5 Illustrative precincts

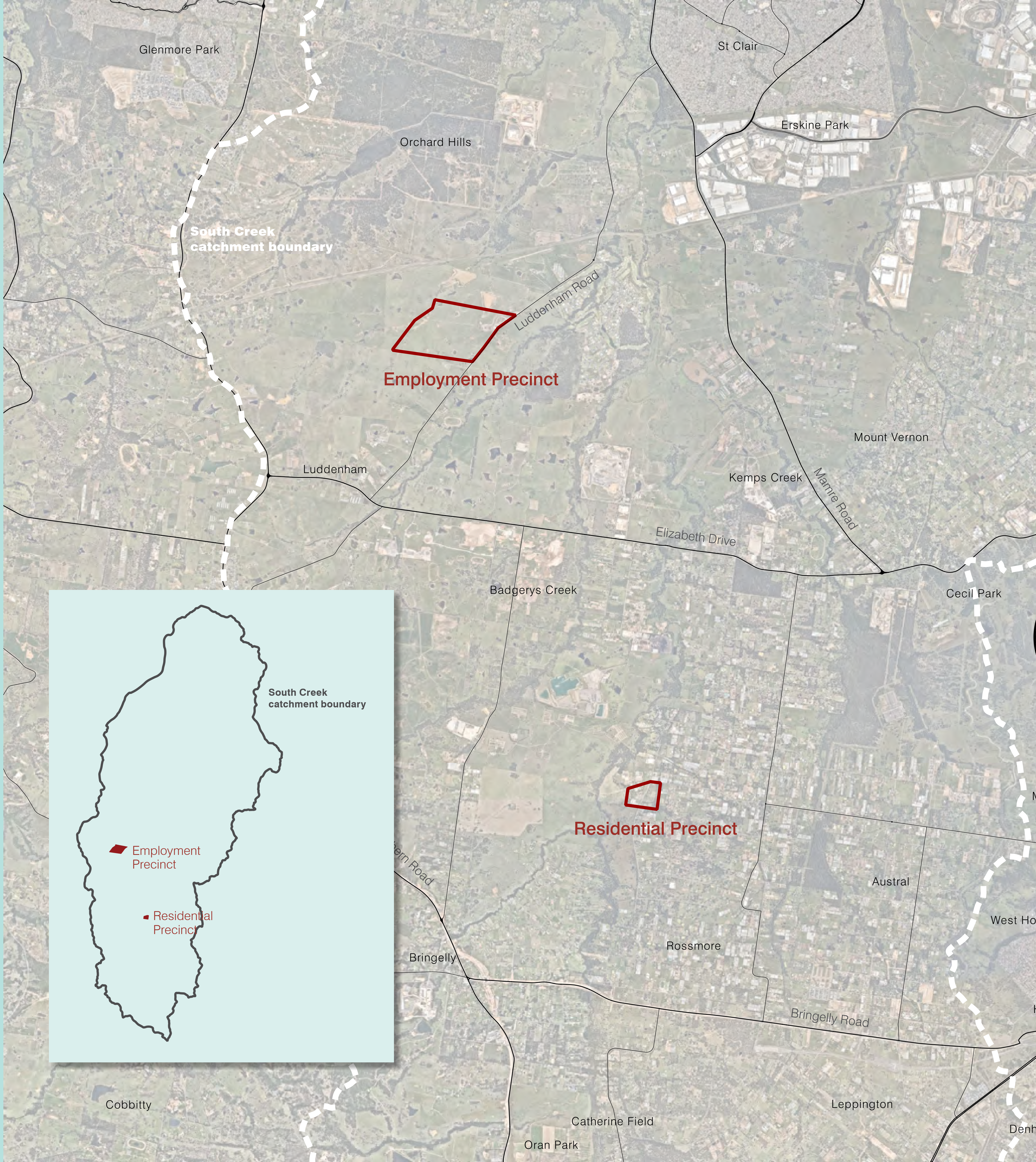
Two sites within the Aerotropolis Growth Area in Western Sydney were selected and planned using a combination of the urban typologies, along with roads, open space and waterways to create a cohesive view of what a future precinct may look like. These precincts were then tested for performance in relation to stormwater retention and overall liveability objectives.

5.1 Precinct selection and purpose

The typologies have been applied at a precinct scale to validate the feasibility and interactions between various land uses, explore interfaces with waterway corridors and open space, and understand the implications of various topography.

This work is indicative only and has been developed primarily to understand water outcomes at precinct scale. The table below summarises some of the key metrics for each illustrative precinct.

	Residential	Employment
Total area (ha)	16	104
Total runoff (ML/yr)	18	202
Runoff per hectare (ML/ha/yr)	1. 09	1.95
Permeability (incl. Streets)	32%	35%
Permeability (incl. excluding streets)	50%	58%
Canopy cover	44%	35%
Tank volume (kL)	1679	360
Wianamatta Street trees	430	4518
Bio Sponge area (m²)	5206	95231
Bio Sponge area (m²)	5,200	95,200



5.2 Residential precinct

Opportunities

1. Existing drainage channel – The channel is part of a larger network of dams on the northern side of Fifteenth Avenue and supports a number of large trees. The channel should be kept to enable the retention of the existing trees.
2. A large stand of trees is located off Ramsay Road and should be retained.
3. The riparian corridor and flooding constraints extend into the site and will provide opportunities for re-vegetation and habitat creation. Connections to these edges should be considered when developing the access and movement network.

Challenges

4. The subdivision pattern of the site presents a challenge in relation to staging and the location of new roads.
5. Ramsay Road provides a good north-south connection through the site, but may require re-alignment to better connect with future development.

Structure Plan

The structure has been developed as a direct response to the site and its existing physical features. Key features of the plan include:

1. North-south collector through-road to act as a new high street for the precinct, located along the existing irrigation channel and line of trees.
2. Reinforcing park to park connections with east-west pedestrian connections across the precinct.
3. East-west road to provide a secondary point of access into the precinct.
4. Secondary north-south green streets with through connections which run to the southern edge of the creek to maximise access to the creek interface.
5. Open space located around a stand of existing stand of trees.
6. Linear parks along east-west local streets provide additional open space provide opportunities for deep soil planting and increased tree canopy.
7. The edge of the creek will feature active walking tracks accessible from the north-south and east-west connections.

Development

Local centres including shops, high density residential and public transport focussed on amenity including the flood plain and close to transport. This includes the new urban park which is located in the centre of the precinct.

Medium density development consisting of terrace houses and three storey apartment blocks transition between the high and low density development as well as providing activity and connections fronting the open space corridors.

Low and medium density development, made up of detached and attached dwellings, furthest from major transport, centres and the riparian corridor.

Residential precinct

Residential Master Plan

The following master plan has been developed in response to the opportunities and constraints identified in our initial analysis of the site. The plan sets out a robust framework for a new residential precinct. It places particular emphasis on providing good walkable connections to the edges of the creek which will become valuable places for recreation in the future. Existing vegetation on site such as the stands of trees have has been retained and further enhanced by co-locating them near new parks.

Key features of the plan include:

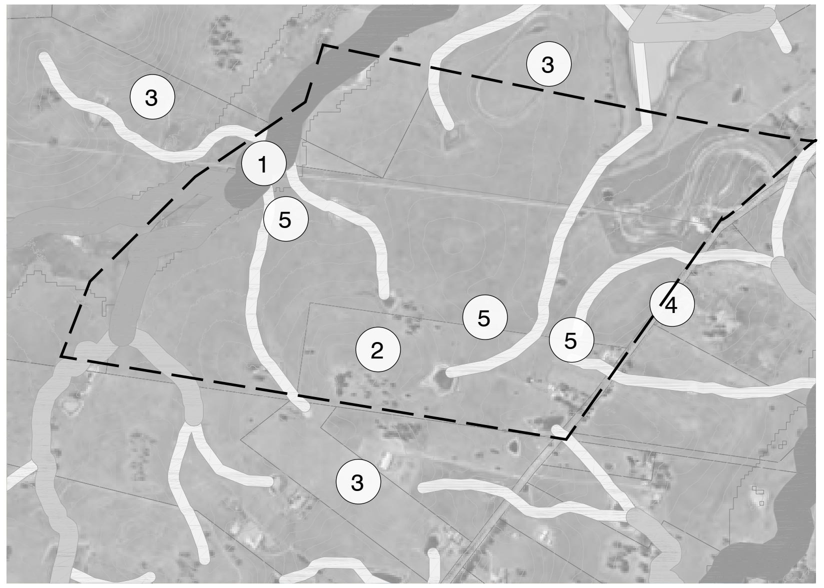
1. Diverse mix of dwelling types and densities ranging from detached, attached to apartment dwellings resulting in a truely diverse precinct.
2. Mix of urban and natural open spaces which include a 5000m² community title park off the new north-south high street and restored open space along the riparian corridor.
3. Application of the 120m x 70m block framework which was the basis of built form testing.
4. Use of street widths consistent with the WSPP Street Guidelines.

