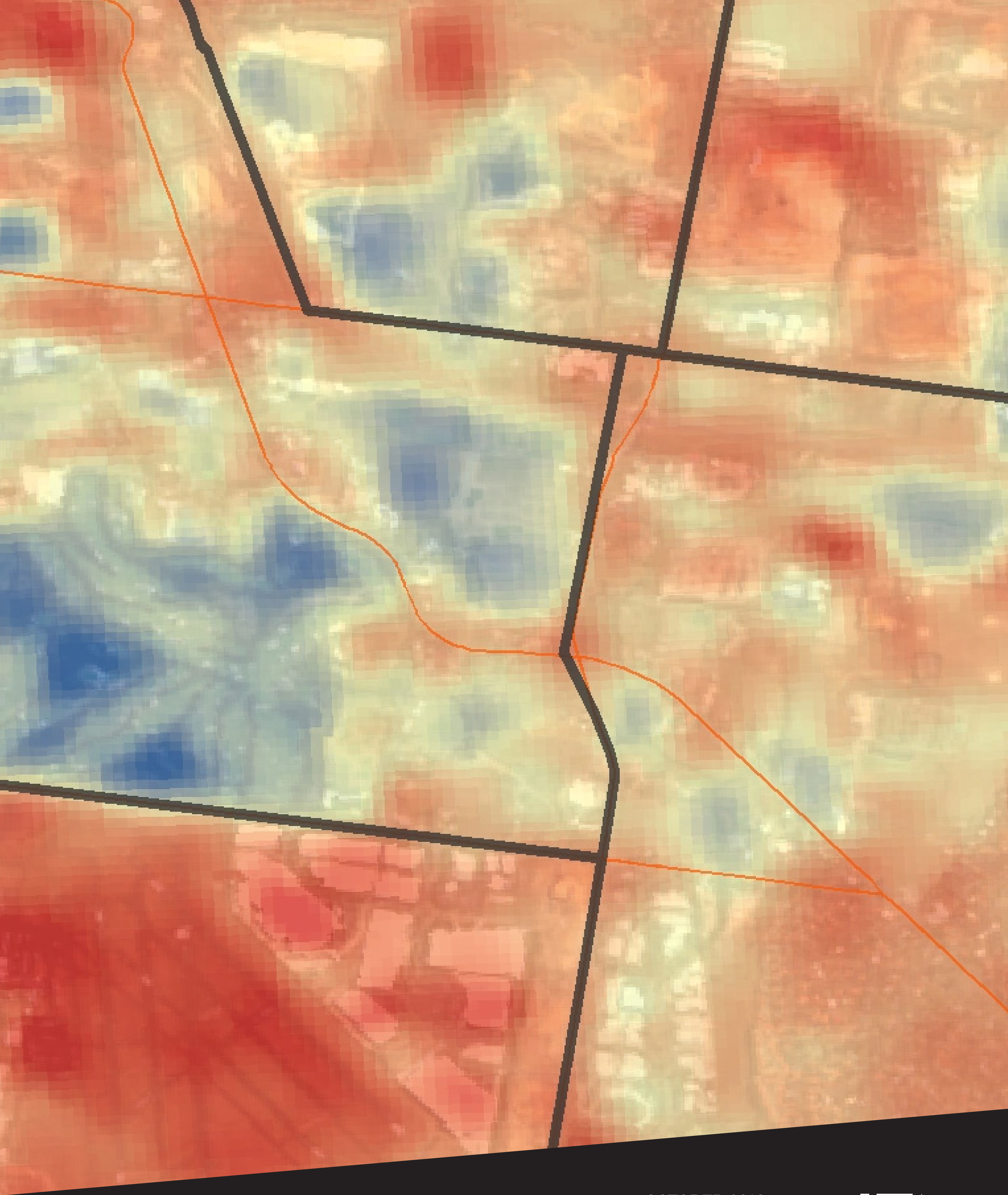

OCTOBER 2019

URBAN COOLING STRATEGY
TECHNICAL BACKGROUND REPORT

Prepared by: Seed Consulting Services, EnDev Geographic and the CRC Water Sensitive Cities

City of
KINGSTON

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Contents

Key findings

1. Extreme heat leads to greater impact on human health, including deaths, than any other natural hazard.

2. Urban heat islands exist in all Australian capital cities and are caused by a change from natural green landscapes to dark, impervious and constructed landscapes.

3. Urban heat islands exist across the City of Kingston, with notable examples occurring at Moorabbin Airport, Patterson Lakes, Chelsea Heights and Heatherton (pages 7-8, Figure 2 and Figure 3).

4. Urban heat islands create the greatest threat to vulnerable members of the community, such as seniors aged over 65 years, children under 4 years of age, people living with a disability and people from culturally and linguistically diverse communities. Results show that residential areas such as Aspendale Gardens, Cheltenham, Clayton South and Patterson Lakes have the highest Urban Heat Island Vulnerability (page 14, Figure 5). Two of the more vulnerable areas in the Council area are Richfield Retirement Village in Aspendale Gardens and Lifestyle Chelsea Heights.

5. The presence of heat islands can be explained by areas with greater proportion of bitumen, dark roofs (e.g. Patterson Lakes Retirement Village), dry grass and bare ground (e.g. Moorabbin Airport). In contrast, cool islands feature irrigated grass, wetlands, water bodies and trees (e.g. golf courses like Capitol, Commonwealth, Kingston Heath, Rossdale, Spring Valley and Woodlands).

6. Urban heat islands could become more widespread as a result of climate change and decisions about how and where future development occurs. Modelling of the impact of climate change suggests that the area of heat islands in the Council could significantly expand. One consequence of this is that the number of aged care facilities located in an urban heat island will increase from 1 under current conditions to 12 (or one third of all facilities) by 2050.

7. Creating a cool city and more heat resilient community will require a range of actions that can either be directly controlled, or influenced by Council. These actions include:

    - greening urban areas through appropriately selected trees and increased irrigation of turf;
    - ensuring an ongoing and consistent source of water to support greening;
    - using cool materials such as light coloured roofs and cool seal road treatments;
    - heat resilient infrastructure such as public transport that can continue to operate in extreme heat;
    - design and plan to cool the built environment by considering implications of residential planning decisions; and
    - emergency and health response such as through community education initiatives.

1. Introduction

1.1 CONTEXT

Metropolitan Melbourne continues to grow rapidly, with the population increasing steadily each year. To support this growing population new developments and supporting infrastructure such as roads are being constructed at an ever increasing rate. This is resulting in the continued transition of green open space to hard impervious surfaces.

It is now well established that the loss of green space and construction of hard surfaces increases the heat captured in cities. While small areas of hard surfaces can create localised hot spots at the scale of a few metres, large areas of heat can accumulate in “heat islands” at the block or neighbourhood scale. Living and working in these areas exposes people to much greater temperatures, which creates health and productivity risks for the community and economy. The presence of heat islands will only be exacerbated in the future by continued in-fill type development and climate change.

While heat islands exist in every capital city in Australia, actions can be taken to mitigate or even eliminate them. Councils are in an ideal position to influence the mitigation of heat islands given their decision making roles in relation to development and planning as well as managing key features of the natural landscape such as parks, sporting fields and streetscapes.

1.2 PURPOSE

The City of Kingston is developing an Urban Cooling Strategy (UCS). The aim of the Technical Report is to:

- understand the current distribution of urban heat islands;
- determine the relationship between urban heat islands and the location of vulnerable members of the community;
- explore how the distribution of heat islands will change under climate change and different development scenarios and how this may impact residents; and
- outline potential actions that can be taken to encourage urban cooling and reduce the impact of the urban heat island effect on residents.

This Technical Report presents the findings of the research and modeling undertaken to inform the development of the Strategy. The Report has been structured so as to inform discussion within Council about the impacts of urban heat and potential response options.

The development of the UCS is being undertaken in the context of a range of other key strategic planning documents at a local level including the Biodiversity Strategy, Climate Change Strategy, draft Housing Strategy & Neighbourhood Character Study, Integrated Water Cycle Strategy, Kingston Green Wedge Plan, Open Space Strategy and the Tree Management Policy. At a State and Metropolitan Melbourne level this complements the Victorian Government’s *Plan Melbourne* (Outcome 6 Action 91), and Resilient Cities *Living Melbourne Strategy*.

Other key contextual information includes that:

- there is currently no tree canopy or urban cooling target;
- KCC has endorsed the metropolitan wide Living Melbourne Strategy, which calls for an increase in tree canopy cover;
- the Parks team is developing a strategy for public tree management (street trees and park trees) that will inform the UCS;

- the UCS should provide direction for tangible actions that Council can undertake directly, as well as where Council can influence others, and identify avenues for further investigation;
- the Green Wedge is a major opportunity for increasing green cover, however, consideration is required for site specific limitations for tree planting; and
- KCC has a strong track record of capturing and re-using stormwater.

2. How are residents impacted by urban heat?

2.1 WHAT IS THE IMPACT OF HEAT ON THE COMMUNITY?

Extreme heat is when air temperatures are high enough that they pose a serious risk to the health of exposed individuals and populations, as well as to public and private infrastructure (Cleugh, et al. 2011). In Victoria, the technical definition of extreme heat is average temperature (average of the forecast daily maximum and overnight minimum temperatures) equal to, or exceeding heat-health thresholds determined for the nine forecast districts of Victoria (Victorian Government Department of Health 2011). The City of Kingston is within the Central Region which has a threshold of 30°C. Periods of extreme heat lasting several days are also commonly called “heat waves”.

Extreme heat causes more deaths than any other natural hazard (Coates 1996). Heat-related illnesses arise if heat gain from the environment or the functioning of the body cannot be effectively reduced through physiological or behavioural changes. These illnesses range from mild to life-threatening, and include heat oedema (fluid retention), heat cramps, heat related fainting, heat exhaustion and heat stroke (Coris et al. 2004). Heat stroke is a medical emergency, leading to rapid death in 10 to 50% of cases (Argaud, et al. 2007). In addition, exposure to extreme heat is reported to exacerbate existing chronic illnesses that account for a high proportion of excess deaths during extreme heat events (Michelozzi 2005, Rooney, et al. 1998).

The temperature related impacts on human health in Melbourne are well documented (e.g. Victorian Government Department of Human Services 2009). For example:

What is the difference between extreme heat and an urban heat island?
Extreme heat can affect all parts of a city or town and is normally measured as a period of prolonged high air temperature. An urban heat island on the other hand is a part of a city or town where heat has accumulated, causing temperatures to rise above a regional average (Figure 1). The experience of extreme heat is greatest in urban heat islands.

