY = 4 exceedances per year

Table 47 Parameter ranges for bioretention (raingardens)

Bioretention	Acceptable parameter ranges
Extended detention depth	Maximum of 300 mm Maximum of 150 mm in streetscape bioretention
Unlined filter media perimeter	0.01 m (i.e. the systems are lined)
Saturate hydraulic conductivity	Maximum of 100 mm/hour
Filter media depth	0.4–0.7 m
TN content	800 mg/kg
Orthophosphate content	40 mg/kg
Exfiltration rate	zero
Lining	Yes – base is lined
Underdrain present	Yes
k & C* values (MUSIC)	Use default values

Table 48 Parameter ranges for swales

Swales	Acceptable parameter ranges
Bed slope	0.5–4%
Vegetation height	Mown turf swales: 50–100 mm Native grasses and sedges: 100–400 mm
Exfiltration	Zero

Table 49 Parameter ranges for tanks

Tanks	Acceptable parameter ranges
Water source	Only roof water or treated water into reuse tanks
Volume below overflow	User defined
Surface area	Calculate with maximum depth = 1.0–2.5 m
Initial volume	Same as volume below overflow
Reuse demands	Irrigation to be modelled as an annual demand Distribution* to be defined with a monthly pattern which is (Jan–Dec): 13%, 6%, 6%, 4%, 2%, 0%, 4%, 7%, 12%, 14%, 13%, 19% Indoor reuse to be modelled as a daily demand

* Irrigation distribution takes into account PET, rainfall and crop types

Table 50 Parameter ranges for storage ponds (dams)

Storage ponds	Acceptable parameter ranges
Water source	Only roof water or treated water into reuse storage ponds
Surface area	User defined
Permanent pool volume	Calculate with depth up to a maximum of 3.0 m
Initial volume	Same as permanent pool volume
Exfiltration rate	Maximum of 0.01 mm/hour
Evaporative loss	Maximum of 100% of PET
Reuse demands	Irrigation to be modelled as an annual demand Distribution* to be defined with a monthly pattern which is (Jan–Dec): 13%, 6%, 6%, 4%, 2%, 0%, 4%, 7%, 12%, 14%, 13%, 19% Indoor reuse to be modelled as a daily demand

* Irrigation distribution takes into account PET, rainfall and crop types

Green roofs

Green roofs can be modelled in MUSIC by setting the soil and vegetation proportion of the roof as pervious in the source node. The urban source nodes with associated soil parameters that are supplied with the MUSIC modelling toolkit can be used (see Chapter 3 of this guide).

Gross pollutant traps

GPTs are primarily designed for removal of litter and debris and some coarse sediment. Generally, GPTs have little impact on nutrient removal because of high through flow rates. GPTs should only be modelled for removal of gross pollutants, with the exception of GPTs that have approved removal rates for sediments and/or nutrients as outlined in the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018). High flow bypasses should be included in the model.

Proprietary nutrient removal devices

Removal rates of particular pollutants for proprietary devices should be consistent with the assessment in the *Stormwater Quality Improvement Device Evaluation Protocol* (Stormwater Australia 2018).

Infiltration/ porous pavements

These are not permitted without site-specific soil capability assessment to demonstrate no adverse impacts of infiltration, and/or WSUD design considerations are demonstrated (Chapter 3 of this guide).

Passively watered street trees

Irrigation of street trees is encouraged for all street trees that are not bioretention street trees or bioretention systems (raingardens). Irrigation can occur in the form of either irrigation from the recycled water reticulation or passive watering. Passively watered street trees operate by diverting small proportions of stormwater via kerb inlet filters to the soil surrounding the trees to increase soil moisture around the tree. Passive irrigation systems divert only small proportions of the total stormwater runoff to the trees, and as such, typically should not be included in the performance (MUSIC) modelling. This is based on the assumption that each tree would only divert 0.1–0.5 L/s, with total diversion of stormwater to be 30–50 L per tree and therefore representing a small volume even with trees spaced every 10 m. The volumes are small and likely to be within the error bands of the modelling, and as such, conservatively excluded.

Appendix B: Water demand data

This appendix provides a consistent set of water demand data to use when undertaking performance modelling to demonstrate compliance with the operational phase stormwater quality and quantity (flow) targets. Water demand data are provided for industrial, residential and business/commercial developments.

Industrial developments

The non-potable water demands presented in Table 51 and Table 52 are applicable to industrial developments.

