# Measuring the performance of water sensitive infill development at Knutsford

| Land use / development type | Scale |
|---|---|
| Residential – medium density infill | Precinct |
| Water source/supply | Scale |
| Rainwater tanks | POS irrigation/Non-potable |
| Sewer mining | POS irrigation/Non-potable |
| Site conditions | |
| Soils | Shallow soil on a limestone ridge |
| Groundwater level | High |
| Groundwater availability | Contaminated/ unavailable |
| Local government | Location |
| City of Fremantle | Knutsford development |

While the energy performance of homes is being increasingly measured and reported, there is less information available regarding the quantified benefits of water sensitive development. Benefits that require quantification include improved hydrological conditions relating to stormwater and groundwater management, alternative water supplies, use of vegetation to manage the water cycle and provide greening and cooling benefits, as well as reduced scheme water use.

The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) has developed a number of tools that can assist in quantifying some of these benefits which include:

- an Infill Performance Evaluation Framework that quantifies the performance of water sensitive infill development; and
- a BCA Tool as part of the Investment Framework For the Economics of Water Sensitive Cities (INFFEWS) that is tailored to assessing investments for water sensitive cities.

This case study provides a summary of how the CRCWSC's tools have been applied to a proposed medium density infill development in Perth, as documented in *Knutsford case study final report: water sensitive outcomes for infill development* (London et al, 2020a). Additional case studies provide further detail on the application of the individual tools.

## The case study site: Knutsford

The case study site, known as Knutsford, is approximately 4ha in area and located 1.5 km from the Fremantle city centre. It is one of eight potential redevelopment sites (including some existing Industrial land uses) in proximity to Knutsford St in Fremantle, Western Australia.

Fremantle has a hot-summer Mediterranean climate, with largely winter-based rainfall ranging from 467 to 861 mm/year. The area has shallow soils on a limestone ridge which poses challenges for traditional drainage via infiltration. There is also a history of groundwater contamination in the area, which is a legacy of past industrial activity.

The vision for Knutsford is that 'an aged industrial area becomes a high amenity, diverse and adaptable precinct while protecting and incubating Knutsford's unique creative culture and sense of place'. Furthermore, 'Knutsford will be a community asset and an exemplar for design and sustainability across Perth' (Knutsford Master Plan, Landcorp, 2016).

A key desired outcome for the project was to improve water security through innovative water servicing, which enables innovative governance arrangements to be explored. This will assist in the creation and maintenance of a green and highly liveable community for a growing population in the context of declining natural water sources. The development is also proposed to achieve net zero energy use through on-site energy generation.

*Proposed water sensitive development*

In order to optimise water sensitive outcomes, several measures were proposed to reduce the demand on mains water supply, including underground rainwater tanks that will be plumbed into dwellings for non-potable use and sewer mining to treat wastewater and supply fit-for-purpose water mainly for public open space (POS) and streetscape irrigation.

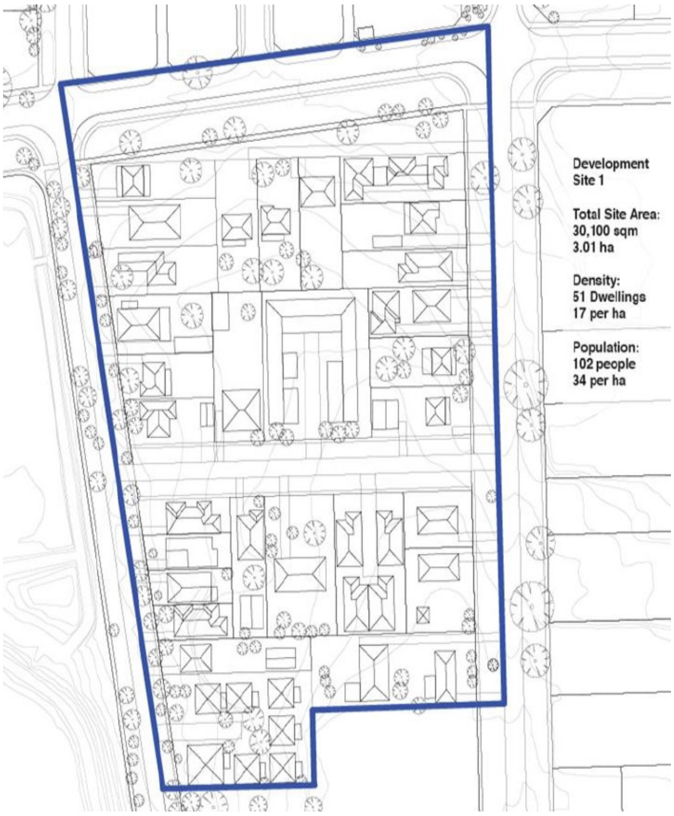
The water sensitive development scenario also aimed to increase access to open space and canopy trees through creation of a linear open space corridor along the northern boundary, as well as increased deep soil zones within individual lots.