- deaths begin to rise when the mean daily temperature reaches 28°C, with hospital admissions for heart attack increasing by 10.8% when the mean daily temperature reaches 30°C. When the average temperature is higher than 27°C for three consecutive days, hospital admissions increase by 37.7%;
- the percentage increase in the number of deaths is largest for daily maximum temperature, with a 65% increase in mortality noted when the temperature exceeded 44°C during the severe 2009 heatwave;
- in south-eastern Australia 374 deaths were associated with a severe heatwave that included peak temperatures of over 45°C (Victorian Government Department of Human Services 2009);
- A study in Melbourne has found that the average daily mortality for people aged 65 years or over increases sharply to between 19 and 21% once overnight temperatures exceed 24°C (Nicholls, et al. 2008).

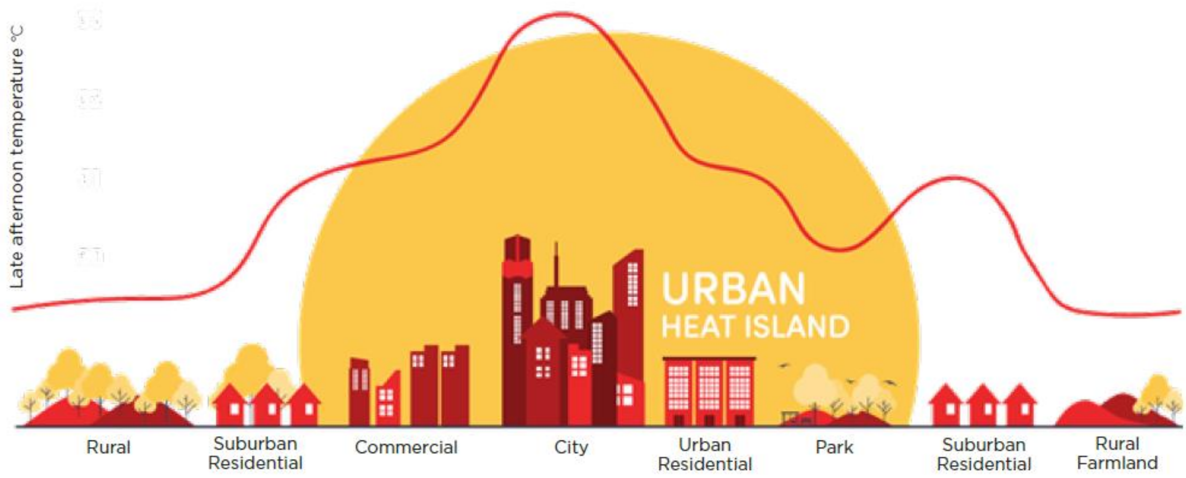

Figure 1. Urban heat island location in the landscape. Source: Western Sydney Regional Organisation of Councils (2018).

Extreme heat also causes productivity related impacts for the community and businesses, especially affecting people who work outdoors through causing lower performance and reduced working hours. Aside from the direct impacts on people, extreme heat also creates issues for the operation and maintenance of essential services infrastructure such as water, energy and telecommunications. Furthermore, transport infrastructure can be impacted through reduced life of roads and buckling of rail lines.

Extreme heat differs from the urban heat island effect, which broadly describes a phenomenon where ambient air temperatures are higher in urban areas than surrounding rural areas (United States Environmental Protection Agency 2012). Urban heat islands have been measured in full or part for many cities around Australia including Melbourne, Sydney and Adelaide. Urban heat islands arise where "hot spots" which occur at the scale of a couple of metres accumulate in a single area larger area at the scale of hundreds of metres.

Hotspots are influenced by land surface materials, where green open space has been replaced with heat-absorbing surfaces such as concrete and bitumen, installation of tall buildings that reduce airflow and ventilation, and generation of heat and greenhouse gases through human activities (Huang, et al. 2012, Coutts et al. 2007). It has been estimated that unchecked, cities will be spending up to 10% of GDP to mitigate UHIs by 2050 (Estrada et al. 2017).

2.2 HOW CAN WE MEASURE HEAT?

Heat can be measured in a range of ways in a city, including:

- Land surface temperature – Describes the surface temperature of materials recorded at a height above the ground. Depending on the device used, this can be the surface temperature of materials on the ground (e.g. grass, bitumen) or materials above the ground that are seen from above the ground (e.g. tree canopy, building roofs).
- Air temperature – The temperature of the air generally measured in the shade at 1.2 to 1.5 m above the ground.
- Thermal comfort – Provides a measure of the heat stress experienced by people and is calculated by combining air temperature, solar radiation, humidity and wind speed.

Norton *et al*. (2015) suggests that while land surface temperature and air temperature are different, addressing high surface temperatures as a way to mitigate the urban heat island effect in cities is an appropriate target. For the purpose of this study, analysis of heat islands has been undertaken using thermal imagery captured from the Landsat 8 satellite platform, which enables measurement of land surface temperature to a scale of 100 m (resampled to 30 m).

3. Where are the heat islands?

The location of heat islands has been determined using satellite images from the Landsat 8 platform. These thermal images measure the surface temperature over the landscape. The images used for this analysis were taken on 27 December 2018 and 28 January 2019, days during which air temperatures reached 37.1 and 33.2 °C, respectively (BOM Moorabbin Airport). These two datasets were averaged together to provide a snapshot of where heat builds up in Kingston on a typical warm summer day (Figure 2).

While small areas of hard surfaces can create localised hot spots at the scale of a few metres, large areas of heat can accumulate in “heat islands” at the block or neighbourhood scale.

To understand where accumulated heat can lead to problems, an urban heat island map was produced by calculating the degrees above or below a reference baseline temperature, calculated as the average land surface temperature of all non-water surfaces in Kingston and the adjacent councils (Figure 3). This results in a relative temperature map showing how many degrees warmer or cooler one area is compared to the baseline temperature. All areas more than 2 °C above the baseline are identified as an urban heat island. The heat island area and proportion and relative surface temperature are summarised in Table 1.

The analysis shows that hotspots and heat islands exist throughout the City of Kingston. Hot areas include:

- Moorabbin Airport with recorded surface temperatures upwards of 34.5 °C, which is more than 4 °C above the baseline temperature classifying as an extreme heat island.
- Patterson Lakes, which has heat islands in the residential areas to the immediate west of Old Wells Road and in the Patterson Lakes Recreation Reserve;
- Various locations across Chelsea Heights, notably Lifestyle Chelsea Heights; and
- Heatherton Sands, an old sand mine located in the suburb of Heatherton

Despite the presence of heat islands, cool spots and cool islands also exist in the City of Kingston. The most notable examples identified in the analysis include:

- Golf courses such as Capitol, Commonwealth, Kingston Heath, Rossdale, Spring Valley and Woodlands; and
- Edithvale Seaford Wetlands and parks and reserves such as Braeside Park, Karkarook Park and Mordialloc Creek; and
- Areas within industrial parks with lighter coloured roofs such as Braeside and Moorabbin.

How do these results relate to your experience of hot areas in Kingston?

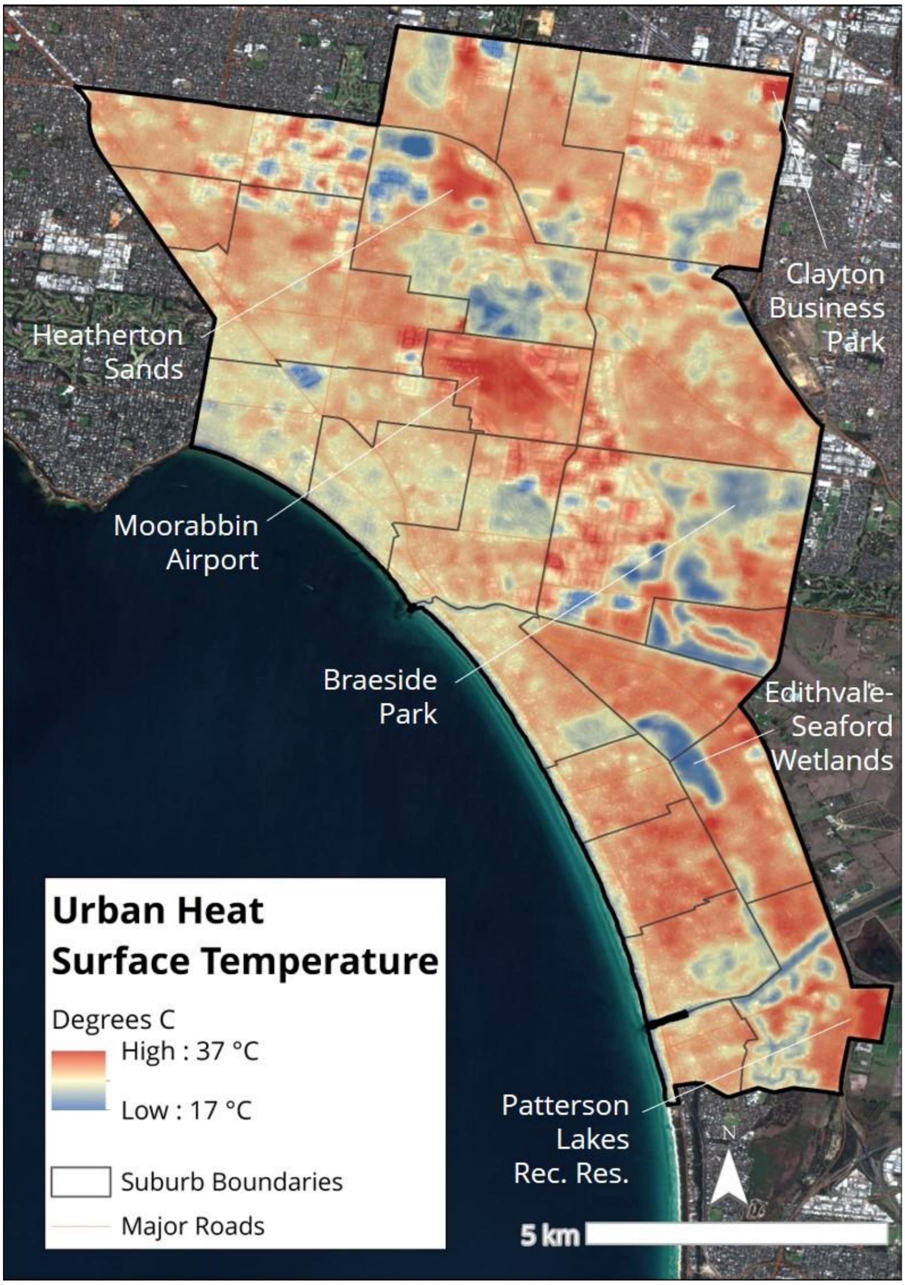

Figure 2. Land surface temperatures averaged from two warm days during the 2018-2019 summer season. High temperatures are red and low temperatures are blue, with yellow indicating average temperatures for the entire council area.