Table 51 Industrial non-potable water demands

Water use	Demand based on moderate uptake of water saving devices
Rainwater tank demand (toilets)	15 L/persons/ha/day persons/ha = refer to planning document or development plan (e.g. 15 L/persons/ha/day x 25 persons/ha = 375 L/ha/day)
Regional reticulation demand*	6.25 kL/ha (excluding regional open space, undeveloped areas) (This demand includes the lot outdoor demands, so when regional reticulation is applied, use this demand without any further outdoor demand on the lots)

* This demand figure was derived as 50% of the total water demands and is adopted for the purpose of assessing a regional-scale WSUD strategy. Future demand figures need to be confirmed by the relevant stormwater drainage manager.

Table 52 Industrial non-potable water demands for outdoor and open space

Water use	Demand	
Irrigation	Area = 50% of landscape areas (and public open space) Irrigation rate = 600 mm/y	
	Monthly distribution	
	January	13%
	February	6%
	March	6%
	April	4%
	May	2%
	June	0%
	July	4%
	August	7%
	September	12%
	October	14%
	November	13%
	December	19%

The irrigation rates and distribution were estimated from Penrith rainfall, evaporation data from the calibrated MUSIC file, and adopting a crop factor of 0.5.

Residential developments

The non-potable water demands presented in Table 53 and Table 55 are applicable to residential developments. The population rates (equivalent persons/ha) should be determined from the specific details of the development, along with the occupancy rates (equivalent persons/dwelling) provided in the following 2 modelling guidelines:

- *NSW MUSIC Modelling Guidelines* (BMT WBM 2015), which contains data provided by Sydney Water
- *MUSIC Modelling Guidelines* (Healthy Land and Water 2018).

Table 53 Residential non-potable water demands for indoor use

Water use	Demand (litres per person per day)	
	Moderate uptake of water saving devices	Full uptake of water saving devices
Toilet	27	26
Laundry	31	21
Total	**58**	**47**

Table 54 Residential occupancy and equivalent persons (EP)

Development type	Size*	Occupancy (EP per dwelling)
Detached dwelling	1 bedroom	1.6
	2 bedroom	1.9
	3 bedroom	2.5
	>3 bedroom	3.5
	Overall mixed	**3.1****
Townhouse	1 bedroom	1.2
	2 bedroom	1.6
	3 bedroom	2.3
	>3 bedroom	3.3
	Overall mixed	**2**
Unit/Apartment	1 bedroom	1.2
	2 bedroom	1.2
	3 bedroom	2.2
	Overall mixed	**1.7**

* The ‘overall mixed’ values should be adopted for land-use planning purposes or when the number of bedrooms is not known.

** Average Western Sydney household population from Western Sydney District Data Profile – Western Sydney and Blue Mountains (Communities and Justice 2021).

Table 55 Residential non-potable water demands for outdoor and open space

Water use	Demand	
Irrigation	Area = maximum of 50% of ground level area Irrigation rate = 600 mm/y	
	Monthly distribution	
	January	13%
	February	6%
	March	6%
	April	4%
	May	2%
	June	0%
	July	4%
	August	7%
	September	12%
	October	14%
	November	13%
	December	19%

The irrigation rates and distribution were estimated from Penrith rainfall, evaporation data from the calibrated MUSIC file, and adopting a crop factor of 0.5.

Business/commercial developments

The non-potable water demands presented in Table 56 and Table 57 are applicable to business/commercial developments.

Table 56 Commercial/business non-potable water demands

Water use	Demand based on moderate uptake of water saving devices
Rainwater tank demand	15 L/persons/ha/day persons/ha = refer to planning document or development plan (e.g. 15 L/persons/ha/day x 25 persons/ha = 375 L/ha/day)

Table 57 Commercial/business non-potable water demands for outdoor and open space

Water use	Demand	
Irrigation	Area = 50% of landscape areas (and public open space) Irrigation rate = 600 mm/y	
	Monthly distribution	
	January	13%
	February	6%
	March	6%
	April	4%
	May	2%
	June	0%
	July	4%
	August	7%
	September	12%
	October	14%
	November	13%
	December	19%

The irrigation rates and distribution were estimated from Penrith rainfall, evaporation data from the calibrated MUSIC file, and adopting a crop factor of 0.5.

