Estimating urban heat: Application to Knutsford infill development

Land use / development type	Scale
Residential – Infill development	Precinct
Water source/supply	
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 St

While the energy performance of homes is being increasingly measured and reported, there is less information available regarding the urban heat performance of water sensitive development.

The Cooperative Research Centre for Water Sensitive Cities (CRCWSC) has developed an Infill Performance Evaluation Framework that helps to assess the performance of a range of outcomes which include urban heat, water performance and architectural and urban spaces quality. This case study outlines the results of the urban heat assessment.

Measuring thermal comfort of water sensitive infill development

This case study addresses one of the benefits of water sensitive development – the creation of cooler places through improved management of the water cycle and application of green infrastructure.

What is water sensitive development?

Water sensitive development improves the way in which the water cycle is managed as part of the design, construction and use of buildings, transport systems and city landscapes. There are a range of water sensitive interventions, including maintenance of natural water environments (water flows and water quality), use of vegetation to manage stormwater, improved water use efficiency, and diversification of water supplies (harvesting of rainwater and stormwater runoff, wastewater recycling). These interventions should be applied in an integrated manner to create multi-functional, resilient and productive places that enhance community amenity and liveability.

What is urban heat and thermal comfort?

Urban areas can be several degrees warmer than their rural surrounds, especially at night, as many urban materials absorb and store energy during the day, releasing it slowly at night. This is compounded by waste energy from vehicles and buildings, as well as the larger proportion of impervious area in cities that reduces the amount of water in soils and vegetation, and corresponding levels of evapotranspiration.

Human thermal comfort describes a person's level of heat stress. It is influenced by a range of environmental parameters, including wind speed, humidity, the radiation loading on the body, the amount of clothing, the level of activity, and physiological parameters (age, gender, weight, height, etc.).

The Universal Thermal Climate Index (UTCI) provides a measure of human thermal comfort. UTCI represents the subjective experience and thermal stress of heat on persons in outdoor areas, calculated from the radiant heat (Tmrt) values for each point at ground level (1.5 m). More simply, UTCI values represent the equivalent temperatures of heat stress, which we refer to as the 'feels like' temperature.

Knutsford development

Knutssford is a 4ha development, located 1.5 km from the Fremantle city centre. The site is one of eight redevelopment sites on Knutsford St that are intended for infill, medium-density development.

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, 2006).

The Knutsford project provided an opportunity to compare dwelling and open space typologies for four (4) development scenarios; existing (EX), business as usual (BAU), water sensitive conservative (WS-CON), and water sensitive maximized (WS-MAX).

Comparing development types

Existing development scenario (EX): contains dwellings that would typically be present in the study area before infill development and provides a baseline to compare the other scenarios. It comprises single storey detached houses on lot sizes of around 600m^2, with an average 33% built cover. This scenario assumes 43 dwellings on the site, with a net dwelling density of 16 dwellings per hectare.

Business as usual development scenario (BAU): contains the type of infill likely be constructed on the case study site in the 2019 housing market. It comprises single storey, affordable dwellings, with a built cover of 58% roof and 34% pavement. The site plan incorporates two new internal roads of a typology typically associated with standard infill development. This scenario assumes 107 dwellings on the site, with a net dwelling density of 45 dwellings per hectare.

Water Sensitive development scenario (WS): includes alternative dwelling types that can achieve a higher dwelling density and population, but with more green space and communal and public space areas. It comprises multiple storeys instead of single storey structures to reduce the amount of built site cover, multifunctional internal roads, and communal green space. Three different dwelling typologies developed for the site (London et al., 2020) provide diversity - apartment units, townhouses and warehouse units.

The WS scenario provides two design variants (WS-Con) and (WS-Max). The conservative case (WS-Con) provides 154 dwellings on the site, whereas the maximised case (WS-Max) has a greater number of storeys and provides 200 dwellings. The respective net dwelling densities (not including communal spaces) are 81 and 105 dwellings per hectare. There is no difference in the water sensitive strategies included.

How was it measured?