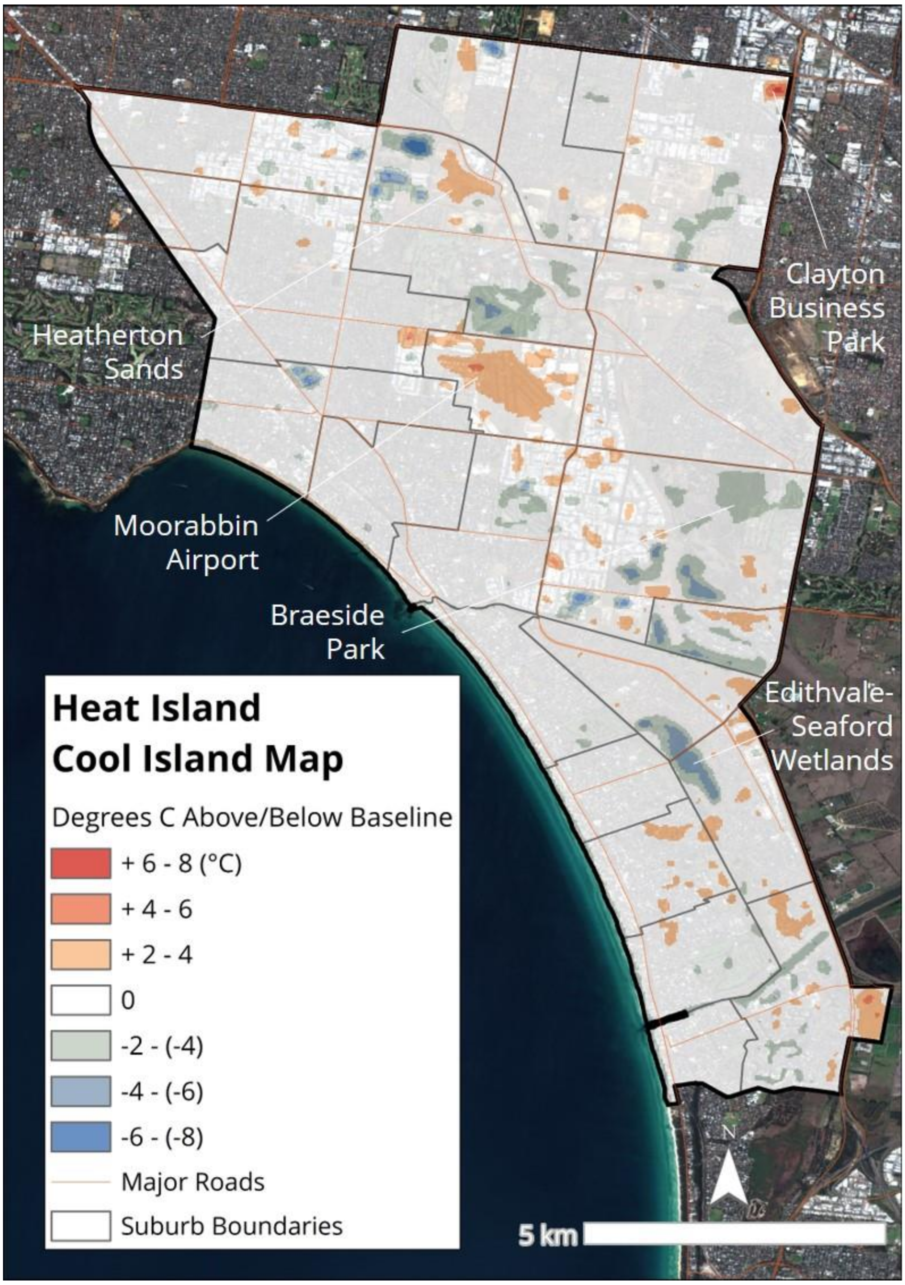

Figure 3. Heat and cool island map showing where temperatures are more than 2ºC warmer or cooler than the regional average.

Table 1. Heat island distribution by suburb.

Suburb Name	Urban heat island area (m^2)	% of suburb in an urban heat island
Moorabbin Airport	1,258,850	41.89
Patterson Lakes	609,775	14.26
Chelsea	287,731	10.94
Waterways	167,461	9.86
Chelsea Heights	218,321	6.81
Braeside	486,620	5.68
Heatherton	320,914	4.50
Oakleigh South	106,200	3.77
Aspendale Gardens	105,300	3.24
Bonbeach	82,192	2.93
Clayton South	230,266	2.89
Cheltenham (Vic.)	191,301	2.66
Mordialloc	114,950	2.60
Moorabbin	85,800	1.87
Dingley Village	103,727	1.27
Clarinda	24,300	0.69
Mentone	16,200	0.36
Edithvale	604	0.03
Aspendale	-	0.00
Carrum	-	0.00
Highett	-	0.00
Parkdale	-	0.00

4. Who is at risk from heat islands?

The most detrimental effects of urban heat islands occur when they intersect with vulnerable members of the community who are least able to avoid their impacts. To measure sensitivity to urban heat, a social vulnerability index is created using six different measures of people's ability to absorb the effects of heat. Urban Heat Island Vulnerability (UHIV) combines the exposure of people to heat with their sensitivity to heat (Figure 4, Yohe and Tol 2002).

Figure 4. Vulnerability assessment illustrative equation.

Exposure is measured as the relative temperature from the heat island assessment (Figure 5a). Sensitivity, or social vulnerability, is measured by creating a social vulnerability index comprised of the number of total population, babies and young children (under 4 years of age), seniors (over 65 years), culturally and linguistically diverse (CALD) households[1], single person households over 65 years, and 6) people with disability. These metrics are integrated into a social vulnerability index scored between 0 and 1 allowing comparisons of social vulnerability across the council (Figure 5b). The choice of these metrics was informed by Loughnan et al. (2013) and is specific to the City of Kingston for this project. As such, the urban heat vulnerability findings in this analysis may differ from other analyses that use alternate metrics such as the Socio-Economic Indexes for Areas (SEIFA) index. Measures of social vulnerability are taken from the Australian Bureau of Statistics (ABS) 2016 Census at the Statistical Area 1 (SA1) level.

Exposure and sensitivity information is normalized and averaged to produce an Urban Heat Island Vulnerability score ranging from 0 (low vulnerability) to 1 (high vulnerability) (Figure 5c). These results show that residential areas such as Aspendale Gardens, Cheltenham, Clayton South and Patterson Lakes have the highest Urban Heat Island Vulnerability.

In terms of specific locations, the Richfield Retirement Village in Aspendale Gardens and Lifestyle Chelsea Heights are two of the more vulnerable areas in Kingston due to their large and predominantly seniors population. These complexes are comprised mostly of dark roofs, densely arranged structures with little green space, making them some of the hottest areas in addition to the most vulnerable.

Areas with low populations generally have low UHI Vulnerability because although heat islands may exist, there is no one living in these areas to directly experience the extreme heat effects. Areas of high heat exposure with sparse population, such as Moorabbin Airport, fall into this category of low UHI Vulnerability. Areas adjacent to Moorabbin Airport are exposed to the same warming seen over the airport, but because they have more residents and social vulnerability, they are categorized as having medium-to-high UHI Vulnerability.

How do these results relate to your experience of hot areas and where vulnerable members of the community live in Kingston?

[1] CALD households are defined as houses where a non-English language is the primary language spoken at home.

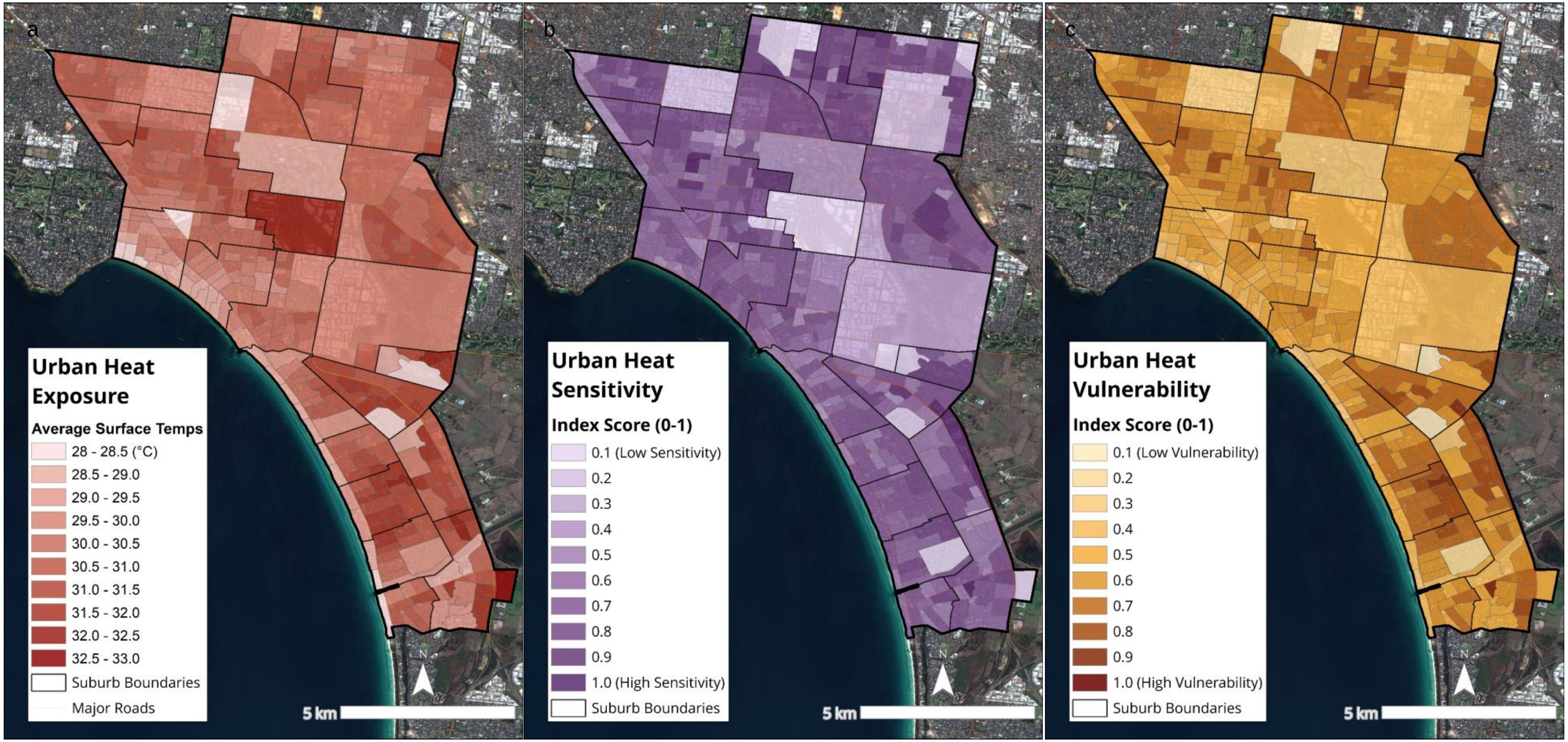

Figure 5. The components of urban heat vulnerability for suburbs (boundaries shown) and SA1 units (shaded areas) for the City of Kingston.