## Measuring performance

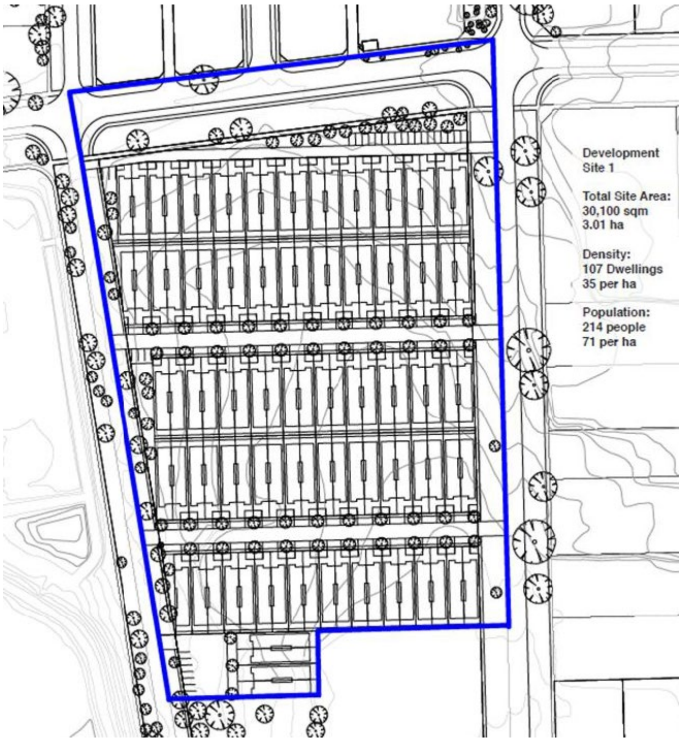
The CRCWSC developed a number of scenarios in order to comparatively assess the performance of water sensitive infill development.

An "existing development:" scenario was created to provide a baseline that was reflective of the usual pre-development state of low-density residential development.

A "business-as-usual" (BAU) scenario was also created to reflect the common infill building practices occurring in Perth in 2019. This scenario comprises single-story, affordable dwellings, with a large development footprint (58% roof and 34% pavement). BAU assumes 107 dwellings on site with two new internal roads, resulting in a net dwelling density of 45 dwellings per hectare. The total landscaped area (including POS and verges) is estimated at 0.65 ha with a total tree cover of 8%. Water for the development will be supplied entirely from mains (Water Corporation Scheme) and has been estimated at 13.23 ML/year (CRCWSC, 2020).



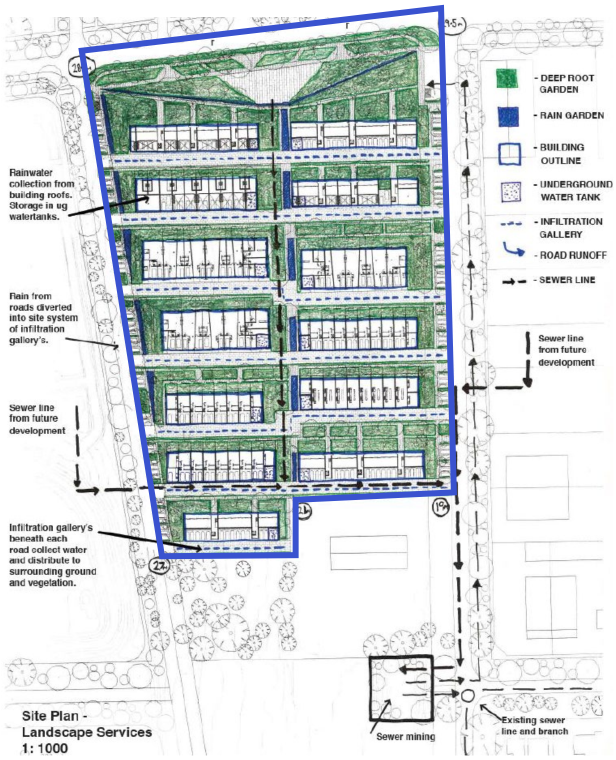

Site plan of existing development scenario




Site plan of Business-as-usual development scenario

Two variants of the water sensitive development scenario were created. The conservative water sensitive scenario (WS-CON) involves the construction of 154 dwellings on the site. These include three (3) distinct typologies; apartments, townhouses and warehouse apartments. The resulting dwelling density is 81 dwellings per hectare (not including communal spaces). The average occupancy per dwelling was assumed to be 2.1, giving a site population of 323 people.