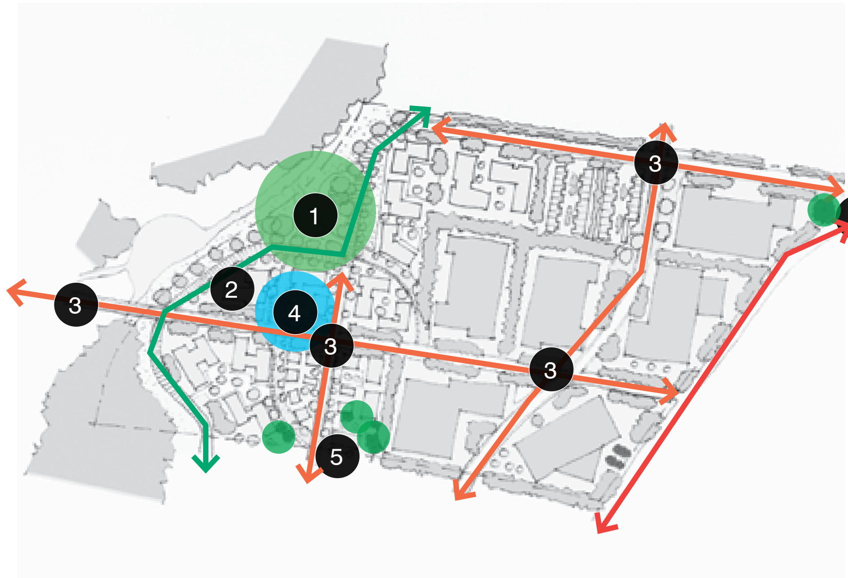
Precinct Summary

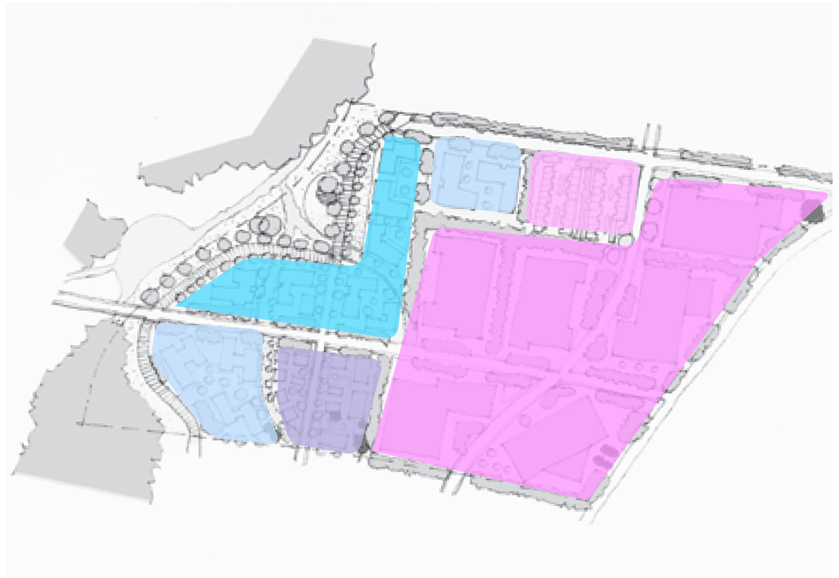
Total Site Area	202,088m²	Water [based on developable area only]	
Riparian / 1 in 100 flood zone (excluded)	51,607m²	Permeability % [Block+street scale]	32%
Net developable area	150,481m²	Surplus Runoff	1.09 ML/ha/yr
Local public open space	14% (20,941m²)	Total Rainwater Tank Volume [per hectare]	104 kL
Streets	31% (46,681m²)	Bioretention "Sponge Area" [per hectare]	324 m²
Development lots	55% (82,859m²)	'Wianamatta' street trees [per hectare]	27
Canopy cover	44%		

Figure 82. Illustrative residential precinct – Rossmore

5.3 Employment precinct







Opportunities

1. Utilise creek corridor as an open space asset, for views and connectivity.
2. Some existing trees which may be considered for retention as focal assets.
3. Connect north and south into surrounding communities. Large existing lot pattern provides opportunity for comprehensive and integrated masterplan.

Challenges

4. Single road as only existing point of access – alignment with masterplan road delivery on neighbouring properties required to ensure coordinated street grid.
5. Areas with complex riparian corridors will be less suitable to some large format uses.
6. Complex geometry of site provided by drainage corridor, road and lot boundaries.

Structure Plan

The structure has been developed as a direct response to the site and its existing physical features. Key features of the plan include:

1. Utilise the complex riparian corridors and flood zone as a focal point for high amenity and development.
2. Ensure attractive and well used frontages to the open space corridor including the flood zone.
3. Build on the existing street network, providing north-south as well as east-west links, all with substantial greening.
4. Ensure public transport links will be accessible to major employers.
5. Retain existing trees and utilise them as a focal point for new development where possible.

Land use structure

- Office core – focussed on a small area of public open space and utilising aspect to the riparian corridor and flood zone. Close to transit links.
- Business park office – some larger floorplate zones and potential for some at grade parking around the edges of the office core.
- Small footprint office – providing employment variety and helping to best utilise complex sites divided by riparian corridors.
- Strata industrial – providing a transition from centre uses to larger format industrial uses and a variety of use.
- Large format industrial/warehouse – Located close to main roads and away from complex riparian constraints.

Employment Master Plan

The following master plan has been developed in response to the opportunities and constraints identified in our initial analysis of the site. The plan particular emphasis on providing good walkable connections to the edges of the creek which will become valuable places for recreation in the future, as well as the commercial needs of a diverse range of employment.

Key features of the plan include:

1. Focus on amenity around the flood plain corridor with high quality open spaces and streets and highest density employment uses.
2. Simple road network with great public transport access and greening. Use of street widths consistent with the WSPP Street Guidelines.
3. A focus on the 'green grid' with ecological connections across the site following lot boundaries as well as roads.
4. Retain existing trees where possible.
5. Diverse mix of employment uses providing for a mix of employment generation and a robust mix of sites to accommodate different needs.

Figure 83. Illustrative Employment precinct – Luddenham

Precinct Summary

Total Site Area	989,092 m²	Water [based on developable area only]	
Riparian / 1 in 100 flood zone (excluded)	32,550 m²	Permeability % [Block+street scale]	35%
Net developable area	956,542 m²	Surplus Runoff	1.95 ML/ha/yr
Local public open space	8% (72,429 m²)	Total Rainwater Tank Volume [per hectare]	3 kL
Streets	20% (193,992 m²)	Bioretention "Sponge Area" [per hectare]	920 m²
Development lots	72% (690,121 m²)	'Wianamatta' street trees [per hectare]	43
Canopy cover	35%		

6 Conclusions and recommendations

The building typologies and precincts identified in chapters 4 and 5 are tested for water management outcomes.

6.1 Hydrologic Performance

A water balance analysis was undertaken on the urban typologies to determine their performance against waterway health objectives. The results of the water balance analysis indicates the breakdown of rainfall and runoff conversion and mitigation. The modelled catchment rainfall of 6.19 ML/ha/yr represents the total inputs. The various outputs can be attributed to the mitigation strategies including permeability targets and various stormwater management assets. The final mean annual runoff volume is represented in blue indicating that the target of 0.9 ML/ha/yr is achievable within the catchment if the urban typologies and stormwater solutions are applied.

<u>What do the results mean?</u>

The results show that the runoff targets are able to be achieved for most development types, with the exception of business parks and industrial where the runoff volumes are significantly higher and means of reducing runoff are limited. For example, consumptive water demands for stormwater harvesting are much lower than residential land uses.

The permeability targets result in significant reductions in surface runoff. Harnessing green space in this way helps ensure that the overall strategy is resilient without placing too much reliance on stormwater management assets that may otherwise have reliability or maintenance issues. It embeds water management into the built form, while also contributing to urban greening and amenity.

Rainwater tanks provide direct benefits to residents by providing water for irrigation and indoor non-potable uses, while also reducing demands on the potable water supply, and minimising runoff. For Business Parks and Industrial land uses, water demands are often low and so rainwater tanks play a lesser role in stormwater management. In most cases, the Wianamatta Street Tree design is able to soak up the balance of the excess runoff and achieve pre-development runoff volumes. There is significant scope to optimise and fine tune the size of the sub-soil gravel storage to adapt to minor variations in development types or site constraints.

Business Parks and Industrial developments would need some additional end-of-pipe stormwater management (bioretention or harvesting) to fully meet the targets.