Suburb Name	Average surface temperature (ºC)	Total population	< 4 years population	Senior population	CALD	Lone Seniors Persons	People with Disabilities
Council total	30.29	151,775	9,129	26,089	47,301	6,098	14,623
Aspendale	29.67	6,948	452	981	1,300	197	730
Aspendale Gardens	30.80	6,522	343	853	1,951	166	654
Bonbeach	30.04	6,412	440	1,109	1,500	316	542
Braeside	29.82	58	-	6	30	-	4
Carrum	30.09	3,988	263	672	873	230	412
Chelsea	31.14	7,753	547	1,612	1,969	513	695
Chelsea Heights	30.60	5,327	355	860	1,369	205	496
Cheltenham	30.47	18,830	1,147	3,653	5,474	904	1,781
Clarinda	30.53	7,490	341	1,572	3,832	230	711
Clayton South	30.23	12,652	853	1,866	8,025	310	1,131
Dingley Vil.	30.51	10,337	501	2,090	2,607	390	1,125
Edithvale	30.49	5,798	403	942	1,144	241	518
Heatherton	29.49	2,914	184	371	1,066	50	211
Highett	30.59	3,455	236	607	1,110	195	340
Mentone	29.49	12,967	697	2,389	3,595	586	1,275
Moorabbin	30.22	5,877	414	1,028	1,969	256	584
Moorabbin Airport	32.03	-	-	-	-	-	-
Mordialloc	30.08	8,494	520	1,172	2,193	316	762
Oakleigh South	30.19	4,168	227	844	1,797	118	473
Parkdale	29.59	11,753	633	1,901	2,534	565	1,231
Patterson Lakes	30.48	7,579	396	1,407	1,872	299	742
Waterways	29.70	2,453	177	154	1,091	11	206

Table 2. Exposure, sensitivity, and social vulnerability variables by suburb. NB: Seniors are over 65 years of age.

5. What is causing heat islands and cool islands?

5.1 IMPACT OF SURFACE MATERIALS

The presence of heat islands is influenced by the type of materials covering the land surface. High resolution thermal imagery (e.g. < 2m x 2 m) can be used to identify this relationship. While the satellite imagery used for this analysis is at too coarse a resolution, the relationship identified from other studies is still applicable to the City of Kingston. One example of such an output is provided in Figure 6, which was produced for the Eastern and Northern Adelaide region of Councils.

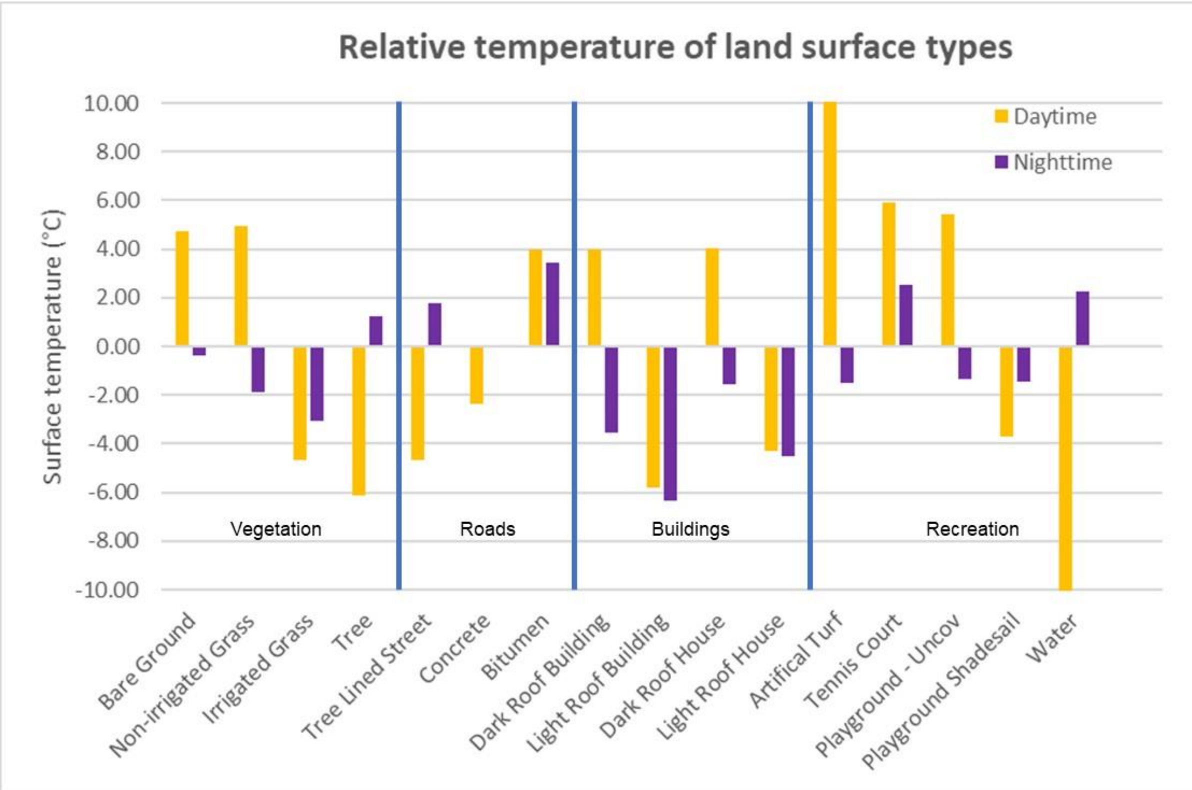

Figure 6. Relationship between surface temperature and land surface type based on thermal data collected during the day and night in Eastern and Northern Adelaide during the summer of 2017/18. Source: Seed Consulting Services et al. (2018).

The data on the relationship between land surface materials and surface temperature produces the following findings:

- surfaces that are cool during the day and night include:
    - light roof building;
    - irrigated grass;
    - light roof house;
    - shadesails;
- surfaces that are cool during the day and retain heat at night include:
    - water;
    - trees;
    - tree-lined streets;
- surfaces that are warm during the day and cool at night include:
    - artificial turf;

- bare playgrounds;
  - non-irrigated grass;
  - bare ground;
  - dark roof house;
  - dark roof building; and

- bitumen is warm during the day and night.

Using these relationships the patterns of urban heat and cooling in the city of Kingston can be explained. For example:

- Moorabbin Airport is a strong heat island because of the combination of hard surfaces like bitumen and concrete combined with large open areas of bare ground or grass that dries off during summer;
- Patterson Lakes Recreation Reserve is a heat island due to the large areas of dry grass;
- the impact of dark roofs and small blocks is illustrated in Patterson Village (Figure 7), which at an SA1 level has very high heat exposure, along with high social sensitivity has high Urban Heat Island Vulnerability (as per Section 4);
- the various golf courses and parks are cooler than the regional average temperature because of the presence of irrigated turf;
- suburbs such as Braeside, Waterways, and Aspendale Gardens have more varied thermal landscapes with some small heat islands driven by dense residential areas with dark roofs intermixed with cool islands created by large green expanses, water, and some cool roofs.
- areas with large areas of green space like Braeside experience a more moderate warming effect as hot areas are balanced out by cool areas. Coastal suburbs such as Mentone and Parkdale have minimal heat islands or cool islands as temperatures are moderated by the nearby ocean.

Figure 7. Patterson Village (area within the yellow line), a notable hot area in the landscape, showing dark roofs and small-medium sized blocks with the total impervious area taking up a larger proportion of the block than in areas of low-density housing.

5.2 URBAN FOREST AND THE URBAN HEAT ISLAND EFFECT

The placement of cool land surfaces throughout the urban landscape has the potential to offset the most detrimental impacts of urban heat by breaking up the large heating surfaces and by providing localised cool spots that residents can visit for relief. Resilient Melbourne and The Nature Conservancy's *Living Melbourne Strategy* provides a snapshot of the 2016-2017 urban forest. In this dataset, 9.7% of Kingston's land area is covered by vegetation greater than 3 m in height (Figure 8). Within the Council, leafier suburbs tend to be cooler than suburbs with a lower proportion of canopy cover with the nearly treeless Moorabbin Airport recording the highest temperatures across the council (Table 3).