The total landscaped area (including POS and verges) is estimated at 1.05 ha with a total tree coverage of 22%.




Site plan of water sensitive development scenario

The maximised water sensitive case (WS-Max) has the same built footprint and water sensitive interventions, but has a greater number of storeys and provides 200 dwellings, giving a site population of 420 people.

## CRCWSC Tools

*Infill Performance evaluation framework*

The Infill Performance Evaluation Framework (Renouf, et al, 2020) provides a methodology to quantity the benefits of different infill development designs. It proposes three groups of performance criteria: (i) water performance (includes hydrology, water demand and supply, greening), (ii) urban heat, and (iii) architectural and urban spaces quality, and provides guidance for measurement of indicators.

The framework also enables the benchmarking of water sensitive infill development types, compiled in the *Infill typologies catalogue* (London, et al, 2020b) as a resource for planners, architects and developers to improve the performance of infill development.

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*Benefit cost analysis*

The CRCWSC's INFFEWS BCA tool was applied to the Knutsford site and development scenarios to assess the costs and benefits associated with water sensitive infill design and construction for both the developer and the resident /community.

The BCA Tool provides evidence for use in business cases to support balanced and systematic decision making. It incorporates project benefits, costs and associated risks to a range of stakeholders to determine a net present value (NPV) and benefit cost ratio (BCR) for the project and allows for sensitivity analysis. It also considers how these risks, costs and benefits are allocated to different stakeholders - further information that can be important in a business case.

## Results

The results of application of the CRCWWC tools are provided in more detail in the accompanying Knutsford case studies. A brief summary follows.

*Water performance*

Assessment of the water balance and water supply strategy reveals significant benefits and improved water performance of water sensitive infill. The decreased site coverage compared to business-as-usual provides significant benefit to the local hydrology through increased infiltration which reduces stormwater runoff and recharges the local groundwater.

The proposed alternative water sources (rainwater tanks and recycled water scheme) reduce the reliance on scheme water and provides a sustainable water source for irrigation of private and public open space, which reduces pressure on groundwater aquifers. This supports the level of greening proposed.

*Urban heat*

The urban heat assessment (Zhu, et al, 2020) calculated the cooling felt by residents in high temperature conditions. The results showed that the additional open space, canopy trees and shading from buildings provided by the water sensitive scenario compared to a business-as-usual development could improve the thermal comfort of outdoor areas by several degrees. This magnitude of cooling has the potential to sufficiently reduce the level of heat stress of residents in heatwave conditions.

*Architectural and urban spaces quality*

The need for high quality building design and amenity is increasingly being recognised by the community and in State and local government policy. Key elements of amenity include greening and trees to provide cooling benefits, access to a variety of open space and diversity and functionality of built form. Application of the Infill Performance Evaluation Framework to three water sensitive infill development types resulted in 80% of the indicators scoring a high level.

Significant improvements in amenity were also observed when the water sensitive building types were compared with business as usual. These were largely associated with the smaller building footprint that provided room for private open space and canopy trees. The diversity of development types and increased access to public open space also improved the rating scores.

*Cost benefit*

While the greatest benefit of water sensitive infill development is felt by the residents, the results of the BCA tool application suggest there is still a positive benefit to the developer.  Building the conservative water sensitive scenario rather than business-as-usual development represents a Net Present Value of $5,228,820 and a Benefit Cost Ratio of 1.49 for the developer.

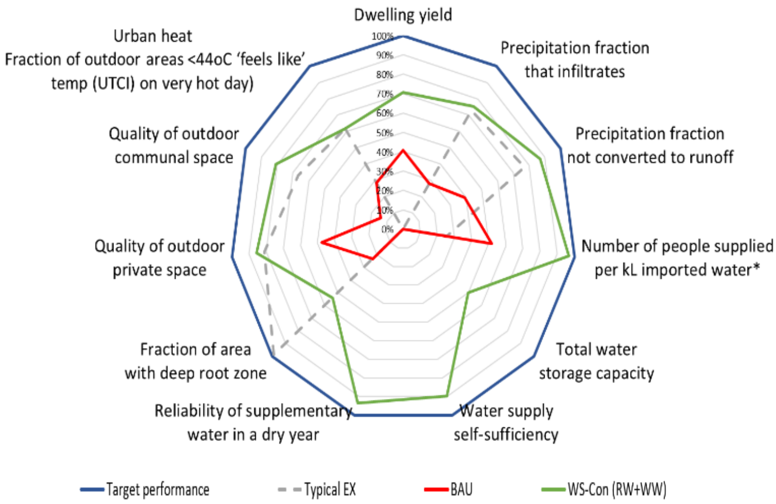
The results from the BCA for the resident and community and for the developer are shown in the table below.

| Stakeholder | NPV | BCR |
|---|---|---|
| Residents/community | $11,260,461 | 2.06 |
| Developer | $5,229,820 | 1.49 |

The benefit for the developer is captured largely in the increased number of dwellings, with a small premium in house prices for sustainable dwellings and lifestyle.  The other main benefits of the water sensitive scenario are decreased demand for mains water supply and decreased power costs to residents from the net zero energy development.