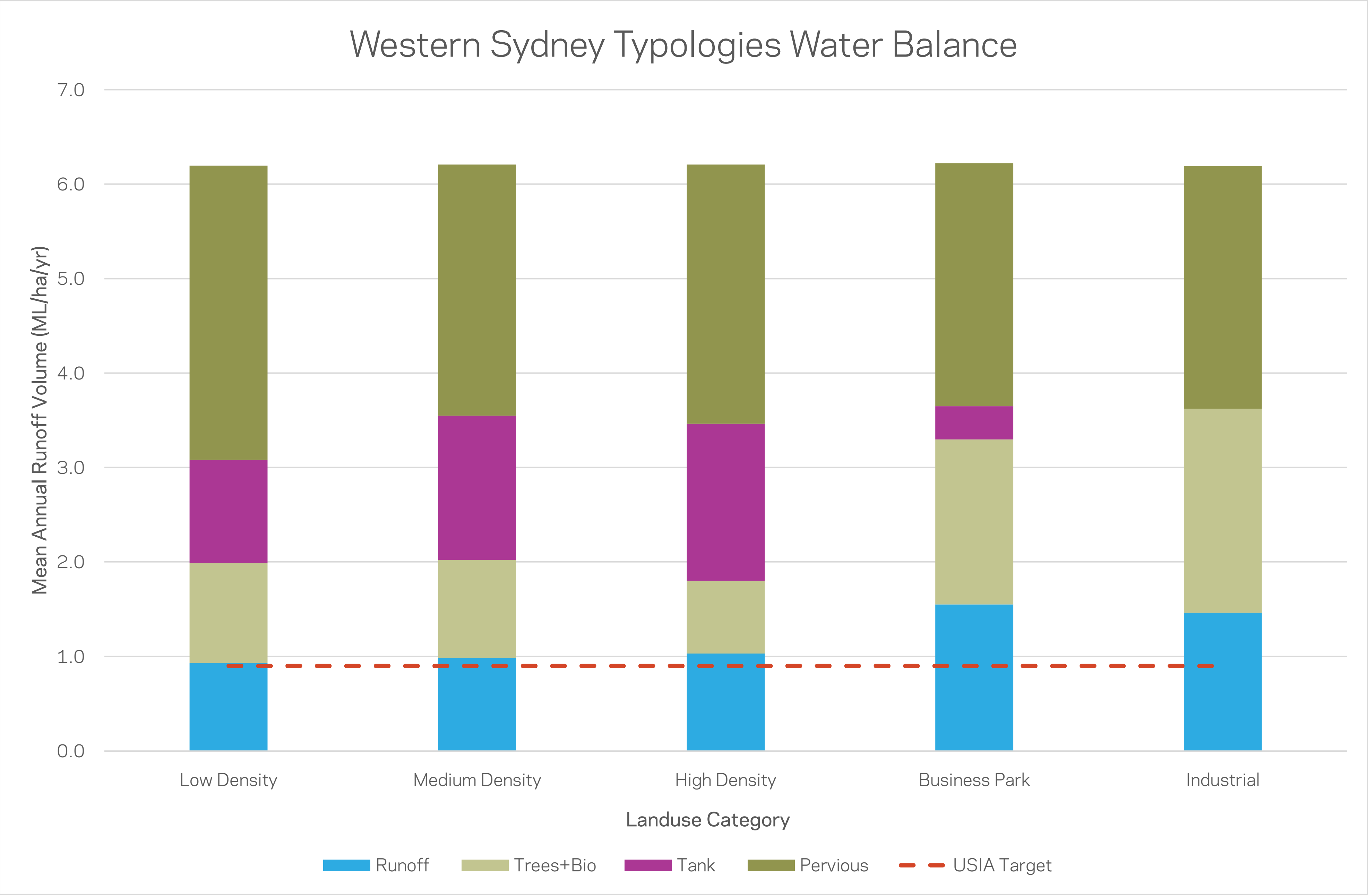


Figure 84. Result of MUSIC Water Balance Modelling – shows the combined impacts of creating more pervious surfaces and WSUD strategies which could significantly reduce surface runoff. Please note the results represent the average of the water balance for the typology variants of each land use category.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6.2 Key findings and recommendations

1. Run-off from urban areas must be reduced from 3.9 megalitres / hectare / year to 0.9 megalitres / hectare / year – a reduction of 75%.

Urbanisation can create profound changes to hydrology largely because of significant increases in stormwater runoff as a result of the introduction of extensive hard, impervious surfaces. This runoff can exacerbate flooding, pollute waterways, cause erosion and degrade valuable natural assets.

A business as usual development will generate run off at about 4 megalitres / hectare / year. At this rate, the urbanisation of the South Creek Catchment will destroy the waterways. The volume of water discharged into the waterways and the velocity will erode the banks, remove habitat and irreparably alter the flow regime and ecological cues that the waterway's ecology depends upon.

The Waterways Health model developed establishes the following benchmarks for development that will preserve the waterways:

- Retention of the creek systems and the 1% AEP areas as vegetated open space
- Run-off from urban areas is reduced to 0.9 megalitres / hectare / year
- Designated set backs from all waterways, including the fragile first-order streams.

Of all the water that is typically flushed down a drain and piped away, or as overland flow, 75% of our water needs to stay in the urban area being absorbed into soil and trees, being recycled on gardens and parks and in bathrooms.

2. Clear requirements for open space and streets are needed to achieve the overall targets

The aspirations of a cool, green western city which cannot be met without increasing the areas of public domain areas achieved in new development. This includes stormwater outcomes, aspirations fore greening/cooling and social aspirations identified with having a high amenity parkland city.

The table below describes our recommended approach for requirements for streets and open space on large masterplanned sites (see Section 3.4 of this document).

Table 29. Recommended open space and street percentages for South Creek

Typology	Minimum Dedicated public open space *	Minimum Streets *
Residential		
Low density	10%	30%
Medium density	15%	30%
High density	25%	30%
Mixed use centre	20%	30%
Business Park	10%	20%
Industrial	5%	20%

* As a percentage 'urban typology' area excluding 1:100 flood prone land and any other regional open space and sporting fields

3. Four key technological solutions have been identified which can perform an important role before building designs are changed

At a technology level, the following have been identified as key solutions for South Creek:

- Bioretention 'Sponges' – 'raingardens' that treat stormwater by vertical percolation through a soil filter media
- Water Smart 'Wianamatta' street trees
- Permeable Pavements
- Rainwater Harvesting and Reuse.

Past this, to reduce runoff rates further relies primarily on reducing building footprints to allow greater deep soil and permeability on sites.

4. As a very simple rule of thumb, 50% of a development site for residential and 40% for employment uses needs to be pervious in order to reach our water performance targets. However this will require a step change from current practice

Achieving the targets

Precinct scale testing reveals that 50% perviousness across a development precinct, along with other measures for the performance of streets and water reuse, precinct run off can be reduced to about 0.9 megalitres / hectare / year.

Higher density urban environments are still able to be green and cool and meet the 50% pervious target, and because of the greater demand for harvested rainwater in toilet flushing, are able to be some of the most waterway friendly development.

Depending on the precinct's proximity to the waterways, the precinct may also require some additional measures to manage run-off, including end of pipe detention, more trees in the landscape, or additional private or public open space for example.

The modelling undertaken assumes that the Order 1, 2 and 3 streams and the 1% AEP flood area are vegetated waterways. It is also assumed that the street types identified in the Draft Western Sydney Street Design Guidelines (Western Sydney Planning Partnership, Draft November 2019) are implemented across South Creek.

Comparison to existing residential precincts

Although there are some best practice residential precincts that comprise a significant quantum of permeable surfaces (35%-40% of the site), there are no examples of any existing building types achieving the required 50% perviousness at a precinct scale.

Analysis of existing urban areas shows that some low-medium density residential areas comprise only 10% permeable surfaces.

Best practice residential developments get closer to the target 50%, with Newington at 42% pervious surfaces and Ermington at 38.4%. Some additional private and communal open spaces, and more pervious streets in these areas and they achieve the required water performance.

High density precincts are much less permeable. Even great examples like Victoria Park in Zetland, with 12% public open space only achieves 17% perviousness, primarily because there are basement car parks under most blocks, and because of the application of the Apartment Design Guidelines (ADG), which only requires 15% deep soil.

Employment areas researched varied from 11% pervious (Eastern Creek Industrial Area) to 30% (Norwest Business Park). Hard stand car parks account for a significant amount of these sites, which means there is real opportunity to improve the water performance of typical business parks and industrial parks. A key challenge for employment uses will be achieving the ambitious water re-use targets modelled.

5. A range of on-lot building typologies have been developed that achieve the desired outcomes however require some changes from current market practice

This document includes detailed testing of a broad range of individual building typologies including:

- Employment: Office
- Employment: Industrial
- Apartments
- Attached housing
- Detached housing.

The building types have also been applied at a precinct scale for indicative residential and employment precincts.

Hydrologic performance testing including Mean Annual Runoff Volume and lot-scale MUSIC modelling has described the outcomes of these typologies.

However, it is noted that implementation of these typologies will require some changes from current design and building practice. These changes must be implemented through the planning framework to ensure outcomes are achieved.