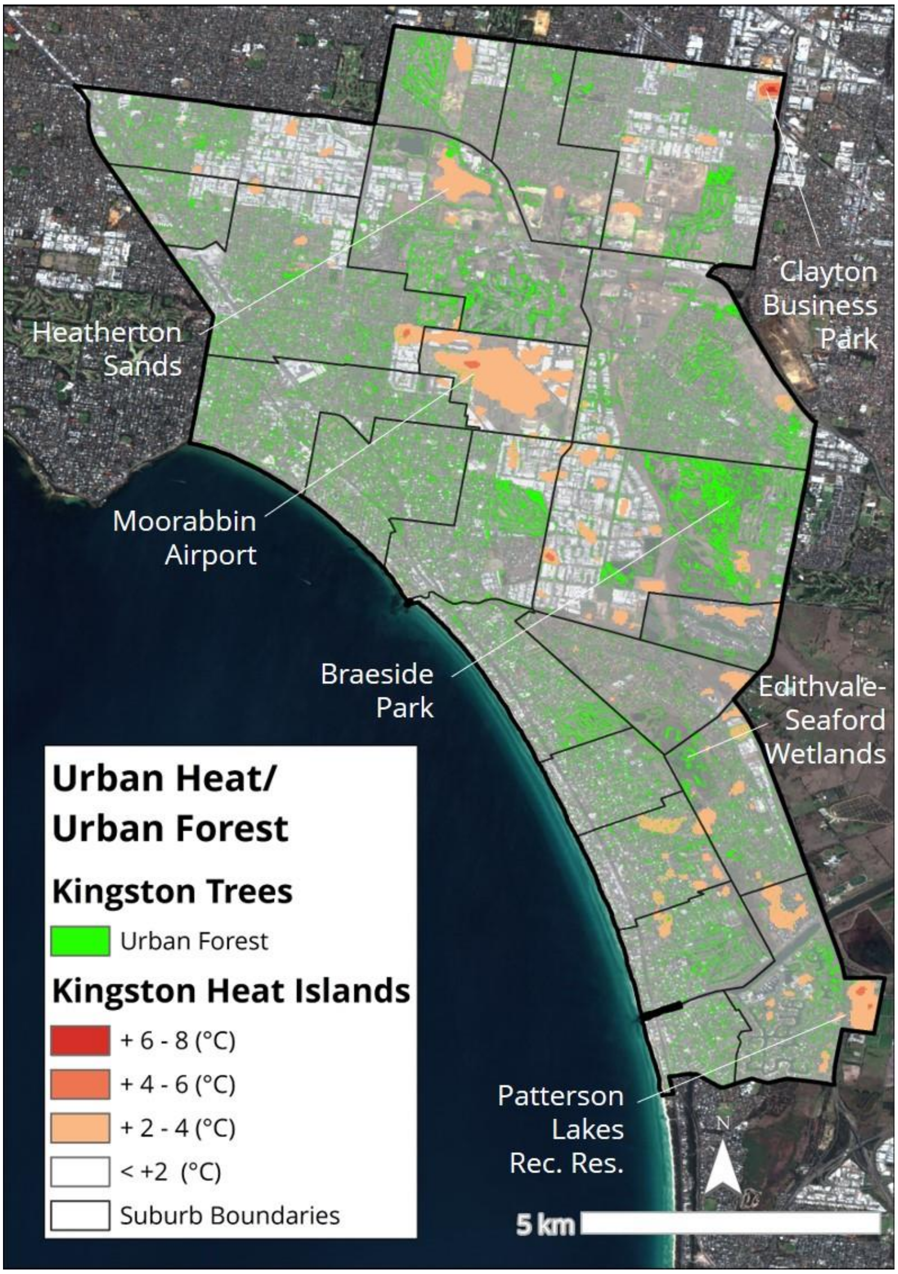

Figure 8. Urban forest and urban heat map with suburb level statistics.

Table 3. Urban forest (based on trees > 3 m) and urban heat suburb level statistics.

Suburb	Urban Forest Area (%)	Mean Surface Temp (°C)
Braeside	14.1%	29.82
Parkdale	13.8%	29.59
Aspendale	12.7%	29.67
Mordialloc	12.0%	30.08
Mentone	11.7%	29.49
Oakleigh South	10.8%	30.19
Highett	10.7%	30.59
Dingley Village	10.6%	30.51
Cheltenham	10.6%	30.47
Carrum	10.5%	30.09
Edithvale	10.4%	30.49
Bonbeach	10.1%	30.04
Heatherton	9.9%	29.49
Chelsea Heights	9.8%	30.60
Chelsea	8.6%	31.14
Moorabbin	7.3%	30.22
Clarinda	7.0%	30.53
Clayton South	7.0%	30.23
Patterson Lakes	6.5%	30.48
Aspendale Gardens	5.3%	30.80
Waterways	4.3%	29.70
Moorabbin Airport	1.6%	32.03
City of Kingston	**9.7%**	**30.23**

6. How might hotspots change in the future?

6.1 IMPACT OF CLIMATE CHANGE

Climate change has already occurred in Australia, with average temperatures having increased in Melbourne by 1.2 to 1.4ºC since 1950. Future climate change will result in hotter and drier conditions in Melbourne and more hot days and warm spells (Department of Environment, Land, Water & Planning 2019).

To understand future urban heat, CSIRO's Climate Downscaling Data for Victoria 2019 (CSIRO 2019) data was used for this analysis, specifically from the Australian Community Climate and Earth-System Simulator (ACCESS) model which is a reference model in the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5). The high greenhouse gas emissions scenario (RCP 8.5[2]) is used as the reference scenario because it has tracked most accurately with observed trends and best represents the business-as-usual scenario.

By mid-century (2050-2059) the model suggests land surface temperatures in the City of Kingston are likely to increase by 1.3 – 1.65 °C under RCP 8.5 with the stronger warming occurring in the north-eastern suburbs. Using this data, future climate heat islands were calculated against current baseline temperatures (Figure 9). This was done because urban heat islands are a relative feature and comparing future conditions against future baselines may reveal fewer relative heat islands even though the whole area may be exposed to greater than 2 °C temperature increases.

[2] RCP = Representative concentration pathway

Using this approach, in the future the severe heat island around Moorabbin Airport becomes larger and more intense. Current heat islands in Heatherton, Oakleigh South, and Patterson Lakes become extreme heat islands. Most suburbs will see a large expansion of heat islands with Moorabbin Airport, Patterson Lakes, Dingley Village, Chelsea, Chelsea Heights, Aspendale Gardens, Clarinda, and Highett all projected to have over half their land fall within an urban heat island. In this future, all cool islands are constrained to water bodies, and areas with concentrated trees and light coloured roofs.

This assessment of the potential expansion of future climate heat islands assumes that increasing temperatures and declining rainfall affect all land surface types equally, but this may not occur without intervention. The most significant factor to consider is green open space, such as areas of living turf and trees. Areas that remain green and irrigated (passively through water sensitive urban design (WSUD) or actively via pressurised sprinkler systems) during warmer months over late spring, summer and early autumn, will contribute to cool spots. However, if such areas are allowed to become dry either as dry grass or bare ground, they could become heat islands, further exacerbating the effects of extreme heat in the area. This re-enforces the need to consider ways to actively maintain green open spaces, and manage the loss of green open space that is occurring as low density residential areas are transitioned into medium and high density neighbourhoods.

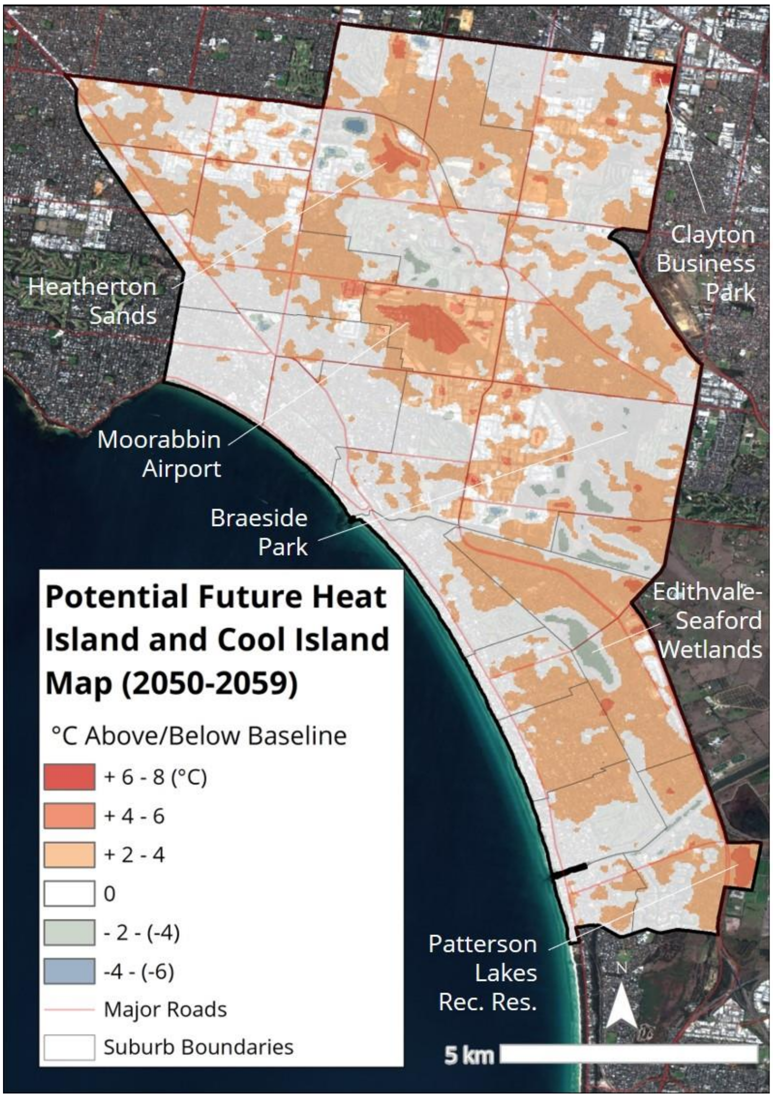

Figure 9. Future heat islands showing how increased surface temperatures will create expanded heat islands compared to current baseline temperatures.

Table 4. Heat island distribution in the future by suburb.

Suburb Name	Current % of suburb as urban heat island	Projected future % of suburb as urban heat island	Increase in % of suburb as urban heat island
Moorabbin Airport	41.89	97.69	55.80
Patterson Lakes	14.26	50.99	36.74
Chelsea	10.94	76.51	65.57
Waterways	9.86	43.31	33.44
Chelsea Heights	6.81	65.77	58.95
Braeside	5.68	34.80	29.12
Heatherton	4.50	28.59	24.09
Oakleigh South	3.77	49.35	45.58
Aspendale Gardens	3.24	75.42	72.18
Bonbeach	2.93	31.82	28.89
Clayton South	2.89	39.27	36.38
Cheltenham	2.66	48.27	45.61
Mordialloc	2.60	30.44	27.83
Moorabbin	1.87	41.39	39.52
Dingley Village	1.27	54.36	53.09
Clarinda	0.69	60.34	59.65
Mentone	0.36	10.85	10.49
Edithvale	0.03	43.09	43.06
Aspendale	0.00	18.94	18.94
Carrum	0.00	32.02	32.02
Highett	0.00	57.94	57.94
Parkdale	0.00	5.43	5.43

6.2 IMPACT OF DEVELOPMENT

Development-driven changes in the composition of Kingston's land cover will influence the amount of heat retained in the urban landscape. Expansion of cooling surfaces such as trees, irrigated grass, and light surfaces will reduce the heat island effect while expansion of warming surfaces such as bitumen, bare ground, and dark surfaces will exacerbate the effect.