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Glossary

Term	Definition
1% AEP	A flood that has a 1% chance of occurring in any given year within a 100-year cycle
Bioretention system	Vegetated sunken garden bed areas that collect and treat stormwater as it percolates through a sandy loam soil medium. They can be a range of sizes and located in a private allotment or local parks and support a wide range of vegetation types
Bioretention street tree	A bioretention system associated with a single street tree located in a road verge that collects and treats stormwater from the road kerb. These systems come in a number of different engineering and landscape forms
Blue grid (natural)	A network of waterways, waterbodies, wetlands, groundwater ecosystems, and vegetation that are water dependent. This includes the riparian vegetation in the Wianamatta–South Creek catchment
Blue–green grid	A network of high-quality green areas and waterways, from regional natural assets to local natural assets, that connect to centres, public transport and public spaces
Blue–Green Infrastructure Framework	An interconnected network of natural and semi-natural landscape elements; for example, blue includes waterbodies, creeks and dams (see definition for blue grid), green includes trees, parks and native vegetation
Coarse sediment	Particles larger than 0.125 mm transported in stormwater
Construction phase	The period during a development until at least 80% of the allotment buildings are deemed complete with occupation certification
Certified Professional in Erosion and Sediment Control (CPESC)	Individuals who demonstrate an established minimum level of competence through the application review process, and an examination process, will be certified in erosion and sediment control
Green roofs	Roof areas that are covered with soil and vegetation. They act to capture rainwater, promote evaporation, reduce runoff volumes and cool the building
Irrigated street trees	Street trees that are irrigated from a reticulated supply, such as from harvested stormwater and/or recycled water
Lot scale (or allotment scale)	WSUD infrastructure/measures that are located entirely within the boundaries of a lot Note: This does not include streetscape or precinct measures.
Operational phase	The period when development is deemed complete with occupation certification
Passively irrigated street trees	Stormwater diverters installed in kerbs to direct small amounts of stormwater into soils around street trees for irrigation (not bioretention)
Precinct scale	WSUD infrastructure/measures that are located in a mix of allotment, street and public open space locations within a precinct
Practitioners	An individual actively engaged in a profession; in this context, individuals such as stormwater engineers, flood engineers or landscape architects

Term	Definition
Regional scale	In this guide, regional scale specifically refers to WSUD infrastructure/measures that include a reticulated stormwater reuse system to provide stormwater treatment and storage at precinct, sub-catchment or catchment scales. A regional WSUD strategy (or otherwise termed regional stormwater system) is planned over multiple land holdings and typically requires a stormwater drainage manager
Storages	Storage for water reuse systems to collect treated stormwater and store it until it is required. They can be open water storages (dams or lakes) or in enclosed tanks that are either above or below ground
Streetscape scale	WSUD infrastructure/measures that are located along streets
Water and Stormwater Management Plan	A document that addresses urban stormwater from a management perspective to ensure the stormwater management targets and other related controls are achieved. These documents are also referred to as Stormwater Management Plans, Water Management Plans, or similar
Waterway	The whole or any part of a watercourse, wetland, waterbody (artificial) or waterbody (natural)
Waterway health objectives	The community environmental values and long-term goals for managing waterways. The objectives consist of 3 components: i) values and uses of waterways, ii) indicators, and iii) numerical criteria needed to protect the values and uses. They reflect NSW Government policy and are accordingly used as environmental standards for delivering healthy waterways, riparian corridors and other water dependent ecosystems
Wetlands (for stormwater management)	Shallow vegetated waterbodies that are intended for stormwater treatment. They can be a variety of scales and are generally configured to capture an initial volume of stormwater and slowly release it over 2–3 days
WSUD	Water Sensitive Urban Design (WSUD) is an approach to planning and designing urban areas to make use of stormwater and reduce the harm it causes to waterways, and provide a range of co-benefits such as urban cooling, public amenity and biodiversity
WSUD measure	A built (infra) structure or landscape feature that is designed to slow and disperse runoff from storm events by promoting retention, infiltration or evapotranspiration while cleaning the runoff of pollutants including litter and harmful chemicals
WSUD strategy/strategies	Method (strategy) of delivering WSUD measures at various scales, including allotment, streetscape, precinct or regional

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More information

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- Guidelines for controlled activities on waterfront land: Riparian corridors [496KB]
- Mamre Road Precinct Development Control Plan 2021 [PDF 5.9MB]
- Managing Urban Stormwater: Soils and Construction Blue Book (PDF 21MB)
- MUSIC (Model for Urban Stormwater Improvement Conceptualisation)
- MUSIC modelling toolkit for Wianamatta–South Creek
- NSW Government Sharing and Enabling Environmental Data (SEED) portal
- Penrith City Council Water Sensitive Urban Design (WSUD) Policy [PDF 336KB]
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