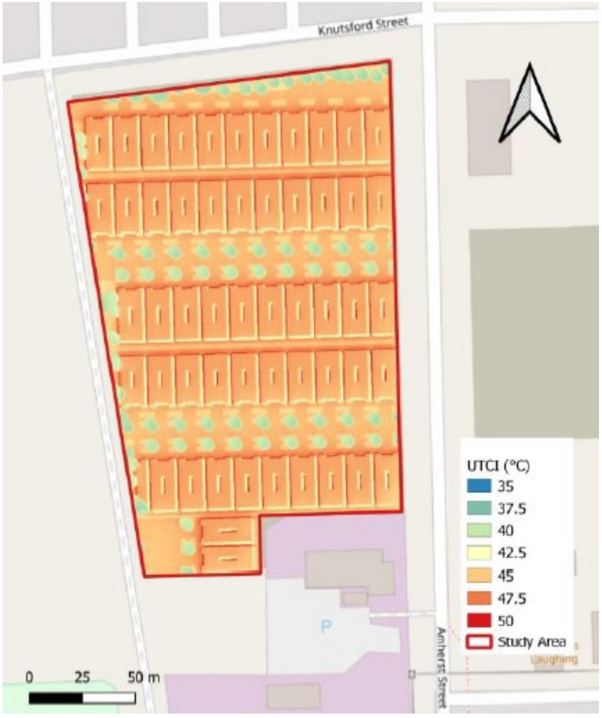
The Solar Long Wave Environmental Irradiance Geometry model (SOLWEIG) module from the Urban Multi-scale Environmental Predictor model (Lindberg et al. 2009) was used to calculate the mean radiant temperature experienced by a human body (Tmrt), for each point in the modelling domains. Using these values, a human thermal comfort index was calculated for each point in the domains (at ground level: 1.5m) using the Universal Thermal Climate Index (UTCI).

The performance indicator for urban heat is the fraction of areas in the precinct that have a 'feels like' (UTCI equivalent) temperature on a very hot summer day that is less than a certain threshold, e.g. 42°C UTCI.

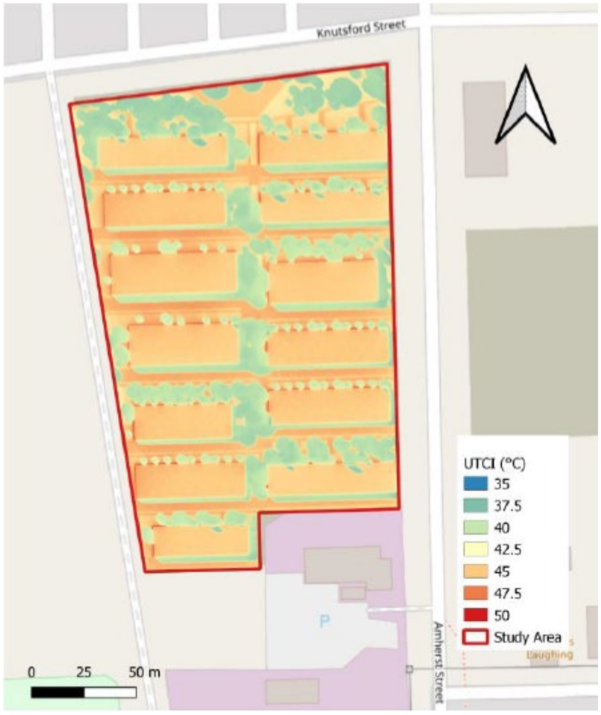
The modelling was performed for a typical hot summer day in Perth (37.4 degrees Celsius at 2pm on 15 February 2004). A base assumption of the modelling for all scenarios was that the green spaces (grass and trees) were irrigated sufficiently for good health.