The Cooperative Research Centre (CRC) for Water Sensitive Cities has developed a state-of-the-art land surface temperature Scenario Tool [3]. This tool estimates the overall land surface temperature for an area based on that area's land use composition, allowing the thermal effects of land use to be modelled before they occur on ground. The tool uses:

- an Integrated City Model comprised of parcel data provided by DEWLP The Integrated City Model calculates how demographic and land use changes may affect surface temperature to highlight urban heat island implications of planning decisions;
- land cover classification derived from 2018 high resolution imagery provided by Council;
- ABS census demographic data;

[3] The CRC Water Sensitive Cities' Scenario Tool is accessible from http://www.wsc-scenario.org.au/

- climate data provided by the Bureau of Meteorology (BoM); and
- land surface temperatures for individual land use classes e.g. roofs, roads, grass, trees.

All modelling has used a baseline scenario designed to be consistent with Scenario 4 from the draft Kingston Housing Strategy and Neighbourhood Character Study: Demographic, residential property market and housing needs analysis (Currie & Brown 2018). This was chosen as it was considered to best represent current observed growth rates of population and the most likely trend in the type of residential development that will occur. The key features of Scenario 4 are a population growth of 5% over census, dwelling type split in favour of medium and high density, and a 96.5% occupancy rate.

The Scenario Tool simulates greenfield and infill development as the main processes for urban development (Rauch et al., 2017 and Löwe et al., 2017). To simulate infill development, it redistributes population projections at the lot-level detail and simulates the subdivision of lots and construction of dwelling and apartments based on the provided planning regulations.

The City of Kingston has proposed that high-density development takes place within Activity Centre Zones and medium-density developments occur within certain General Residential Zones. The Scenario Tool was used to explore two theoretical development scenarios.

6.2.1 Industrial to high density development scenario

The proposed Clayton Business Park located in the far north east corner of the City of Kingston is an industrial area currently dominated by large warehouse type buildings that occupy more than 51% of the area. Under current conditions, a large part of this area is identified as an urban heat island.

Proposed redevelopment would see this landscape transformed into a high-density residential area comprised of buildings ranging between 3 and 10+ stories in height intended to include 5,500 dwellings and house more than 10,500 people. These proposed development conditions were approximated within the Scenario Tool to understand how this land use change may influence land surface temperatures.

Modelling of high density residential development in Clayton Business Park (i.e. standard high density development scenario) suggests that the roof fraction as a percentage of the landscape area will decrease from 51% to 37%, roads will increase by 3%, and open green space will increase by 13%. This will result in an overall land surface temperature decrease of 1.44 °C, which is enough of a change to reduce or remove the presence of urban heat islands (
Figure 10).

In addition to the baseline scenario, several other scenarios were modelled with the results as follows (also see Table 5):

- increasing the tree fraction by 50% (equal to planting an additional 2% of the whole landscape) compared to the standard high density development scenario would achieve 0.4 °C average cooling over the area;
- increasing the tree fraction by 5% (equal to planting an additional 0.4% of the whole landscape), would achieve 0.1 °C average cooling over the area;
- irrigating an additional 5% of the non-irrigated grass (equal to irrigating an additional 0.5% of the area or 1,600 m^2 which is approximately one quarter of a soccer pitch) would produce a 0.14 °C average cooling benefit over the area with much stronger localised cooling; and
- in areas where additional planting or irrigation are not suitable options, new reflective road sealants are becoming available which create cooling through lightening the colour of the road. These products have been shown to achieve 5.5 °C of cooling on roads where it is applied. Applying one of these treatments to 5% of the future development road surface (equal to 0.8% of

the whole area) would achieve average cooling over the area of 0.06 °C with much stronger localised cooling.

The modelling results suggest that a development scenario that reduces the roof fraction, increases the area of green space (trees and irrigated grass) and uses reflective surface treatments for roads could reduce the average surface temperature by nearly 2ºC, which would be enough to reduce or remove urban heat islands in Clayton Business Park.

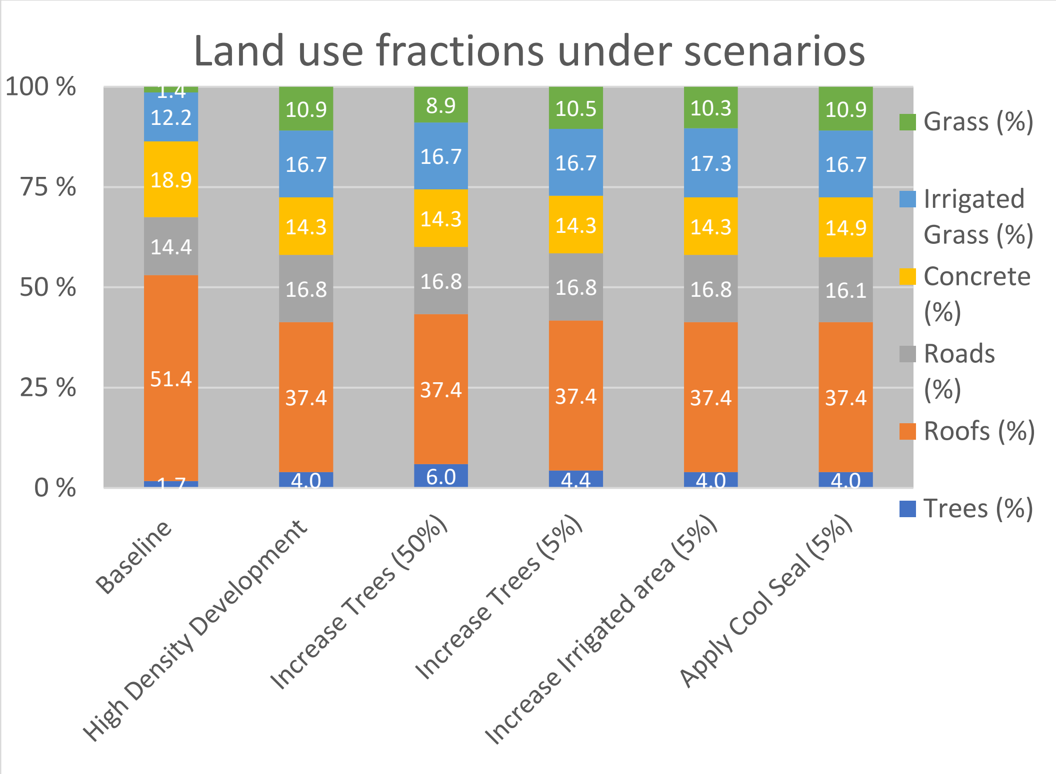

Figure 10. Land use fractions under various Clayton development scenarios.

Category	Baseline	High density development	Increase trees (50%)	Increase trees (5%)	Increase irrigated area (5%)	Apply reflective road treatment (5%)
Trees (%)	1.7	4.0	6.0	4.4	4.0	4.0
Roofs (%)	51.4	37.4	37.4	37.4	37.4	37.4
Roads (%)	14.4	16.8	16.8	16.8	16.8	16.1
Concrete (%)	18.9	14.3	14.3	14.3	14.3	14.9
Irrigated Grass (%)	12.2	16.7	16.7	16.7	17.3	16.7
Grass (%)	1.4	10.9	8.9	10.5	10.3	10.9
Water (%)	0	0	0	0	0	0
Temperature impact (°C)	n/a	-1.44	-0.42	-0.10	-0.14	-0.06

Table 5. Land use scenarios and their impact on land surface temperature. The benefits of the cooling treatments are compared to the high density development scenario.

6.2.2 Medium density infill scenario

A scenario was developed for exploring the impacts on land surface temperature of infill. For this scenario, an area of land was chosen where the typical land parcel size for lots that have not been developed was 14 m of street front and 45 m extending away from the road.

Using the subdivision module within the Scenario Tool, the impact of subdividing the single dwelling lots into two lots of 14 m x 22 m, each featuring a new single-family dwelling was assessed. This development scenario results in 80% of the site being covered by the house "footprint", with the remaining area on the block divided between impervious (60%) and pervious (40%) ground. The Scenario Tool projects that subdividing lots in this way would accommodate an additional 684 dwellings, in addition to the current 1,076 dwellings. This equates to an additional 1,709 people, an increase of 63% over the current 2,692 residents.

The results of the modelling on land surface temperature are as follows:

- subdividing the remaining single dwelling lots into two lots with a new single-family dwelling without additional greening would result in a 0.5 °C increase in land surface temperature;
- pursuing this same infill approach while also requiring one tree to be planted on each new parcel would increase the overall tree canopy by 69% (increasing from 4.2% to 7.1%), while also cooling the area by 0.15 °C over baseline conditions (0.65 °C cooler than the no-tree infill approach);
- under this infill approach, 6.7% of the area would be covered by non-irrigated grass. Irrigating half of that area would achieve 0.2 °C cooling over baseline (0.7°C cooler than the no-tree infill approach);
- other cooling approaches, such as the application of a reflective road sealant, may also contribute to mitigating heat islands. In the infill scenario, roads make up 12% of the future landscape. Applying reflective road sealants to 5% of the roads would result in a 0.04 °C cooling benefit averaged across the whole area with greater cooling in areas near the treatment. Broader applications covering 50% of the roads in this area would result in 0.37 °C cooling.

The results of the modelling suggest that while medium density infill can result in an increase in the surface temperature across the landscape, appropriate greening treatments and other options like reflective road sealants could contribute to offsetting this increase.

6.3 FUTURE DAY HEAT VULNERABILITY AREAS

As climate change occurs in the coming century heat exposure will continue to cause greater impacts for individual and community well-being, causing additional heat-related illness and death, especially for the most vulnerable people in the community such as older people, babies and young children, people with disabilities and chronic disease.

To understand where growth in vulnerable members of the community is likely to occur, and what types of heat environments future residents are likely to encounter, ABS census data from 2011 and 2016 were used to calculate the rate of population change over the five year period at the SA1 level. This five-year rate of change was then used to project the population distribution across the Council area at mid-century. The population projections for this study were capped at 2x the projected state average to prevent over exaggerating the effect of short-term trends in the census data. This approach estimates Kingston's 2050 population at 195,357 an increase of 29% over 2016. Total population, babies and young children and seniors were projected to mid-century. The projected percentages of total, babies and young children, and seniors' populations for each SA1 area formed the future heat sensitivity component in the Urban Heat Island Vulnerability assessment. It should be noted that due to data discrepancies cited in Currie and Brown (2018), the base population for 2016 used for this future day heat vulnerability analysis was 151,389 instead of the 2016 figure of 159,023 in the Estimated Residential Population (ERP) report published by the Australian Bureau of Statistics. Further explanation of this limitation is provided in Appendix A.

The future temperatures (exposure – Figure 10a), and future babies and young children, seniors, and total population (sensitivity – Figure 10b), were then reassessed to identify future urban heat island vulnerability (Figure 10c). The future vulnerability assessment identifies potential trouble spots and highlights where current cooling efforts may have their largest impact.