*Overall results*

The combined assessment of water performance, urban heat and architectural and urban space quality, as depicted in the spider diagram and table below, shows that water sensitive development performs significantly better than business as usual infill development. Water sensitive development achieves scores between 50 and 95% for all indicators, whereas business-as-usual development rates much lower, from 0 to 50%.

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| Indicator | Performance range | | Performance rating | | |
|---|---|---|---|---|---|
| | Bad | Good (Target) | EX | BAU | WS-Con |
| Precipitation fraction that infiltrates | 0.0 | 0.4 | 0.3 | 0.1 | 0.3 |
| Precipitation fraction not converted to runoff | 0.0 | 0.97 | 0.7 | 0.4 | 0.8 |
| Total water storage capacity | 0.0 | 3.0 | 0.0 | 0.0 | 1.5 |
| Number of people supplied per kL imported water | 0.0 | 12.0 | 3.1 | 6.2 | 11.6 |
| Water supply self-sufficiency | 0.0 | 0.7 | 0.0 | 0.0 | 0.6 |
| Reliability of supplementary water in a dry year | 0.0 | 1.0 | 0.0 | 0.0 | 0.9 |
| Fraction of area with deep root zone | 0.0 | 0.5 | 0.5 | 0.1 | 0.3 |
| Quality of outdoor private space | 0.0 | 21.0 | 17.0 | 10.0 | 18.0 |
| Quality of outdoor communal space | 0.0 | 21.0 | 14.0 | 3.0 | 17.0 |
| Urban heat - Fraction of outdoor areas <44°C 'feels like' temp (UTCI) on very hot day | 0.0 | 0.6 | 0.4 | 0.2 | 0.4 |

## Outcomes

The comparative analysis enabled through application of the CRCWSC's BCA Tool, Infill Performance Evaluation Framework and Infill Typologies Catalogue demonstrates the significant benefits that can be delivered by water sensitive infill development compared with business-as-usual infill. Key contributors to the additional benefit include smaller building footprints, deep root zones and space for stormwater infiltration, alternative sources of water and increased vegetation and trees.

This case study also enforces the need to look at energy, water and built form in an integrated manner rather than separate systems, as this is more representative of the range of outcomes that are delivered. While it is recognised that housing developments are substantially driven by construction, economic and market factors, the quantification of performance and economic justification in this case study can be used to support improved business case development by the development industry.

The work also demonstrates that with appropriate site-specific consideration, water sensitive designs and servicing options can increase the dwelling yield on the development site, while mitigating and even reversing the potential adverse impacts of densification.

Key considerations to assist in application of the CRCWSC tools are:

- Clarity of project design – Refer to Infill Typologies Catalogue early in the design process to identify development types that might inform the project. This will assist in providing a clear understanding of the development and layout to enable definition and quantification of built form elements and the interventions proposed.
- Options to be assessed – it is important to define the condition to compare the results to. This is usually the current state or business as usual development.
- Application via a multi-disciplinary team approach for both the design and performance analysis to optimise perspectives and opportunities as well as access to information to enable measurement.

*References and resources*

London, G., Bertram, N., Renouf, M. A., Kenway, S. J., Sainsbury, O., Todorovic, T., Byrne J., Pype, M.L., Sochacka, B., Surendran, S., and Moravej, M. (2020a). *Knutsford case study final report: water sensitive outcomes for infill development*. Melbourne, Cooperative Research Centre for Water Sensitive Cities.

London, G., Bertram, N., Sainsbury, O. & Todorovic, T. (2020b). *Infill typologies catalogue – Revision A*. Melbourne, Victoria: Cooperative Research Centre for Water Sensitive Cities.

Renouf M.A., Kenway S.J., Bertram N., London G., Todorovic T., Sainsbury O., Nice K., Moravej M., Sochacka B. (2020). *Water Sensitive Outcomes for Infill Development: Infill Performance Evaluation Framework*. Melbourne, Australia: Cooperative Research Centre for Water Sensitive Cities.

Zhu, Y., Nice, K., Eadie, M. (2020). Knutsford Urban Heat Modelling Report - Draft. Melbourne, Australia: Water Sensitive Cities Institute

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