Results

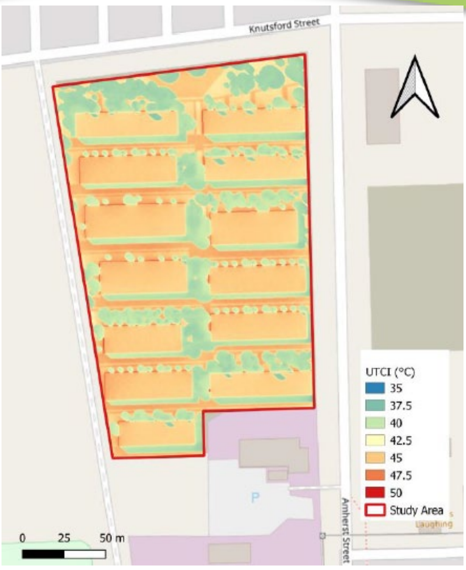
The calculated UTCI temperatures and the difference in UTCI temperatures between the two Water Sensitive scenarios (WS-Max) and (WS-Con) are shown below.



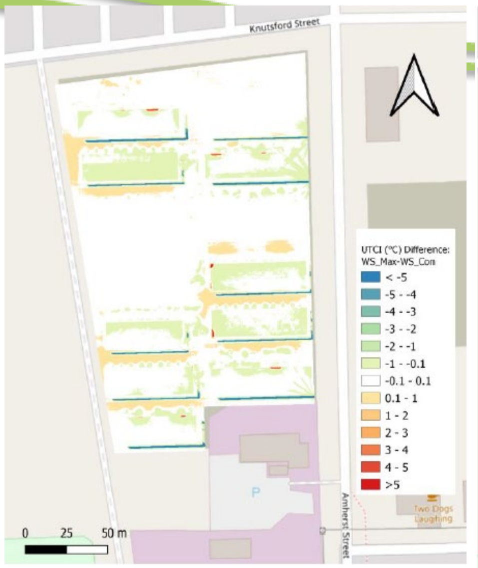
Modelled UTCI for BAU scenario



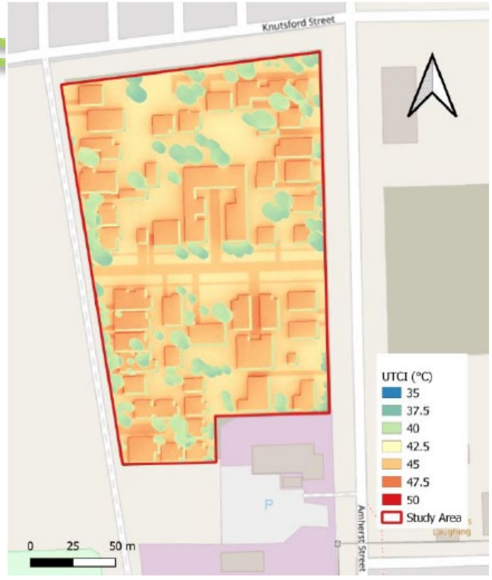
Modelled UTCI for Water Sensitive – Conservative Scenario



Modelled UTCI for Water Sensitive – Maximised



UTCI difference plot: WS-Max and WS-Con



Modelled UTCI for existing scenario

Outcome

The modelling results (Zhu et al, 2020) show human thermal comfort, as measured by UTCI, is within the strong to extreme heat stress categories for all scenarios, reflecting the high human heat stress induced by Perth's hot summer day temperatures.

Increasing site cover (imperviousness) strongly shifts the distribution of heat stress towards the "extreme heat–low" heat stress category, as shown by the comparison between BAU and existing scenarios. This shift is likely to result from the significant reduction in irrigated garden space in the BAU scenario compared to the existing scenario, compounded by the increase in hard un-shaded surfaces (roofs and pavements) in the BAU scenario.

Adopting the Water Sensitive infill development typologies (London et al., 2020) reduces the area of hard surface compared to BAU and increases the amount of vegetation. This results in much cooler streets and communal public open space areas, as well as cooler buildings. This will provide benefits to the community particularly during heatwave conditions.

It is noted that the performance of the two WS scenarios is comparable to the existing, low density development scenario. This is likely to reflect the increased shading of ground surfaces from the higher buildings which offsets, in part, the reduction in irrigated garden area compared to the existing scenario.

There is marginal difference between the two Water Sensitive scenarios as they have the same built footprint. However, there are minor thermal comfort benefits at the base of buildings for the maximised scenario due to the shade produced from increased building heights.

References and resources

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