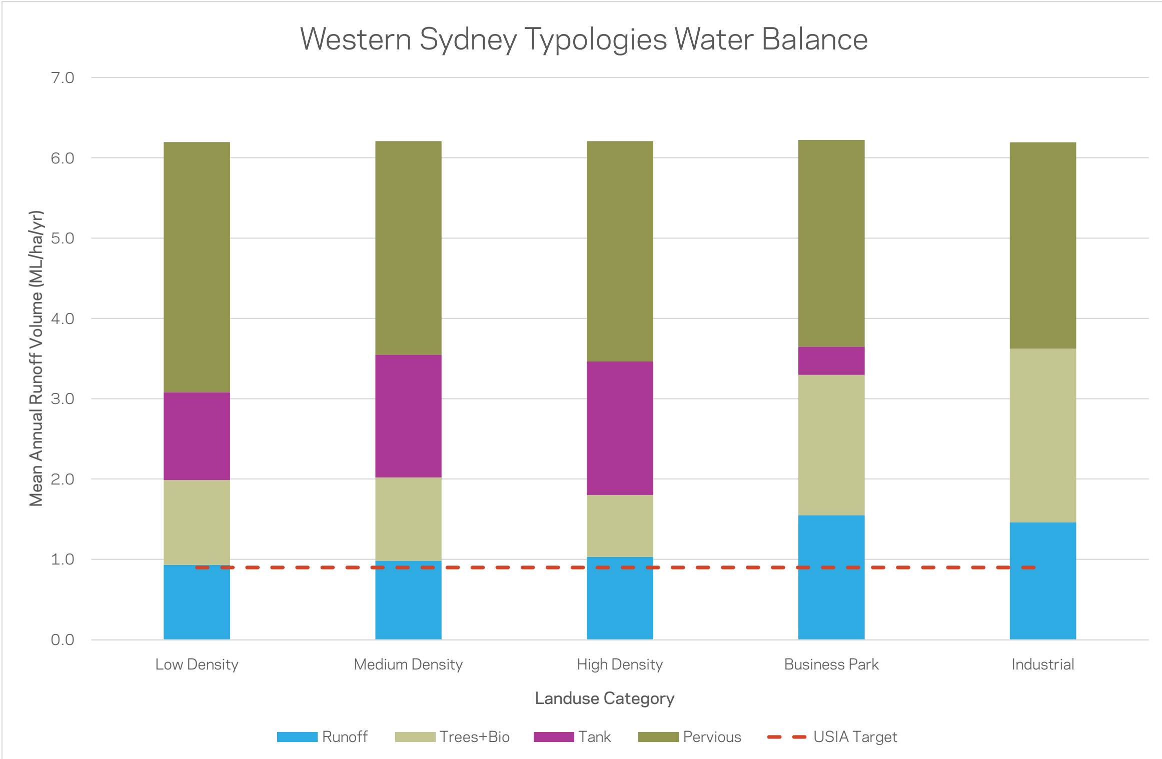

Figure 85. Result of MUSIC Water Balance Modelling – shows the combined impacts of creating more pervious surfaces and WSUD strategies which could significantly reduce surface runoff. Please note the results represent the average of the water balance for the typology variants of each land use category.

6. Implementation of the planning framework needs careful attention to ensure the targets are delivered

The overall planning framework for the first precincts in South Creek is currently being led by the Western Sydney Planning Partnership.

Implementation needs to be carefully managed to ensure that there is clear understanding of requirements for developers, property owners and Councils particularly over density, open space and maintenance/management.

6.3 Key issues towards implementation of typologies

Key themes from the typology testing that require consideration towards implementation include the following:

Delivery feasibility

The typologies tested could have economic implications for development in some cases including:

- **Greater land take** for the same density (particularly for industrial/commercial uses due to recommended requirements for open space).
- **Potential for increased costs for technology** including permeable paving and other uses.
- **Potential insurance premiums for new products** that are not common in the market.

Maintenance and management

- **Management of additional green spaces** is an ongoing cost. In different forms this may be borne by landowners, a strata or community title, councils or other owners.
- **Some building products and technologies used may have a lower life cycle than established market practice** (e.g. permeable paving).

Planning constraints

- **Existing planning policy** permits much lower greening and open space than the typologies tested and would perform much lower in key outcomes. These would need to be amended or 'switched off' to meet the targets here.
- **Implementation of the WSPP Street Design Guidelines**, will also be required to reach the figures in this testing.

Divergence from the established market standards

- **The housing typologies propose larger open space areas than the market has delivered in recent development.** This issue is tied to the planning controls where higher lot coverages have been permitted in other areas.
- Some typologies have focussed on strata-titled community areas which is not a typical market practice.
- Car parking approaches will also vary significantly from business as usual and may include at-grade parking for apartments, above ground parking and separated parking structures.

The above challenges must be weighed against the government's broader vision to deliver a 'Parkland City' which is cool, green and sustainable, with healthy waterways. A 'business as usual' approach to urban development in the South Creek Catchment will not deliver on this vision.

6.4 Recommendations towards planning framework

To best achieve the waterway health targets and outcomes for South Creek, clear and robust planning controls are required. The following framework is suggested as a foundation for the development of planning controls that will position the Western Parkland City for success in relation to integrated water management outcomes.

Objectives of these controls

To ensure that the urbanisation of the South Creek Corridor is undertaken in a sensitive and sustainable way, where flooding and wastewater is managed within the catchment, and where run-off does not have an adverse impact on the existing waterways.

Principle control for sites 20 hectares and over

The following water retention strategies are required to achieve the run-off target of 0.9ML/ hectare/ year:

- Permeability of the Development Area
- Water reuse on site
- Trees and bioretention.

Development will need to rely on each of these measures to achieve this target, and rely more heavily on certain strategies, depending on the site's context and specific opportunities and challenges.

Table 30. **Minimum Requirements for Water Retention Strategies**

Land Use	Permeability of the Development Area 1	Water Reuse on site	Trees and Bioretention
Low Density residential	**50%**	• 5000L rainwater tank / dwelling • Rainwater for toilet flushing, laundry and hot water use and irrigation for at least half the on lot green space	• 1 large tree on the private lot per 1 dwelling • 13 x 'super trees' in the street per 5 dwellings
Medium Density residential	**50%**	• 5000L rainwater tank / dwelling • Rainwater for toilet flushing, laundry and hot water use and irrigation for at least half the on lot green space	• 0.4 x large tree on the private lot per 1 dwelling • 4 x 'super trees' in the street per 5 dwellings
High Density residential	**50%**	• 0.4 ML of rainwater tank storage per 5 dwellings • Rainwater for toilet flushing, laundry and hot water use and irrigation for at least half the on lot green space	• 0.16 large tree on the private lot per 5 dwellings • 1.6 x 'super trees' in the street per 5 dwellings
Mixed Use Centre	**50%**	• 0.4 ML of rainwater tank storage per 5 dwellings • Rainwater for toilet flushing, laundry and hot water use and irrigation for at least half the on lot green space	• 0.16 large tree on the private lot per 5 dwellings • 1.6 x 'super trees' in the street per 5 dwellings
Business	**40%**	• 20 ML of rainwater tank storage per hectare • Rainwater for toilet flushing and irrigation for at least half the on lot green space	• 46 x super trees on the private lot per hectare • 34 x 'super tree' in the street per hectare
Industrial	**40%**	• No rainwater tank use	• 56 x super trees on the private lot per hectare • 17 x 'super tree' in the street per hectare

Notes:

1. Development Area is all land, excluding the Blue Green Grid, District open space and Regional Open Space, but including streets, and all other types of open space

2. To clarify, the 0.9ML/ hectare / year limit for run-off is to be measured at the edge of the site, at precinct scale.

Table 31. Benchmarks for achieving the minimum permeability requirements

Land Use	% of the Development Area comprising streets	% of the Development Area comprising open space (public local parks, linear parks and neighbourhood parks)	Super Tree canopy	Large trees and super trees (trees/ha)
Low Density residential	30	10	33	25-30
Medium Density residential	30	15	23	19
High Density residential	30	25	28	7
Mixed Use Centre	30	25	28	25
Business	20	10	28	42
Industrial	20	5	37	19

Table 32. Business as usual comparison – Employment

	BAU – Business Park	BAU – Industrial	Parkland Typologies
Development lots	80%	90%	72%
Streets	20%	10%	20%
Open space	0%	0%	8%
Detention basins	450-500m^3	450-500m^3	-20% (possibly up to -50%)
Perviousness (excl. streets)	30%	11%	58%
Canopy cover	10-15%	<10%	35%
Surplus runoff	5-7 ML/ha/annum	5-7 ML/ha/annum	1.95 ML/ha/annum
Average temperature 24 hr (2055)	30.5 degrees		28.7 degrees
Maximum temperature (2055)	46.5 degrees		41.9 degrees

Table 33. Business as usual comparison – Residential

	Business as usual	Parkland Typologies
Development lots	53%	55%
Streets	35%	31%
Open space	12%	14%
Detention basins	350-500m^3	-20% (possibly up to -50%)
Perviousness (excl. streets)	20%	50%
Canopy cover	10-20%	44%
Surplus runoff	4-5 ML/ha/annum	1.09 ML/ha/annum
Average temperature 24 hr (2055)	30.5 degrees	29.1 degrees
Maximum temperature (2055)	46.3 degrees	42.4 degrees

Conclusion

The rapid urbanisation planned for the South Creek Catchment presents many challenges. But the opportunity to create a new, vibrant and liveable city in a greenfield location is a unique, once in a generation chance to set new benchmarks in urban planning and development. We know that significant change is required from 'business as usual' if we are to achieve the Parkland City vision. Water will be central to the success of the Western Parkland City - in protecting and enhancing Wianamatta-South Creek, in creating cool, green neighbourhoods and in realising amenity and liveability objectives. The urban typologies and stormwater management work is an important tool to bring water to the forefront of strategic planning as part of a landscape led approach t to deliver the government's vision.