Warming is expected to be more pronounced in Kingston's northern suburbs, with the strongest warming measuring ~0.3 °C stronger than the warming in the southern suburbs. Within these warming suburbs, areas with the highest population and higher social vulnerability are the areas that have the highest urban heat island vulnerability by mid-century, exemplified by areas such as Moorabbin.

Urban heat affects the population differently with seniors being most susceptible to the detrimental effects of exposure to heat. Many aged care facilities are densely populated with a high degree of social vulnerability. Poor design can further exacerbate this vulnerability by creating urban heat islands exactly in the location where they can have their most adverse impacts. Currently, only one of Kingston's aged care facilities is located within a heat island (greater than 2 °C above baseline temperature), although 22 of the 30 facilities experience above average temperatures (Table 9). Under future conditions, 12 aged care facilities will fall within heat islands and all 30 will be subject to higher than average baseline temperatures.

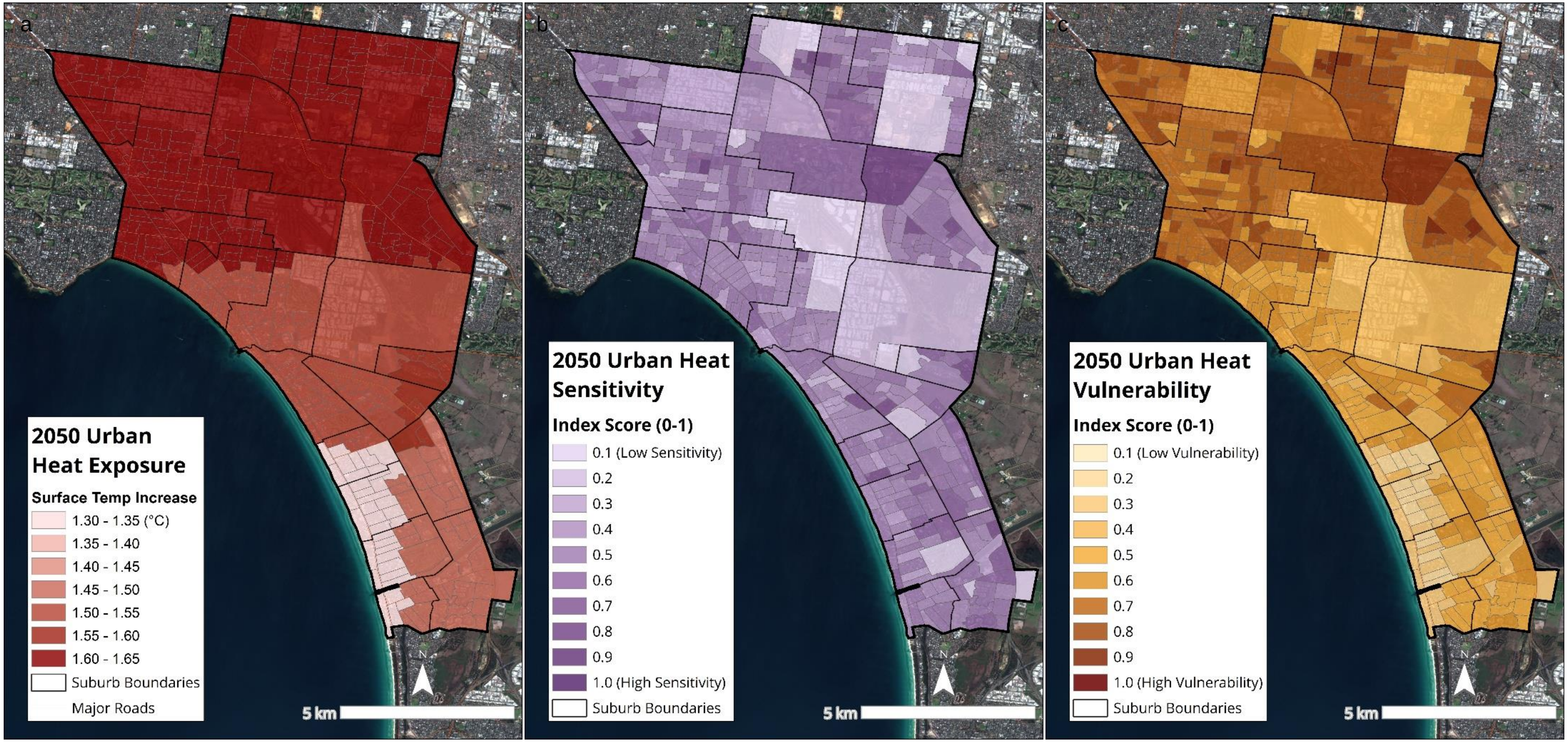

Figure 11. Future components of urban heat vulnerability at 2050.

Table 9. Current and future temperatures of aged care facilities across Kingston with facilities in heat islands shown in peach, and facilities warmer than average shown in gold.

Aged Care Facility	Suburb	Current Relative Temperature (2019)	Future Relative Temperature (2050)
Chelsea Manor Hostel	Chelsea	2.13	3.60
Argyle Court Hostel	Chelsea	1.89	3.44
Northcliffe Lodge	Edithvale	1.61	2.96
Abbeyfield House	Dingley Village	1.34	2.96
BlueCross Gardenia Nursing Home and Hostel	Chelsea	1.27	2.69
BUPA Edithvale	Edithvale	1.10	2.43
Greenwood Manor Hostel	Dingley Village	1.08	2.65
BUPA Bonbeach	Bonbeach	1.02	2.32
Kingston Centre Nursing Home	Cheltenham	0.89	1.92
St James Terrace	Cheltenham	0.76	2.42
Arcare Sandfield Aged Care Service	Cheltenham	0.65	2.25
Fronditha Care	Clayton South	0.54	2.09
Nixon Hostel	Mordialloc	0.48	1.97
Allambie Nursing Home	Cheltenham	0.46	1.92
Clarinda Manor	Clarinda	0.37	2.10
BlueCross Autumdale Lodge	Cheltenham	0.28	1.93
Bonbeach Residential Care	Bonbeach	0.21	1.71
Berkeley Living Patterson Lakes	Patterson Lakes	0.18	1.76
Cheltenham Manor	Cheltenham	0.16	1.84
Achmore Lodge	Clarinda	0.15	1.82
Bayside Aged Care Facility	Mordialloc	0.14	1.62
Sandy Lodge	Aspendale	0.07	1.63
A.G. Eastwood Hostel	Cheltenham	-0.07	1.26
Nepean Gardens	Cheltenham	-0.11	1.59
Corben House	Mentone	-0.19	1.54
The Elly-Kay Centre	Mordialloc	-0.25	1.22
Mordialloc Community Nursing Home	Mentone	-0.34	1.36
Avonlea Grange	Mentone	-0.72	0.85
Parkdale House	Parkdale	-0.85	0.70
Mentone Gardens	Mentone	-0.87	0.78

7. How can we cool Kingston?

7.1 OPTIONS FOR COOLING KINGSTON

Managing the impacts of the urban heat island effect and extreme heat on the community means that action needs to be taken to address the factors that influence extreme heat vulnerability. Table 10 summarises these factors as they relate to heat exposure, heat sensitivity and heat adaptive capacity (Loughnan, et al. 2013). Council needs to consider which of these factors are under their control and which factors they can influence.

Table 10. Factors that influence vulnerability to extreme heat.

Factors contributing to heat exposure	Factors contributing to heat sensitivity	Factors contributing to heat adaptive capacity
• Heatwave characteristics • Strenuous outdoor activity • Urban heat island effect	Biophysical • Land use • Urban design • Housing • Accessibility of health services Socio-demographic factors • Age • Pre-existing medical conditions • Socio-economic status • Social isolation and homelessness • Ethnicity and language	• Air conditioning • Heat-health plans • Knowledge and skills for how to minimise heat impacts

A variety of reports and strategies identify potential options for reducing vulnerability to extreme heat in cities (e.g. Western Sydney Regional Organisation of Councils 2018, Osmond and Sharifi 2017). Building on this past work, potential actions that could be taken by Council include:

7.1.1 Greening urban areas

It is well established that urban canopy cover and green spaces contribute to shade and evapotranspiration. However, to reap the benefits of trees, enough trees need to be planted where people are. Trees and other green spaces must be viewed as critical urban infrastructure, rather than “nice to have” elements. There is also now a movement, being led by City of London, to turn urban greening on its head, and rather than trees and green spaces being an element of cities, making cities an element of green spaces (e.g. London National Park[4]). Council could consider:

- Increase the urban forest - Where and to what extent the total urban forest cover for Council can be increased. This needs to be based on an understanding of total plantable space, the spread of tree canopy over the public and private realm, the number of trees to be planted to achieve target canopy, and the resources required to achieve this. The City of Kingston is currently undertaking extensive tree mapping to better understand the change in vegetation and canopy cover over both private and public land over time. This will inform the type of urban forest strategies that could be prioritised in Council;

- Maintaining areas of green open space as either irrigated grass or shrubs - Dry grass or bare ground can result in major heat islands, as demonstrated by the results of this analysis (e.g.

[4] http://www.nationalparkcity.london/

Patterson Lakes Recreational Reserve). Maintaining such areas as green cover will be an important future strategy, especially in areas where tree planting is not practical or feasible (e.g. parts of the Green Wedge). Maintaining or expanding areas of green cover should also consider an ongoing an consistent water supply, connecting with Council's Integrate Water Cycle Strategy (City o Kingston 2012) and how maintaining and expanding areas of green cover can support actions under the Kingston Biodiversity Strategy 2018-2023 (City of Kingston 2018);

- Retrofitting and re-thinking how we use existing infrastructure – A substantial amount of cooling benefits can be achieved in existing built areas, despite a lack of open spaces traditionally used to plant trees and other greenery. Green walls and green roofs are one example of retrofitting which are now widely recognised in urban greening strategies, with additional innovative examples starting to emerge, such as Madrid's *Madrid + Natural*[5], Melbourne's *Green Your Laneway*[6], and NYC's *The High Line* (Box 1).

BOX 1. NYC's The High Line https://www.thehighline.org/visit/

The High Line in New York City, now a globally leading example of novel urban greening retrofitting, was created on a decommissioned elevated freight rail line on Manhattan's West Side. The High Line was successfully saved from demolition in 1999 by the local community who rallied to advocate for its preservation and repurpose it as a public space. Together with the City of New public space, featuring over 500 plant and tree species, where visitors experience leading examples of urban nature, art and design. The High Line also now supports a vibrant suite of freely accessible public engagement programs and world-class artwork and performances. York a 2km length of The High Line was transformed into a continuous hybrid public space, featuring over 500 plant and tree species, where visitors experience leading examples of urban nature, art and design.