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Appendix A – Key assumptions

Urban typologies, precinct components and scales considered in this document

The following definitions form the basis of the analysis and recommendations.

Urban typologies

Urban typologies' are a land use definition at a broad scale. Each will include a range of building types. Five typologies are considered within this document including both employment and residential uses.

Table 34. Uban typology building types

Urban typology		Building types within
Employment	Office	May include a mix of higher and lower densities. Lower densities will typically include at-grade parking.
	Industrial	Large distribution centres through to smaller strata-title lots.
Residential	High density	Primarily apartments. Includes centres with shoptop housing.
	Medium density	Will include a mix of apartments, attached and detached.
	Low density	Primarily detached with some attached dwellings.
Mixed use	A higher density mix of employment, residential and community uses.	

Precinct components

A precinct includes a mix of lots, streets and open space with some complexity. For the purpose of this study, the following definitions have been used.

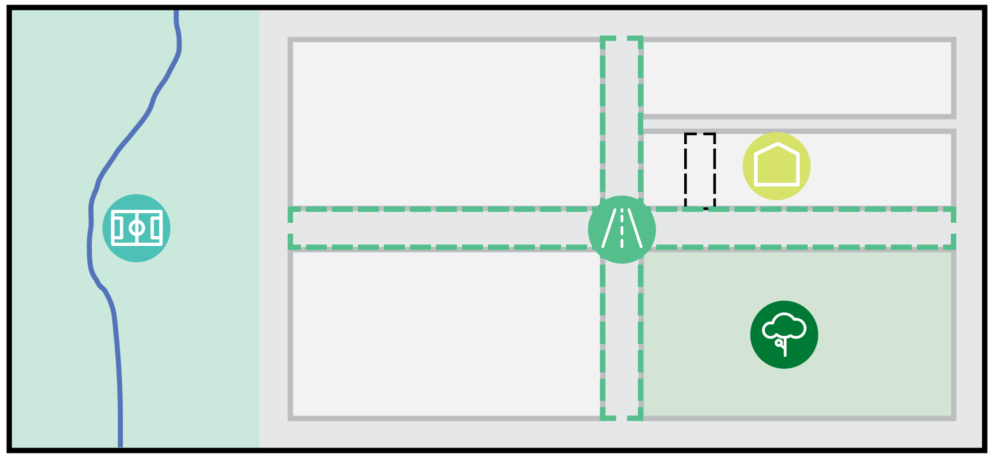


Table 35. Precinct components

Building lots	Note: This may include laneways and through-site midblock links under community title
Streets	Note: This may not include community title lots (see above)
Local public open space	Spaces providing amenity to local residents and workers, without a regional function
Regional open space / riparian land	Includes the floodplain, riparian land, regional open space such as sports fields and regional links and other regional elements of the blue-green grid

Urban scales

Across a variety of scales, density, canopy, permeability and stormwater flow may be considered. The following definitions are used in this document.

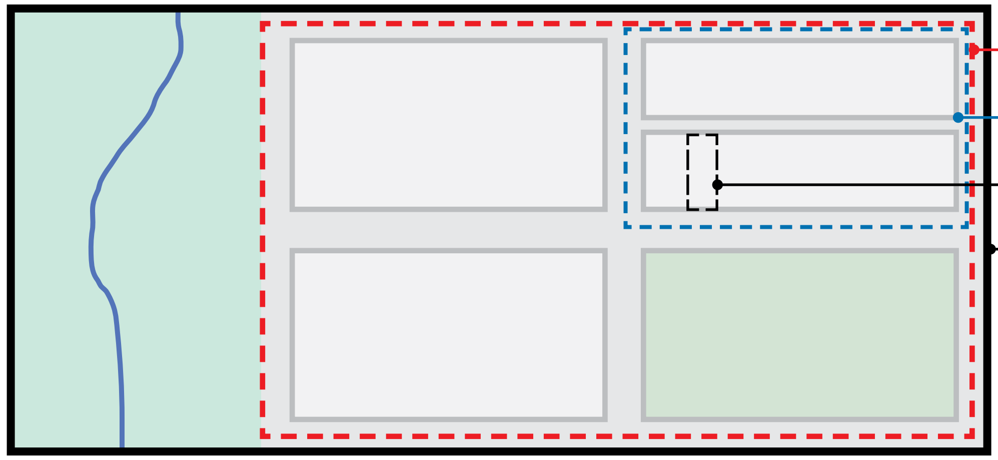


Table 36. Urban scales

Urban scales	Building lots	Streets	Local open space	Regional open space	Use
Building lot	✔	✕	✕	✕	The simplest and preferred density comparison between sites
Block + street	✔	✔	✕	✕	Used for the purpose of AMCORD net residential density** Typically similar to ABS Mesh Block measurements of population density (note: some will include open space)
Urban typology	✔	✔	✔	✕	Typically used for setting Floor Space Ratios on large sites where local open space will need to be provided on site Similar to AMCORD 'neighbourhood density'
Precinct	✔	✔	✔	✔	Precincts defined by government e.g. Aerotropolis Core.

Building typologies

Population Density Estimates

The figures for medium and low density are based on comparison to Jordan Springs and Rossmore. The high density figure has been extracted from the 2016 Census conducted by the ABS used to determine the number of occupants in a household:

Table 37. Population Density (People per household)

Building Type	People per dwelling
Detached Housing (Low Density)	3.2
Attached Housing (Medium Density Housing)	3.2
Apartments (High Density Housing)	1.9

Source: ABS 2016 Census https://www.abs.gov.au/ausstats/abs@.nsf/Lookup/by%20Subject/2071.0~2016~Main%20Features~Apartment%20Living~20

Gross Floor Area Calculations

The following building types have been assigned the following building efficiencies to enable a conversion to be made between the envelope outlined and an indicative Gross Floor Area (GFA) conversion to be made.

Table 38. Building Envelope Area (BEA) to Gross Floor Area (GFA) Factor

Building Type	Factor (%)
Detached Housing Low Density	80
Attached Housing (Medium Density Housing)	75
Apartments (High Density Housing)	75
Commercial Office Buildings	80
Industrial Warehouse Buildings	90

Dwelling Estimates

The following figure has been used to derive an overall dwelling count from GFA.

Table 39. Gross Floor Area (GFA) to Dwelling Count

	Average dwelling size (GFA m^2)
Apartments (High Density Housing)	100

Tree Sizes and Soil Volumes

The tree and soil volume assumptions outlined in the Western Sydney Street Design Guidelines have been adopted as part of this study.

The corresponding tree canopy dimensions have been added to these assumptions to serve as a guide to calculating the overall tree canopy of lots in the private domain. No centres for planting were nominated for any of the trees as no species have been specified.

Table 40. Tree Sizes and Soil Volume

Type	Typical Height	Crown spread	Soil volume (max. 1m from surface level)	
			Per tree in single tree pit	Per tree in shared trench (type up to 3 trees)
Small	up to 4m	3m	8.65m^3	5.80m^3
Small/ Medium	4m-9m	5m	13.80m^3	9.20^3
Medium	7m-12m	7m	21.40^3	14.25^3
Tall	9m-12m	8m	32.65^3	21.80m^3
Large Tall and Wide	8m+ canopy 14m+ wide	+9m	43.70m^3	29.15m^3

Tree Canopy across Pervious Surfaces

For the purposes of the study, a base assumption has been made that all surfaces which are deemed to be permeable (50% or 100%) for all residential and commercial building types including apartment buildings and laneways in the study are capable of supporting vegetation and tree canopy. This is reflected in the table below:

Table 41. Ground Perviousness and Tree Canopy Cover

Ground Perviousness	Canopy Cover
50%	50%*
100%	

*The assumption above excludes Industrial and Commercial Park building types, where the canopy percentage is determined by the number of large trees nominated multiplied by the large tree canopy area divided by the total lot area.

Large Tree Density

The planting of large trees will over time assist areas with absorbing water from the system while providing vital shade and habitat to wildlife in the South Creek corridor. This classification of tree is the largest available under the definition outlined by the work undertaken by Aspect in the Street Design Guidelines document produced by the Western Sydney Planning partnership.

For the purposes of the study, a large tree is defined as:

- Canopy 9m in diameter or 65m^2 in surface area.
- Corresponding root area is 29.15m^2 (5.4x5.4m within canopy)
- Occupies soil depth of 1m.
- Root zones must be located within a contiguous section that is defined as 100% permeable (excludes 50% permeable).
- Canopy zone must be clear and not be obstructed by vertical building planes.

Planting density for large trees vary between contexts which include:

- Detached Housing (Low Density)
- Attached Housing (Medium Density Housing)
- Apartments (High Density Housing)
- Commercial Office Buildings
- Industrial Warehouse Buildings
- Community Title Green Space incl. Parks / Urban Open space

Table 42. Large Tree Density

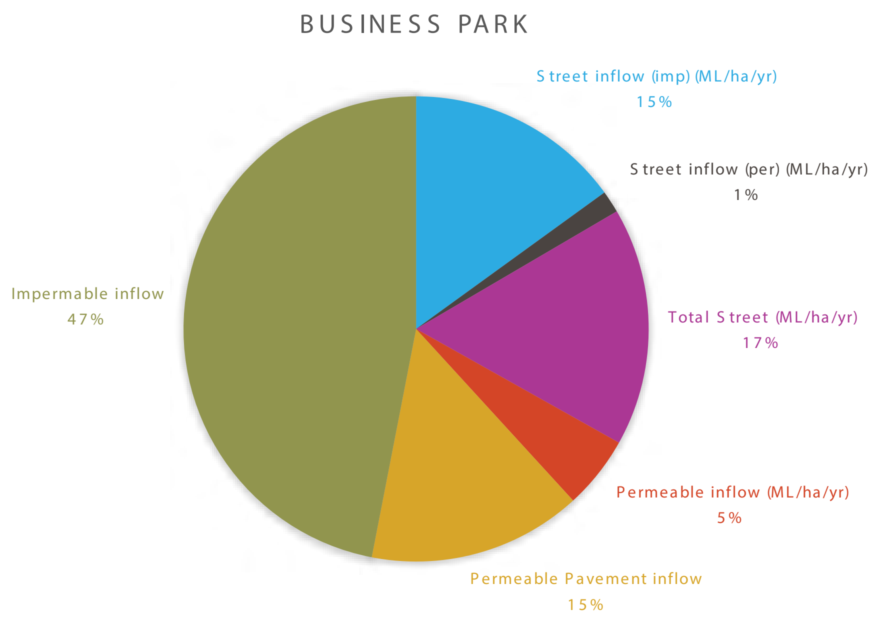
Building Type / land use	Assumptions	Large Tree Density Target (trees/ha)
Detached Housing Low Density	1 tree per dwelling *	25-30
Attached Housing (Medium Density Housing)	15m spacing for all urban areas including community title spaces	19
Apartments (High Density Housing)	9m spacing for trees in tree pits or trench in central courtyard	7
Commercial Office Buildings	8m spacing (1metre overlap) for perimeter tree planting.	25
Industrial Warehouse Buildings	8m spacing (1metre overlap) for perimeter tree planting	42
Community Title Green Space incl. Parks / Urban Open space	Minimum 9m spacing in open space or park setting	19

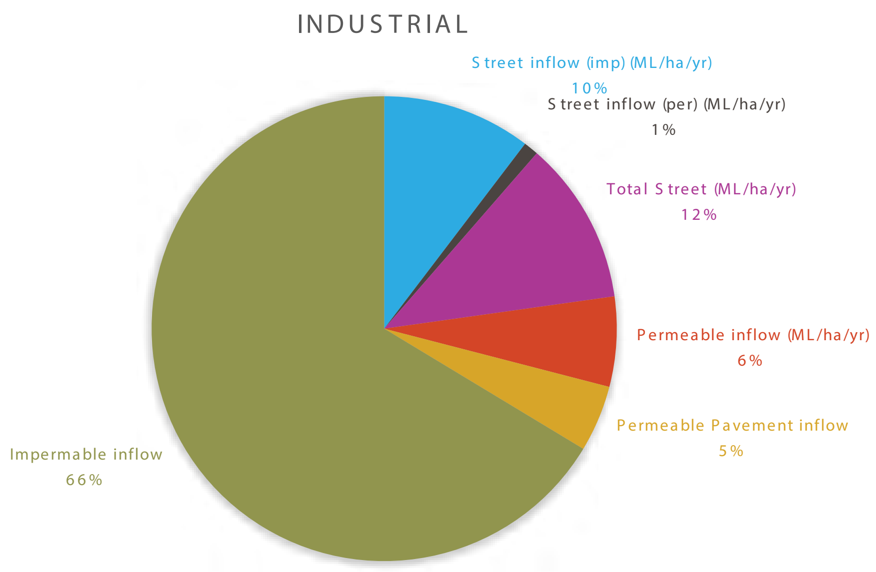
Appendix B – Detailed water balance modelling results

Catchment inflows

Water balance modelling results from MUSIC are shown below. The rainfall and the resultant runoff from various portions of the catchment. The lot runoff has been separated from the street runoff to identify the largest contributors of runoff. It is clear the majority of runoff in all cases are sourced from the impermeable surfaces of the lots and streets in all land use types.

Understanding the sources of runoff also helps to target treatment solutions. For example it is clear that the main source of runoff in the industrial land use type is the impermeable portion so the runoff mitigation solution is focused within the site.





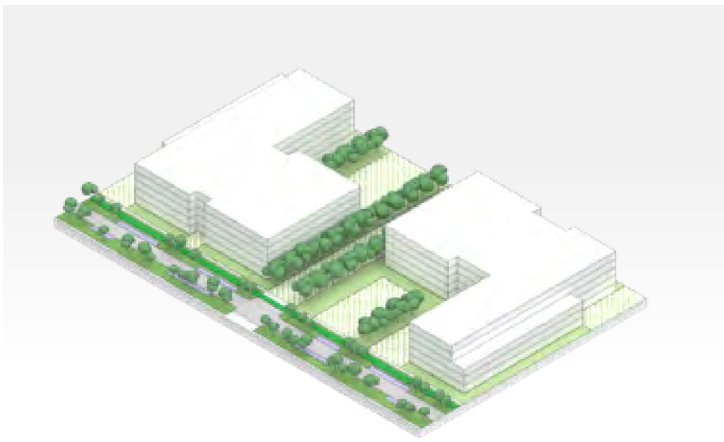


Figure 86. Employment: Office – Urban Office: Deep soil setbacks and planting

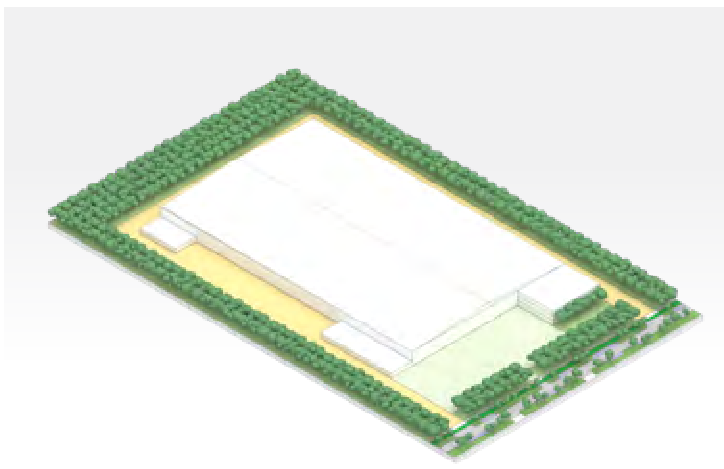
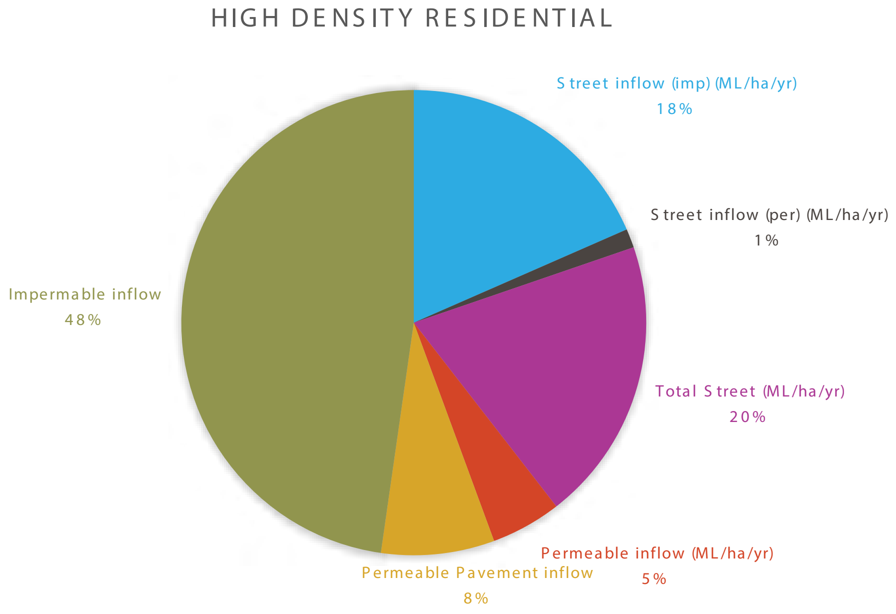
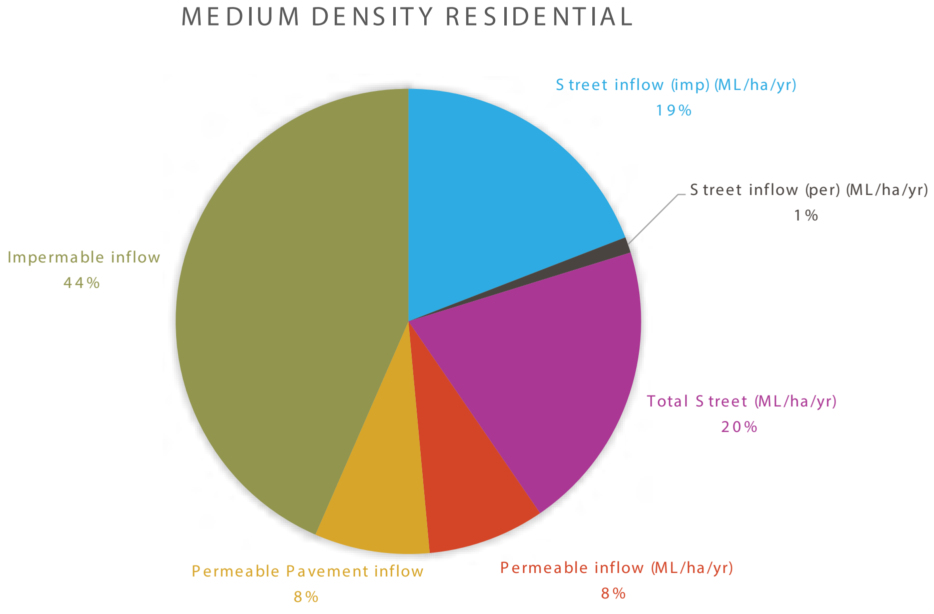