Photos source: https://www.thehighline.org/visit/

7.1.2 Using cool materials

Building and construction materials are major contributors to the urban heat island effect. They can store heat and by doing so reduce indoor and outdoor thermal comfort. Council could consider encouraging stronger requirements in relation to:

- Creating cool roofs - It is well established that dark tiled roofs contribute greatly to urban heat islands, especially in areas of medium and high density development. In contrast, reflective and lighter colour roofs absorb less heat;
- Choosing cool road and pavement materials – Bitumen is extremely effective at absorbing and storing heat from the sun. This effect can be reduced significantly through the use of road

[5] https://www.arup.com/perspectives/publications/research/section/madrid-and-natural
[6] https://participate.melbourne.vic.gov.au/greenlaneways

sealants that increase reflectivity and reduce temperatures, incorporation of permeable paving (e.g. Cool LA initiative, Box 2);

- Avoid creating hot sporting and recreational areas – Manufactured surfaces like synthetic turf and rubber softfall are well known hot areas in the landscape, capable of generating surface temperatures exceeding bitumen. Where possible, avoiding their use will help create a cooler city.

BOX 2. Cool LA

https://streetsla.lacity.org/marquerite-street-cool-pavement

The City of Los Angeles' Cool LA is an ongoing initiative aimed at "…*making Los Angeles streets and neighbourhoods cools, safe, and sustainable.*" Part of this program includes the application of CoolSeal, a water-based, asphalt emulsion sealcoat applied directly over bitumen road surfaces, and which has been shown to reduce road surface temperatures by up to 10 degrees. This cooling effect has benefits relating to: reduced heat island effects, improved human thermal comfort and health and wellbeing, decreased costs of cooling buildings, reduced carbon emissions, and improved infrastructure lifetimes. CoolSeal trials are also currently underway in two South Australian Cities, including the City of Charles Sturt[7], with results currently pending.

Photo source: https://streetsla.lacity.org/marquerite-street-cool-pavement

7.1.3 Heat resilient infrastructure

Council has a role in building and maintaining a broad range of infrastructure and supporting state government agencies and businesses who construct and maintain infrastructure in the region. It is important that critical infrastructure can continue to function under extreme heart to provide essential services to all residents and businesses. Council could consider:

- Extreme heat planning - Facilitate collaboration between utilities, infrastructure and essential services providers in the City of Kingston and ensure clarity of roles in continuity of services and interdependencies during urban heat events; and
- Cool public transport - Raise awareness among transport infrastructure providers regarding the role of transport to keep people cool and opportunities to provide places of respite during urban heat events.

7.1.4 Design and plan to cool the built environment:

Planning and design decisions made today influence how housing and suburbs perform under heat, even in medium and high density areas. Council could consider:

- Land use and design controls that prioritise resilience – Advocating for appropriate changes to building codes, land use, development and design controls to prioritise and incorporate green space and green infrastructure could be investigated (e.g. Sutherland Shire's Site Tree Replacement, Box 3). This could include undertaking research to amend elements of the

[7] https://www.charlessturt.sa.gov.au/CoolSeal

planning scheme to better prioritise green space and to facilitate green and blue infrastructure;

- Existing building retrofit programs - A program to retrofit existing buildings could include funding and outreach around cool roofs and improved home insulation. An example of an outreach program is the NYC (New York City) CoolRoofs Initiative (Box 4); and
- Social housing retrofit program – Collaborate with social housing providers and the State Government to work toward appropriate retrofits to social housing, such as installing appropriate cooling units for vulnerable residents.

BOX 3. Sutherland Shire Site Tree Replacement

https://www.sutherlandshire.nsw.gov.au/Development/Development-Applications/Off-Site-Tree-Replacement-and-Deed-of-Agreement

Sutherland Shire Council has recognised that tree removals are at times a necessary part of urban development. However, they also recognise the importance of urban trees and the need to increases urban trees. To help address this, Council had a requirement that each tree permitted for removal was to be replaced at a 1:1 ratio. However, in 2012, Council determined this ratio was insufficient for achieving the City's canopy retention and growth targets and new replacement ratios were resolved as follows:

- 4:1 for single dwellings;
- 8:1 for dual occupancies, medium- and high-density, and commercial developments;

The replacement plantings should ideally occur on the private property where removals occurred. However, if this is not possible, replacement plantings can be accepted by Council as offset plantings on public land through activation of a Deed of Agreement.

BOX 4. NYC CoolRoofs

https://www1.nyc.gov/nycbusiness/article/nyc-coolroofs

NYC CoolRoofs initiative was launched in 2009 and supports the City's carbon emissions reduction goal (80% by 2050) by installing specialised energy-saving white coatings (high solar reflectivity and high infrared emissivity) on rooftops of eligible buildings. Through this initiative, the City can reduce its annual carbon footprint by 1 tonne per 232 m^2 of roof coated. Installation is offered at no or low cost, with non-profit and affordable housing given priority. This initiative provides multiple benefits, including:

1. Directly cooling the local urban environment by reducing a roof's ability to absorb heat during the day and release it at night;
2. Reducing the City's carbon emissions by cooling internal building temperatures and thereby reducing cooling demands and associated carbon emissions; and
3. Direct savings to building owner/occupier by reducing cooling costs by 10-30%; and
4. Upskilling local jobseekers with training and job experience.

Since its launch, more than half a million square meters of rooftops have been coated, resulting in a reduction of more than 2,282 tonnes of CO_2 per year. Legislation has also been updated to incorporate minimum requirements for roofing thermal reflectance and solar emittance.

Photo source: https://cooperator.com/article/how-cool-roofs-help-your-property-and-the-environment/full

7.1.5 Emergency and health response

Education and communications have a significant role to play in community preparedness for periods of extreme heat. An engaged community, especially those vulnerable to urban heat such as people over 65 years of age living alone, will better understand the risks of urban heat and ways to prepare and reduce risk. Council could consider:

- Urban heat community engagement and communications - Develop a regional community engagement and communications strategy to raise awareness around the dangers of heatwaves, actions that can be taken to improve resilience and adaptive capacity at home, and help create more prepared, resilient communities (e.g. Cool Parramatta, Box 5);
- Update heat response framework - Develop a preventative heat response framework to integrate emergency management procedures and preparation with outreach to the community service providers that interact with vulnerable populations.

BOX 5. Cool Paramatta

http://coolparramatta.com.au/

Cool Paramatta is an online community engagement hub provided by the City of Paramatta. The online hub provides a portal where community members can readily access a wealth of information regarding heat and heatwaves in the City. Information provided includes:

- a user-friendly summary of what heat waves are, who is most vulnerable, and what's being done by the City to help reduce heatwave events;
- information about free, cool places and offers for the community;
- interactive technical outputs on the spatial distribution of hot spots across the city;
- practical information about how people can stay cool during heat wave events; and
- contact information for people seeking further details/advice.

Question for discussion: What actions do you think could be taken now to address current and future heat islands?

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9. Appendix A

The following information is provided to explain some of the assumptions and limitations of the analysis undertaken for this project:

Assumptions

- The population and development scenario baseline has been designed to be consistent with Scenario 4 from the Kingston Housing Strategy and Neighbourhood Character Study: Demographic, residential property market and housing needs analysis (Currie & Brown 2018). This scenario was chosen as it was considered to best represent current observed growth rates of population and the most likely trend in the type of residential development that will occur. It assumes a population 5% higher than presently projected (i.e. 215,145 people), and with density trends moving towards medium and high-density dwellings at the expense of low density development.

- Future climate hotspots were developed using RCP (representative concentration pathway) 8.5 from CSIRO's Climate Downscaling Data for Victoria 2019 (CSIRO 2019), specifically from the Australian Community Climate and Earth-System Simulator (ACCESS) model. RCP 8.5 was chosen because it is the high emissions scenario and best reflects current observed global emissions.

- The ACCESS model was selected for projecting land surface temperature because it has been developed in Australia and understood to better reflect Australian conditions.

Limitations

- Seasonal weather variations influence the greening of an area over months to years which may have a pronounced effect specifically on non-irrigated vegetation. Data collected during wetter years can show non-irrigated grass as a cool surface whereas in drier years they may show as hot surfaces, which can significantly affect inter-annual comparisons.

- Landsat 8 provides the highest resolution thermal data (100m2 resampled to 30m2) freely available from satellite platforms. Each image for this analysis was converted from raw digital data into land surface temperature using the standard processing protocol (Landsat 8 User's Manual 2016, Martin et. al., 2015). For each of the two Landsat datasets, land surface temperature was calculated using both bands 10 and 11 resulting in two thermal images that were then averaged to produce the composite Land Surface Temperature maps. While useful for identifying heat islands, the resolution of this imagery is too coarse to relate small scale landscape features (e.g. footpath, minor roads, trees) to a specific land surface temperature.

- Climate data used here are dynamically downscaled to 5 km resolution. Even though this is a major improvement over global climate model resolutions of 100 km or more, the scale of this data does not allow for meaningful differentiation between adjacent SA1 areas and is intended to broadly indicate the magnitude of temperature changes in this area.

- The future climate hotspots are calculated against current baseline temperatures. Because urban heat islands are a relative feature, (i.e. urban areas are hotter than their natural counterparts), comparing future conditions against future baselines may reveal fewer relative heat islands even though the whole area may be exposed to greater than 2 °C temperature increases.

- The variables included in the analysis of the sensitivity of people to heat do not fully encapsulate all the ways in which people are vulnerable to the impacts of urban heat. Other populations may also be at-risk and heat mitigation efforts should work to incorporate all people who may experience undue impacts. Projecting these data to mid-century using only two time points (2011 and 2016) may exaggerate short term trends of that period. Projections have been capped to limit the influence of such trends.

- This report refers to two different population numbers. Currie and Brown (2018) note that: “The 2016 Census gives Kingston Local Government Area (LGA) population as 151,389. There is a discrepancy between this figure and the 2016 figure of 159,023 in the Estimated Residential Population (ERP) report published annually by the Australian Bureau of Statistics (ABS) and utilised by the City of Kingston – notably the ERP statistics indicate that the population of Kingston exceeded 151,389 at some point between 2012 and 2013.” The population number of 151,389 informs the ABS SA1 level data, whereas 159,023 is the ABS ERP number used to drive the scenario development in this analysis. The ERP data do not appear to be available at the SA1 level. The ABS SA1 data were selected for the vulnerability analysis as the higher resolution is more beneficial for this purpose.