Figure 87. Employment: Industrial – Large floorplate: Pervious paving and perimeter planting

Appendix B – Detailed water balance modelling results





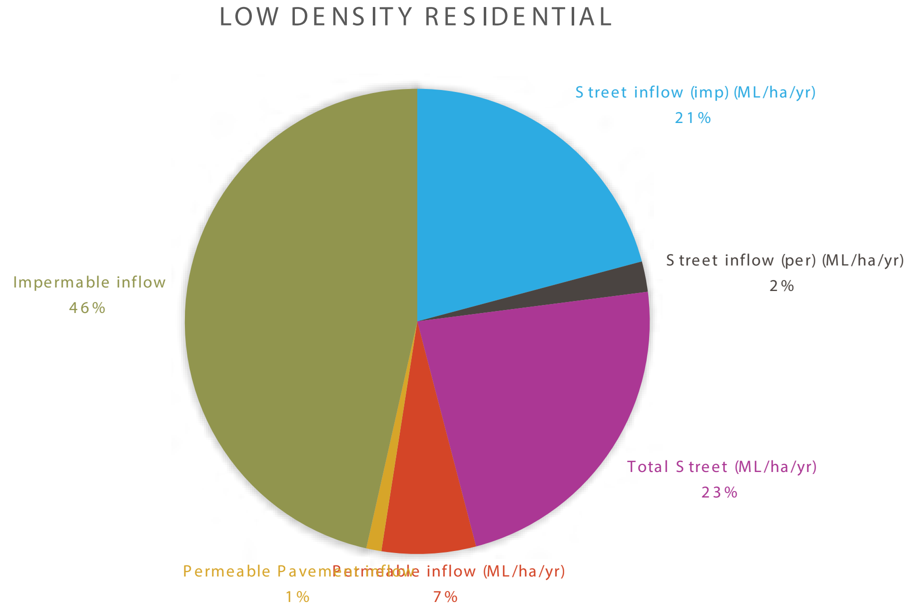


Figure 88. *Apartment buildings – Deep soil front setbacks*

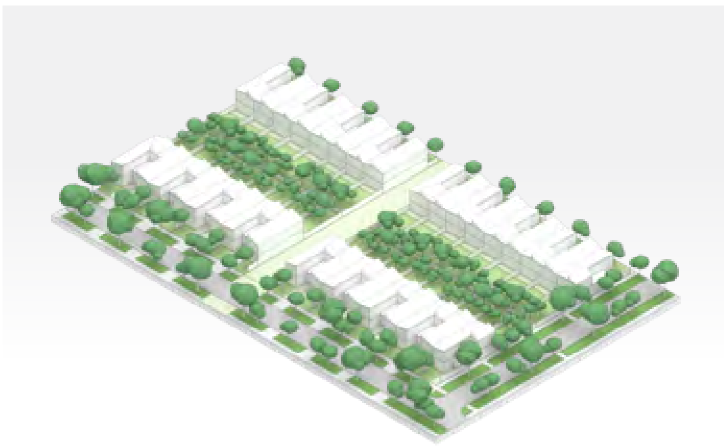


Figure 90. Attached housing – Large rear yards

Figure 89. *Detached housing – Two storey dwelling on a regular lot*

Runoff Losses

Figure 84 on page 126 152 illustrates the data presented in the table below. It provides statistics regarding each mitigation solution.

The infiltration strategy made possible by elevated building levels can provide reasonable reductions with limited areas. The configuration of the infiltration trench modelled in the low density residential scenario was just 0.5m x 5m. This area can be readily accommodated under the elevate housing.

Modelling suggests that rainwater tanks could provide up to 37 % of internal and irrigation demands for Low Density Residential typologies and up to 25% of internal and irrigation demands for Medium Density Residential.

The main component of runoff losses in the bioretention area occurs through evapotranspiration. Notably, the extended detention of the bioretention is just 50mm proving considerable retention of runoff. It is also easily incorporated into streetscapes and landscapes. In addition, the passive irrigation of street trees will provide healthy and cooling street trees.

Table 43. **Runoff losses through Stormwater Solutions**

	Low density residential	Medium density residential	High density residential	Business park	Industrial
Infiltration under building (ML/ha/yr)	0.05		0.04		
Rainwater Tank Reuse (ML/lot/yr)	0.06	0.04	1.60	1.47	
% of Demand Supplied	37	25	11	24	
Rainwater Tank Reuse (ML/ha/yr)	1.09	1.53	1.66	0.35	
Bio infill (ML/ha/yr)	0.00	0.00	0.00	0.00	0.00
Bio ET (ML/ha/yr)	0.97	0.91	0.71	1.39	1.48
Bioretention loss (ML/ha/yr)	0.97	0.91	0.71	1.39	1.48
Street tree usage (ML/ha/yr)	0.09	0.13	0.06	0.35	0.77
Total Losses (ML/ha/yr)	2.20	2.57	2.48	2.10	2.25

Table 44. **Summary of Runoff Reductions**

	Low density residential	Medium density residential	High density residential	Business park	Industrial
MARV from typologies (ML/ha/yr)	3.1	3.5	3.5	3.6	3.9
MARV with SW solutions (ML/ha/yr)	0.9	1.0	1.0	1.5	1.8
Reduction	70%	72%	70%	57%	54%

Lot-Scale MUSIC Modelling

Combining Urban Lots and Streets

The various typologies were paired with the ASPECT Street Design types to provide a holistic assessment of the water balance. The Street Design parameters such as the pervious and impervious areas helped model the runoff. The Street Design types also indicate the number of street trees that can be incorporated in the design with consideration of space, soil volume and services.

Thus the combination of the lot and streets were modelled for runoff generated. Then treatment nodes were sized based on the green space available. The water reuse demand was also based on the areas given in the typologies and street designs.

Climate Model

The local and regional climate will play a significant role in the final urban water balance in Western Sydney. To provide standard modelling parameters that can easily be accepted by the local governments in the region, the Penrith USIC-Link file was used to represent local climate conditions.

These parameters were agreed upon with AECOM for consistent MUSIC modelling assumptions for both lot scale and catchment modelling.

Note the annual rainfall value is considerably lower than the annual rate of evapotranspiration.

The data is relatively recent which provides greater confidence in the modelling compared to modelling historical data which does not acutely capture a changing climate and its impacts to the water balance.

Model Configuration

Source Nodes

The MUSIC model utilises the spilt catchment method to capture the various surface types that will be considered at this scale. These include the lots and the streets. More details about the rainfall runoff parameters are given in the following section.

Infiltration at source

Infiltration at source nodes were redirected to a separate junction node to capture what is infiltrated. This baseflow volume is useful to understand what volume of water will end up at downstream creeks and waterways.

Normally the baseflow is considered as interflow and is considered that it reappears at the end of the treatment train. However, at-source treatment train would not capture and treat this runoff.

The lot scale model consists of several nodes which can be configured together to form precinct scale models.

Infiltration under elevated buildings

Elevated building structures was noted as an effective means of reducing hydrological impact to the catchment. Detached housing is an example were the elevated building model could apply.

The infiltration capacity of the soil underneath the house is captured through the infiltration trench node. It was assumed that overflow from the rainwater tank can be directed into gravel trenches which allow the overflow to completely infiltration. Below is an image of the MUSIC model's configuration which replicates the effect of the elevated buildings.

Source Nodes

Soil hydrologic parameters have been adopted from the Penrith City Council MUSIC Link – recommended MUSIC nodes.

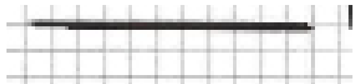
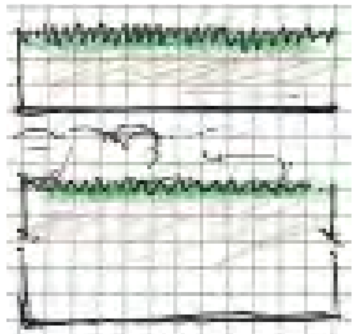
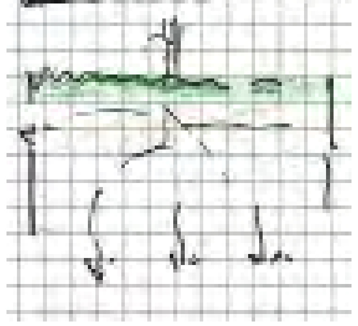
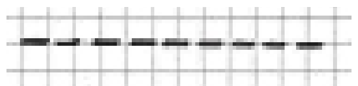
Pervious Surfaces

The incorporation of several types of pervious surfaces in the typologies allow for greater at-source losses in runoff. The typologies refer to several types of pervious surfaces including deep soil, shallow soil and partially permeable pavements. Permeable Pavement Surfaces are also modelled here with modified infiltration parameters. More details regarding the adjustments of parameters to each surface type can be found on the following page.

Impervious Surfaces

These areas will contributed the largest portion of runoff in the water balance. No adjustments have been made to the rainfall-runoff parameters.

Lot-Scale MUSIC Modelling continued

Type	Illustration	Soil depth	Vegetation	Permeability	Rainfall-Runoff Parameters
Impervious		-	-	0%	Standard hydrologic parameters from Penrith City Council.
Shallow		~200-600mm	Turf	100%	The values for field capacity and infiltration coefficients are based for shallow soils are based on the Penrith defaults assuming that this soil type is cognisant with generally disturbed urban soils. This surface type represents areas of limited soil deep such as areas over basement carparks.
Deep soil		Infinite	Large trees	100%	For the deeper soils, the field capacity is being doubled assuming there is much deeper soil profile therefore much greater capacity to hold water within the soil profile. The infiltration coefficients are kept the same as for shallow soil, this is probably a conservative assumption.
Permeable		-	-	100%	Permeable pavements can be constructed in a variety of configurations as documented in the American Society of Civil Engineers Permeable Pavements guideline. For the purpose of this analysis, the field capacity of permeable pavement was adopted as the same as the shallow soil, i.e. 70 mm. In practice the field capacity would be highly variable, depending on the adopted substrate for permeable pavements. Assuming permeable pavements, in most situation would ultimately to subsoil, adopting a similar field capacity is considered reasonable. In terms of infiltration coefficients, the “a” coefficient has been significantly reduced to 50, reflecting a far lower infiltration capacity across the majority of permeable pavement types. For example, gap pavers, would have a far smaller opportunity for water to infiltration The infiltration coefficient “b” has not been altered as there is no basis for adjusting this parameter.

Treatment nodes

Rainwater Tanks

The rainwater tanks were sized accordingly to the land use. It was assumed detached dwellings which are coherent with the low and medium density land uses had 5 kL tanks for each lot. It was assumed the high density apartment blocks had four 20 kL tanks on each lot. Finally the business park had just one 40 kL tank for reuse. It was determined that the feasibility of stormwater reuse within the average industrial development would be very limited.

The usage rates were determined by AECOM in their previous work for the aerotropolis. The daily water demands included toilet flushing, laundry and hot water demands which remaining consistent daily.

Whilst the yearly demand consisted of the irrigation demand of the landscaped areas on the lot and the verge. This demand was also dependant on rainfall and PET which means there was no irrigation if there had been rain.

Planter Area (Bioretention / Raingardens)

The practical implementation of bioretention raingardens in the Western Sydney urban landscape was thoughtfully considered. The area available to credit towards actual treatments areas had to be scaled down to what is practically achieved.

The treatment parameters were also tuned to include a wider range of possible raingarden configurations and considers the reality of these systems.

One consideration includes the avoidance of "bioretention filter media" as it is traditionally known. It has been found that soil that supports plant growth should be provided to the bioretention areas so the plants can establish and provide its nutrient removal functions. As opposed to focusing on hydraulic conductivity. Well established plant and tree roots can provide improve soil infiltration capacities naturally. Rather than replacing large volumes of soil with the normally prescribed "sandy loam" material.

Wianamatta street trees

The Wianamatta street trees are not only passively irrigated but have access to stormwater through "wicking bed" gravel layer. The gravel layer will be modelled like a pond. The volume of gravel compared to the volume of pond storage is equivalent to the porosity.

The stormwater uptake of the street trees will function like a reuse linked the pond storage. The average daily reuse was derived based on a method proposed by Geoff Connellan.

It conservatively considers pan evaporation, crop factor and canopy cover. The annual average daily evaporation at Prospect Reservoir was recorded to be 3.4 mm/day (BOM, 2019). The average tree canopy cover was determined to be 30 m^2. This is a reasonable assumption considering the "medium" sized trees have a canopy diameter between 5-8m. The assumed crop factor is 0.5. This factor captures a variety of other factors where a healthy non-stressed tree would have a crop factor of 0.8. However, as the trees in the streets of Western Sydney may be stressed during the summer months we have assumed a lower crop factor. Note that these assumptions are meant to be conservative in the absence of recorded data. Our calculated value is cognisant with average water use of 20 year tree as estimated to be 50 L/day (Agriculture Victoria, 1999).

Thus the yearly usage rate applied in the model was 18.25 kL/yr per Wianamatta Water Smart street tree which is then scaled by PET.

Infiltration Trench under Elevated Building

The trenches were modelled to be minimal surface areas with a limited filter depth of 300 mm. The assumed configuration was 5 m long and 0.5m wide.

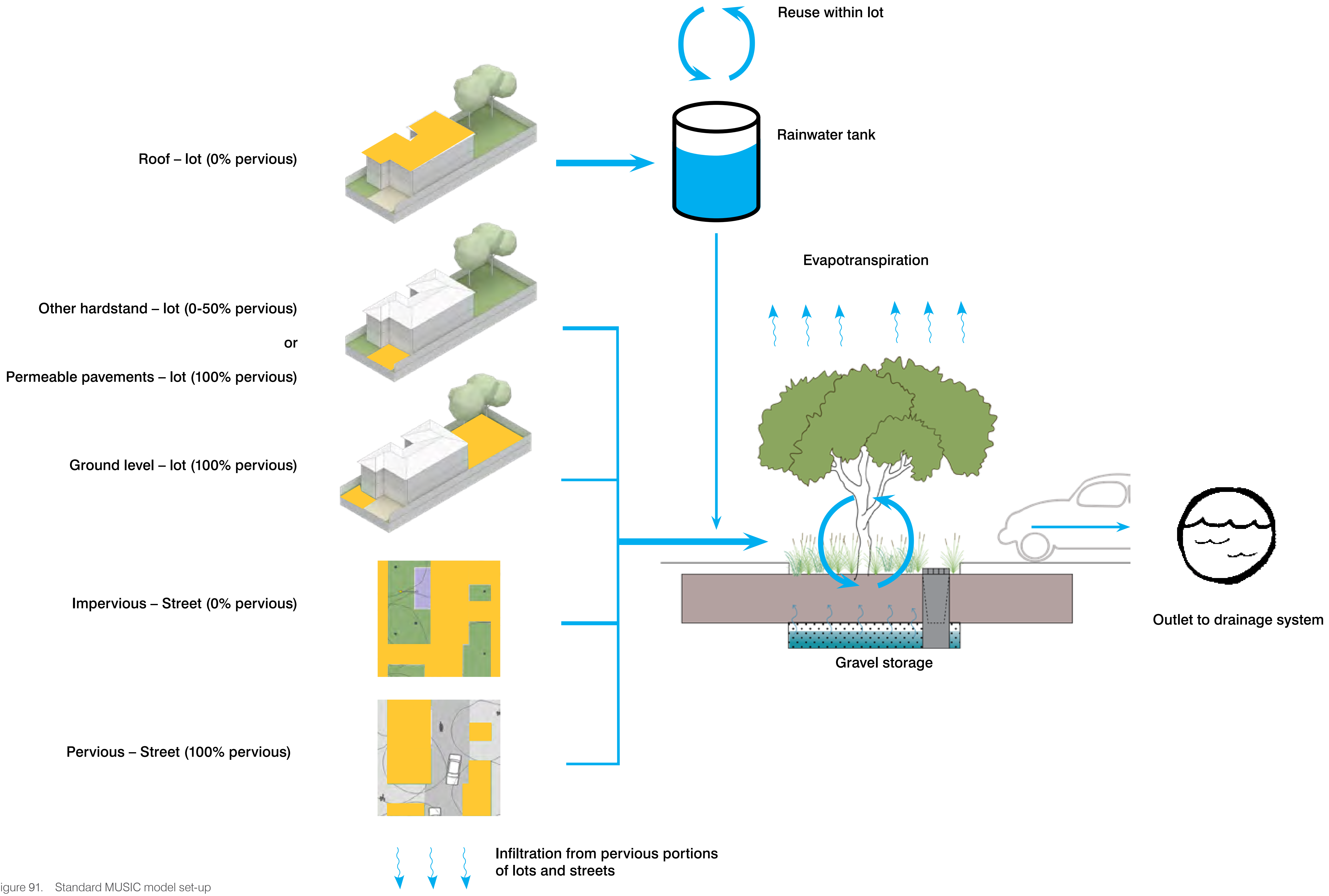


Figure 91. Standard MUSIC model set-up

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